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Transactions Of The New Zealand Institute.

Art. I.—*Some New Zealand Amphipoda: No. 1.*

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[*Read before the Philosophical Institute of Canterbury, 1st October, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.*]

During recent years many additional facts have become known with regard to the Amphipoda of New Zealand through the investigation of collections from the various Antarctic and other expeditions. As circumstances are not at present favourable for the publication of a comprehensive review of the group, it is proposed- to issue, under the title given above, a series of notes briefly detailing some of the new facts, and giving references to sources where additional information can be obtained. It will be seen that frequent use has been made of the MS. notes and drawings and of the specimens placed in my hands by the Hon. G. M. Thomson; in several cases these are most useful for elucidating points in connection with some of the earlier records of Amphipoda from New Zealand.

The names of authors followed by a date in parentheses refer to the list on page 8.

Leptamphopus novae-zealandiae (G. M. Thomson). Figs. 1 to 5.

Pherusa novae-zealandiae G. M. Thomson, 1879, p. 239, pl. 10 C, figs. 2, 2 a-c.

Pherusa neo-zelanica G. M. Thomson and Chilton, 1886, p. 148. *Panoploea debilis*

G. M. Thomson, 1880, p. 3, pl. 1, fig. 3; G. M. Thomson and Chilton, 1886, p. 150.

Acanthozone longimana (part) Della Valle, 1893, pp. 604, 620. *Oradarea longimana*

Walker, 1903, p. 56, pl. 10, figs. 77-89; Stebbing, 1906, p. 727; Chevreux, 1906, p. 54;

Walker, 1907, p. 32. *Leptamphopus novae-zealandiae* Stebbing, 1906, p. 294;

Chilton, 1909, p. 621; Chilton, 1912, p. 488; Chevreux, 1913, p. 143.

There has been considerable confusion in connection with this species, and it seems desirable to support the synonymy given above by the following historical account.

In 1879 Mr. G. M. Thomson published his first paper dealing with New Zealand Crustacea. In it he described several new species, including *Pherusa novae-zealandiae* from Dunedin, of which he gave a brief description and figures of the whole animal, of the gnathopoda, and of the telson (1879, p. 239, pl. 10 C, fig. 2).

The only work of reference on the Amphipoda available to Mr. Thomson at that time was Spence Bate's *Catalogue of the Amphipoda in the British Museum*. The amount of dissection and minute examination that is necessary to distinguish between allied species was not then realized, and

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it will be seen from what is recorded below that Mr. Thomson's description was a composite one based on specimens belonging to more than one species.

In the next year Mr. Thomson described and figured another new species under the name *Panoploea debilis*, also from Denedin Harbour, the genus *Panoploea* being new and including *P. debilis* and *P. spinosa*, another new species described at the same time (1880, p. 3).

In 1882 I had identified specimens collected at Lyttelton Harbour as *Panoploea debilis* G. M. Thomson, and later on was able to compare them with specimens from Dunedin named by Mr. Thomson and to ascertain that they were identical with his species. This species proved to be moderately common in New Zealand seas, and was long known to New Zealand workers under the name *Panoploea debilis* G. M. Thomson.

In 1893 Della Valle placed the species in the genus *Acanthozone* as a doubtful synonym of *Acanthozone longimana* (Boeck), a species which is now placed under the genus *Leptamphopus*, and remarked that *Pherusa novae-zealandiae* G. M. Thomson seemed to coincide with *Panoploea debilis* G. M. Thomson.

In his account of the Amphipoda Gammaridea in *Das Tierreich*, Stebbing (1906, p. 294) includes both *Pherusa novae-zealandiae* and *Panoploea debilis* under the name *Leptamphopus novae-zealandiae* (G. M. Thomson), but without making any reference to the differences in the descriptions of the two species as given by Thomson. In 1903, before Stebbing's *Das Tierreich Amphipoda* was published, Mr. A. O. Walker, in his account of the "Southern Cross" Antarctic Expedition, had described and figured a new genus and species, *Oradarea longimana* (1903, p. 56), and in the appendix of *Das Tierreich Amphipoda* Stebbing quotes this species and says of it "strangely like *Leptamphopus novae-zealandiae*" (1906, p. 727).

In 1906 Chevreux recorded *Oradarea longimana* Walker from Flanders Bay and other localities in Graham Land visited by the French Antarctic Expedition, 1903–5 (1906, p. 54).

In his account of the Amphipoda of the National Antarctic Expedition, Walker in 1907 records *Oradarea longimana* from Coulman Island and other localities visited by the expedition, and in a footnote referring to Stebbing's remarks points out that his species differs from Thomson's description of *Pherusa novae-zealandiae* "in having only the first two pleon segments dorsally produced into one tooth, instead of the two posterior segments of the mesosome and two anterior of the pleon produced into two teeth; also in the upper antennae having an appendage" (1907, p. 32).

In 1909, in the account of the Crustacea in the *Subantarctic Islands of New Zealand*, I followed Stebbing in considering *Panoploea debilis* to be the same as *Pherusa novae-zealandiae*, and recorded the species under the name *Leptamphopus novae-zealandiae* (G. M. Thomson), from Carnley Harbour, in Lord Auckland Islands, and after comparing it with Walker's description came to the conclusion that *Oradarea longimana* Walker was identical with *Leptamphopus novae-zealandiae* (G. M. Thomson). as Stebbing had suggested, the differences pointed out by Walker being apparently due to individual variation or to errors in the descriptions (1909, p. 621). In his account of the Amphipoda of the second French Antarctic Expedition, 1908–10, Chevreux adopted this view, referred specimens from Petermann Island to *Leptamphopus novae-zealandiae* (G. M.

Thomson), and gave a few further particulars of the species. This species was collected by the Scottish National Antarctic Expedition at South Orkneys, and, was recorded by me in the account of the Amphipoda of the expedition under the name *Leptamphopus novae-zealandiae* (G. M. Thomson) (1912, p. 488).

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Though I have all along been convinced that Stebbing was right in combining *Panoploea debilis* G. M. Thomson with *Pherusa novae-zealandiae* G. M. Thomson, it has been a little difficult to understand the differences in the descriptions of these species, and how it was that Mr. Thomson came to describe the same form as two different species in two successive years.

In January, 1914, in the collections of the Dunedin Museum, I found a bottle labelled "*Pherusa novae-zealandiae* G. M. Thomson, Dunedin; Type," in the handwriting of the late Captain Hutton, who was Curator of the Museum at the time when the species was first described, and through the kindness of Professor Benham I have been able to make an examination of its contents. The bottle contained altogether ten specimens, all more or less imperfect; seven of them are without doubt the species common in New Zealand and long known under the name *Panoploea debilis* G. M. Thomson. All of these specimens have lost their antennae except the peduncles, but the character of the gnathopoda, of the projection of some of the segments into dorsal teeth, and of the uropoda and telson leaves no doubt as to the identity of the species. Of the other three specimens, two, one of them imperfect, are small examples of *Paradexamine pacifica* (G. M. Thomson), which have apparently been included by accident, and are of no importance in the present discussion. The remaining specimen, which is the largest of the lot, and of which the head and anterior part of the peraeon are missing, is a specimen of a different species altogether, *Panoploea spinosa* G. M. Thomson, which is no longer considered congeneric with *Panoploea debilis* and is placed by Stebbing in a different family.

It seems evident that these specimens had been grouped together owing to the fact that in all of them some of the segments are produced posteriorly into dorsal

teeth and that a portion of the original description of *Pherusa novae-zealandiae* had been based on the specimen of *Panoploea spinosa*: e.g., the statement that "two posterior segments of the pereion and two anterior segments of the pleon produced dorsally into two teeth," and "three last pairs of pereiopoda much longer than the preceding; their coxae with comb-like teeth on their posterior margins"; also, "third segment of pleon with the sides produced posteriorly, and ending abruptly in a serrated margin." The characters thus quoted agree well with this specimen of *Panoploea spinosa*, and some of them are indicated in the figure given by Thomson in describing *Pherusa novae-zealandiae*. These points do not show clearly in the very small figures accompanying Mr. Thomson's published paper, for "instead of lithographing the plates, the draughtsman traced them on to a large sheet, from whence they were photo-lithographed" (see Stebbing, 1888, p. 500), and in the process they were so much reduced that many of the points shown clearly in the original drawings cannot be made out. Mr. Thomson has, however, given me the tracings of the originals, and in the tracing of the figure of the whole animal of *Pherusa novae-zealandiae* it is evident that the dorsal teeth, the basal joints of the posterior pereiopoda, and the hind-margin of the third pleon segment have been drawn from the specimen of *Panoploea spinosa*, and not from the genuine *Pherusa novae-zealandiae*. The other characters have been based on the specimens really belonging to *Pherusa novae-zealandiae*, and the description is therefore composite, being based on more than one specimen, as is shown by the statement that the posterior margin of the third segment of the pleon "is almost smooth in young specimens," the "young specimens" being the genuine *Pherusa novae-zealandiae*, and quite different from the *Panoploea spinosa* which was confused with them.

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It is therefore evident that *Panoploea debilis* (G. M. Thomson) is indeed the same as *Pherusa novae-zealandiae* G. M. Thomson, but was thought to be different owing to the errors in the original description and figures; and that the differences pointed out by Walker between his *Oradarea longimana* and the description of *Pherusa novae-zealandiae* are due to the fact that the original description was based on the examination and confusion of two different species.

The history of this species has perhaps been detailed at tedious length, but it is interesting as another example of the necessity of examining type specimens, whenever they are available, in order to settle disputed points, instead of trusting too greatly to published descriptions and figures and relying too much upon their accuracy.

The exact generic position of this species is a little doubtful, owing to the fact that in the group to which it belongs there are so many genera much alike and distinguished by characters which are perhaps not all of generic importance. It will be seen that the species was first placed under *Pherusa*, then under *Panoploea*, next under *Acanthozone*, then under *Oradarea* (a genus specially created for it), and finally under *Leptamphopus*. In *Das Tierreich Amphipoda* there is only one other species, *L. longimana* (Boeck), placed in this genus, and that was originally described by Boeck under the genus *Amphithopsis*.

If we compare the species under consideration with the generic characters of *Leptamphopus* as given by Stebbing (1906, p. 293) it is found to agree in most points. The first point mentioned, however, "Body not acutely dentate," requires some modification, for in this species the last segment of the peraeon and the first two of the pleon are dentate; again, in the generic characters it is stated that there is no accessory flagellum, though Walker describes and figures one in the specimens of this species obtained from Cape Adare, and his observation is confirmed by Chevreux, and there is certainly a minute accessory flagellum in a specimen in my collection collected at the South Orkneys by the "Scotia" Expedition. On the other hand, there is none in the New Zealand specimens nor in the northern species *L. longimanus* (Boeck). In the mouth parts there is nothing that appears to me specially characteristic of the genus, which seems best recognized by the long slender gnathopoda and the entire telson. Most of the characters of *Leptamphopus* are the same as those of *Djerboa* Chevreux, but in that genus the telson is deeply cleft.

The following brief description will be sufficient to distinguish *L. novaezealandiae* from the northern species, *L. longimanus*:—

Back rounded, peraeon segment 7 and pleon segments 1 and 2 each produced posteriorly into a dorsal tooth. Antennae subequal, slender, about as long as body. Antenna 1 with second joint of peduncle produced on each side into a short subacute lobe, a minute accessory appendage present in Antarctic specimens but not in those from New Zealand. Gnathopod 1 with carpus and propod subequal, narrow-oblong, palm short, oblique. Gnathopod 2 much longer and more slender, carpus and propod elongate, linear, with small tufts of setae on their posterior margins, propod longer than the carpus, palm short, oblique. Uropods 1 and 2 with outer branch much shorter than the inner; uropod 3 with basal joint acutely produced on inner side, outer branch not much shorter than inner, both lanceolate, slightly flattened and broader than in uropods 1 and 2, inner branch with an elevation or ridge on its upper surface near the inner margin. Telson

tapering slightly, extremity broadly rounded or truncate, sometimes a little irregular, and with one or two minute setae.

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Length of New Zealand specimens, about 9 mm.; Antarctic specimens, up to 12 mm. or more.

Colour greyish or light-brown, made up of dark dots or stellate markings.

Distribution: New Zealand (Dunedin Harbour, Lyttelton, Akaroa, &c.); Cape Adare; Coulman Island; McMurdo Strait; Petermann Island; Flanders Bay; Port Charcot; Orkney Islands: probably circumaustral.

Leptamphopus novae-zealandiae.

Fig. 1.—First gnathopod.

Fig. 2.—Second gnathopod.

Fig. 3.—First uropod.

Fig. 4.—Second uropod.

Fig. 5.—Third uropod and telson, showing ridge on inner branch of the third uropod.

This species very closely resembles *P. longimanus* (Boeck), a species found in the Arctic and North Atlantic Oceans, the chief difference being that in *P. longimana* no segment of the body is produced into teeth.

The Antarctic specimens appear to differ constantly from those occurring in New Zealand in the presence of a minute accessory appendage on the upper antenna. Both Walker and Chrevreux remark on the variation in the dorsal teeth of the body-segments in Antarctic specimens of different sizes; all the mature New Zealand specimens seem to agree in having the last peraeon and first two pleon segments produced into teeth.

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As I have previously suggested (1909, p. 621), the small side lobes at the end of the second basal joint of the upper antenna, which were first noticed by Walker, appear to be for the support of the rest of the antenna, allowing it to move freely in a vertical plane but not from side to side. In a similar way there is a slight hollow or depression on the upper surface of the inner branch of uropod 3 formed on the outer side of the ridge mentioned above, and into this the outer branch fits closely when it is not in use (see [fig. 5](#)). Analogous structures will probably be found in other Amphipoda of similar habits.

Ampelisca eschrichtii (Kroyer).

Ampelisca eschrichtii Chilton, 1917, p. 75.

In the Index Faunae Zealandiae two species of *Ampelisca* are put down as found in New Zealand, *A. chiltoni* and *A. acinaces*, both described by Stebbing in the report on the "Challenger." Amphipoda. In the paper quoted above I attempt to show that these are only forms of the species long known in Arctic seas as *A. eschrichtii* Kröyer, and that *A. macrocephala* Liljeborg should also be considered as belonging to this species. The species is widely distributed both in Arctic and in Antarctic seas, where it may attain a length of 34 mm. In intermediate seas it is represented by forms of smaller size, in which the distinctive characters of the species are less evident.

Urothoides lachneëssa (Stebbing).

Urothoe lachneëssa Stebbing, 1888, p. 825, pl. 57. *Urothoides lachneëssa* Stebbing, 1906, p. 132.

This species was described from specimens obtained from Kerguelen Island by the "Challenger" Expedition. I have a specimen, washed on to the shore of Stewart Island and sent to me by Mr. Walter Traill, that I feel confident belongs to the same species. The specimen had been dried and somewhat shrivelled, but by

mounting it in dissected form sufficient of the appendages can be made out to render the identification pretty certain. The first and second gnathopods agree closely with Stebbing's figure except that in the first the propod is narrower. The first, second, and third peraeopods are also closely similar. The fourth and fifth cannot be distinctly made out, but appear to agree except in having fewer setae. One of the uropods also can be seen to agree with Stebbing's figure.

This appears to be the first specimen that has been seen since the original ones were taken by the "Challenger."

Parapherusa crassipes (Haswell).

Harmonia crassipes Haswell, 1879, p. 330, pl. 19, fig. 3. *Parapherusa crassipes* Stebbing, 1906, p. 383; Chilton, 1916, p. 199, pls. 8–10.

This is a species widely distributed in Australia and New Zealand, and for some time there was an uncertainty as to its systematic position. It seems, however, rightly placed under the genus *Parapherusa* in the family Gammaridae, to which it was assigned by Stebbing. A full account of its external structure and of the marked sexual differences is given in the last of the references quoted above.

Eurythens haswelli (G. M. Thomson).

Maera haswelli G. M. Thomson, 1897, p. 449, pl. 10, figs. 6–10.

Wyvillea haswelli Stebbing, 1899, p. 350, and 1906, p. 648.

In Mr. Thomson's collection are two imperfect specimens labelled "*Maera haswelli* G. M. T., Bay of Islands, 8 fathoms," which are presumably co-types of his species. These are identical with specimens from

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Akaroa and Lyttelton obtained years ago, and provisionally labelled as an

undescribed species of *Eurystheus*. Stebbing in 1899 placed the species under *Wyvillea*, a genus of doubtful validity, and retained it in the same position in 1906. The species is, however, quite evidently a *Eurystheus* and comes near to *E. dentifer* (Haswell); the third side plate in the male is produced anteriorly below that of the second gnathopod in the same way as described for *Paranaenia typica* Chilton (1884, p. 259), a species which Stebbing considers a synonym of *Eurystheus dentifer* (Haswell).

In addition to the Bay of Islands specimens I have others of *E. haswelli* from Lyttelton; Akaroa; Longbeach, near Otago Harbour; Stewart Island; Chatham Islands; and also one from Port Jackson, New South, Wales, sent to me in 1918 by Professor W. A. Haswell.

***Eurystheus crassipes* (Haswell).**

Maera crassipes Haswell, 1880, p. 103, pl. 7, fig. 2. *Eurystheus crassipes* Stebbing, 1906, p. 612.

I have specimens from Wellington and Auckland Harbours that evidently belong to this species, which was described from Port Jackson and Jervis Bay in Australia by Haswell; it is well characterized by the large size and breadth of the fourth pereaeopod, and has rightly been placed in *Eurystheus* by Stebbing. The species has not hitherto been recorded from New Zealand.

***Eurystheus chiltoni* (G. M. Thomson).**

Maera chiltoni G. M. Thomson, 1897, p. 447, pl. 10, figs. 1–5. *Eurystheus chiltoni* Stebbing, 1906, p. 617. *Eurystheus longicornis* Walker, 1907, p. 35, pl. 12, fig. 21.

This species was described by Mr. Thomson from specimens dredged in the Bay of Islands. I have a specimen from Mokohinou, found by Mr. C. R. Gow on seaweed at a depth of 25 fathoms. I think there is no doubt that *E. longicornis* (Walker) is the same species; the descriptions agree generally, and the drawing given by Walker of the second gnathopod of the male agrees well with my specimen from Mokohinou and also with co-types of Mr. Thomson's species which I have been able to examine. Walker's specimens were collected at the winter quarters of the "Discovery" in McMurdo Strait during the National Antarctic Expedition, 1901–4.

***Eurystheus dentatus* (Chevreux).**

Gammaropsis dentata Chevreux, 1900, p. 93, pl. 12, fig. 1. *Eurystheus afer* Chilton, 1912, p. 510, pl. ii, figs. 30–34.

I have a few specimens of *Eurystheus* that I have had some difficulty in identifying. I find, however, in the better-developed specimens that the lower

margin of the first side plate is distinctly dentate, as described and figured by Chevreux for the species named above, and the general agreement in other characters shows that they must be referred to that species. In the New Zealand specimens, both in the male and the female, the gnathopoda are more elongated and slender than those figured by Chevreux, but in others from the Kermadec Islands which seem to be otherwise the same the gnathopoda are stouter and like those of Chevreux' specimens. The New Zealand specimens are certainly the same as those from Gough Island collected by the "Scotia" "Expedition that I referred with much hesitation to *E. afer* Stebbing in 1912, and in two the merus of one or more of the last three pairs of pereaeopoda is expanded in the same way as it is in one of the Gough Island specimens, though not quite to the same extent.

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The terminal segments of the pleon are dentate as in *E. thomsoni* Stebbing, to which I was at first inclined to refer my specimens, and, indeed, the two species may possibly prove to be identical; in the meantime, however, I have not been able to satisfy myself on this point.

Chevreux' specimens were from the Azores. It should be remembered that another, quite different, species from Alaska was described under the same name by Holmes in 1908; for this Stebbing has suggested the name *alaskensis* (1910, p. 613).

The specimens that I refer to *E. dentatus* (Chevreux) are from Cook Strait; off Cape Saunders; Stewart Island; and the Kermadec Islands. If I am correct in my identifications, it is also found at Gough Island and at the Azores.

Paracorophium excavatum (G. M. Thomson).

Corophium excavatum G. M. Thomson, 1884, p. 236, pl. 12, figs. 1-8.
Paracorophium excavatum Stebbing, 1906, p. 664; Chilton, 1906, p. 704.

This species was described by Mr. Thomson from specimens taken in Brighton

Creek, near Dunedin. Since then it has been found in several localities around the New Zealand coast where the water is more or less brackish, and also in the fresh-water lake Rotoiti, in Auckland. In 1918 some amphipods were sent me from brackish water in Brisbane River, Queensland, where they had been collected, along with the destructive wood-boring isopod *Sphaeroma terebrans* Bate, by Dr. T. Harvey Johnston, and these prove to belong to the same species. The males are distinguished from the females by a lobe on the end of the penultimate joint of the peduncle of the lower antenna, and by a differently shaped second gnathopod. The form originally figured by Thomson is an immature male. I have redescribed the species and given an account of the development of the sexual characters in a paper which will shortly be published in the *Queensland Museum Memoirs*, vol. vii.

The occurrence of the species in brackish waters in New Zealand and also in northern Australia is of considerable interest.

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Art. II.—Contributions to a Fuller Knowledge of the Flora of New Zealand. No. 7.

By T. F. Cheeseman, F.L.S., F.Z.S., F.N.Z.Inst., Curator of the Auckland Museum.

[*Read before the Auckland Institute, 22nd December, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.*]

Colobanthus Muelleri T. Kirk.

Dry ground near the verge of sea-cliffs, Manaia, Taranaki; *Mrs. F. Mason!* I am not aware of a more northern locality on the western side of the North Island.

***Plagianthus cymosus* T. Kirk.**

Mr. Phillips Turner informs me that this species occurs in the valley of the McLennan River, a branch of the Tahakopa River, which flows into the sea about twenty miles south of Catlin's River, Otago. The locality is not far from the sea,

and it would be interesting to ascertain whether both *P. betulinus* and *P. divaricatus* are to be found in the vicinity. In the *Illustrations of the New Zealand Flora* vol. 1, pl. 21) I have hinted at the probable hybrid origin of the plant.

Gunnera arenaria Cheesm.

Moist sandy places on the coast near Manaia, Taranaki; *Mrs. F. Mason!* Not previously recorded between New Plymouth and Patea, but probably always to be found in damp places on sand-dunes of any extent.

Eugenia maire A. Cunn.

So far as I am aware, no one has recorded the presence of pneumatophores in *Eugenia maire*. They were first brought to my notice by Mr. Colin Stewart, late of Mangatai, Mokau, who supposed that they were connected with the remarkable floating roots of *Freycinetia Banksii*, mentioned farther on in this paper. The mistake is a very natural one to make in a wooded swamp, where the roots of both species are almost inextricably mixed. As *Eugenia* is plentiful in swampy gullies at Birkdale, near Auckland, I induced Mr. F. S. Fisher, a resident in the locality, to make a careful search, which resulted in proving that the pneumatophores were abundant in most suitable localities. At a later date I visited the district under Mr. Fisher's guidance, and was able to prepare the following notes.

The pneumatophores of *Eugenia maire* rise from the ordinary roots of the tree, and reach a height of 9 in. to 18 in. above the level of the ground. They are about $\frac{1}{4}$ in. in diameter at the surface of the ground, seldom more, and are rigidly erect, and usually fasciculately branched. The ultimate shoots are – in. in diameter, cylindric, faintly constricted here and there. They somewhat resemble the branches of *Salicornia* in

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appearance, but are not jointed, and are much more stiffly erect. They are obtuse and frequently swollen at the tip, spongy or corky, but are always furnished with a hard woody central axis. The young and growing part of the pneumatophore is

usually coloured a reddish pink. When old and apparently ceasing to perform its duties as an air-breather the outside layers die, and are thrown off in thin whitish flakes. No pneumatophores were noticed bearing leaves; but many of them give off thin slender shoots which turn downwards at an acute angle and, entering the ground, assume the appearance of true roots. The contrast between the stiffly erect true pneumatophores and the thinner branches all turning sharply downwards is very remarkable. It is much to be desired that some one would work out the anatomical peculiarities of these curious structures.

Aciphylla Cuthbertiana Petrie.

I have to thank *Mr. James Speden*, of Gore, for an excellent suite of specimens of this distinct species, collected on The Hump, near Lake Hauroko, at an elevation of about 3,000 ft.

Coxella Dieffenbachii Cheesem.

Mr. E. R. Chudleigh informs me that until comparatively recent years *Coxella* was fairly abundant on the north-east to north-west slopes of Cape Young (Mairangi), on the north side of Chatham Island, and may still linger there. Originally the plant was more or less abundant on the whole of the cliffs of the northern side, but has been destroyed by sheep in all localities to which they can gain access.

Angelica rosaefolia Hook.

Sea-cliffs near Manaia, Taranaki; *Mrs. F. Mason!* Not previously recorded anywhere on the coast-line south of New Plymouth.

Panax Edgerleyi Hook. f.

I am indebted to *Mr. W. Martin*, of Christchurch, for a specimen of this, gathered in forest at Akaroa. It is not mentioned in Mr. Laing's valuable paper on the "Vegetation of Banks Peninsula," nor in the earlier lists of Raoul and Armstrong. At the same time, considering its distribution elsewhere in New Zealand, it is precisely one of those species that might be reasonably expected to occur.

Gnaphalium Lyallii Hook, f.

Damp places on sea-cliffs near Manaia, Taranaki; *Mrs. F. Mason!* As this handsome plant has been gathered northwards at Opunake by the late Mr. T. Kirk, and to the south at Waingongoro by Dr. Cockayne, we may assume that it is probably abundant on the Taranaki sea-coast to the south of Cape Egmont.

Cotula coronopifolia Linn.

Var. *integrifolia* T. Kirk is certainly nothing more than a starved diminutive form. On the railway reclamations on the foreshore of Auckland Harbour it has

appeared in immense abundance during the last two or three years, chiefly in places where water has stagnated in winter or

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spring. The ordinary form of the species, which is abundant in the same locality, when growing in good soil and plentifully supplied with moisture has numerous branching stems, creeping below but ascending at the tips, and has an average-height of from 5 in. to 10 in. From that it passes imperceptibly into much smaller states, in which the stems are unbranched, the leaves linear and entire, and the flower-heads much smaller and solitary, thus constituting the so-called variety. When seeds are abundantly produced, and the surrounding area is unoccupied, multitudes of seedlings appear, so closely packed and so reduced in size as to resemble patches of moss when seen from a little distance. The individual stems, in such cases, are often not more than $\frac{1}{2}$ in. in height, bearing 2 or 3 minute leaves, and with a solitary flower 1 mm. in diameter. A patch of these seedlings, measuring 2 in. by $1\frac{1}{4}$ in., contained no fewer than 343 separate plants, the tallest of which was under 1 in. in height, Another piece, cut out of a patch some yards in extent, and measuring $1\frac{1}{2}$ in. by 1 in., contained 213 separate plants. A yard square, if covered in a similar manner—and several such instances were observed—would contain at least half a million plants.

Dracophyllum Townsoni Cheesem.

Mr. James Speden, of Gore, sends me specimens of this, gathered at an elevation of 3,000 ft. on The Hump, near Lake Hauroko. Mr. Speden informs me that he frequently observed leaves over 2 ft. in length, thus equalling those of *D. latifolium* and *D. Traversii*. None of the specimens of *D. Townsoni* sent to me by its discoverer has leaves much over 12 in., but Mr. Townson informs me that possibly small specimens were selected for convenience of carriage. Mr. Speden's plant has the peculiar decurved lateral panicle of *D. Townsoni*, but he saw no branched specimens.

Solanum aviculare Forst. var. *albiflora* Cheesem. n. var.

It has long been known that although this species ordinarily produces purplish flowers, yet occasionally white-flowered specimens are seen; but no one seems to have observed that in such cases the colour of the stems and of the veins of the leaves is also affected. As far back as 1880 I noticed that in white-flowered specimens observed by myself at Buckland the aspect of the plant was somewhat different from that of the purple-flowered variety; and at various times since then the same thought has occurred to me, but I failed to carry the inquiry any further. Early in 1915, however, Mr. W. Townson observed that the white-flowered variety was by no means rare near Pukekohe (Auckland District), and was induced to pay a little attention to it. He ascertained that not even one single white flower is ever produced on a purple-flowered plant. He also established the fact that on a white-flowered plant the leaves are pale green, and much thinner and more delicate in texture, so that the whole plant has a more slender and graceful appearance; and the stems and veins of the leaves are pale-greenish or yellowish-green. On the other hand, the plants with purple flowers have coarser leaves, and the veins of the leaves and the stems are purplish or brownish-purple.

Mr. James Graham, of Patumahoe, has also investigated the matter. He informs me that, having noticed several plants with white flowers on the earthworks of the Waiuku railway, he collected a number of seeds and had them sown in the Patumahoe School garden. About thirty plants

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were raised, all of which have the thin leaves and yellowish veins of the white-flowered variety. All the plants that have flowered up to the present time have borne white flowers. The facts thus collected by Mr. Townson and Mr. Graham may be taken as a satisfactory proof that the white-flowered plant constitutes a stable variety, "coming true" from seed, and well worth distinguishing by a varietal name.

Atriplex Billardieri Hook. f.

Sandy shores of Matakana Island, between Tauranga and Katikati; a few plants

only; *T. F. C.* This plant is singularly rare, and is seldom seen in any quantity. I am not aware that it has been gathered in any locality on the *western* side of either the North or the South Island.

Pimelea Gnidia Willd.

Mr. W. Townson has forwarded specimens gathered on the summit of a lofty hill between the Kauaeranga River and the Hihi Stream, Thames. This is at least 150 miles from the nearest part of the Ruahine Mountains, the most northerly locality previously known.

Tupeia antarctica Cham. & Schl.

I am indebted to *Mr. B. E. Sixtus*, of Umutai, on the western flanks of the Ruahine Range, for specimens of this, parasitic on *Olea Cunninghamii*, which is quite a new host so far as my own knowledge is concerned.

Dactylanthus Taylori Hook. f.

Mr. W. Townson, so well known from his fruitful botanical exploration of the Westport district, but now resident at the Thames, has been fortunate enough to discover this remarkable plant in great abundance in the elevated forest district lying north-east from the town of Thames. So far as I can judge, this is a continuation of the locality where it was observed by the late Mr. T. Kirk in April, 1869 (see *Trans. N.Z. Inst.*, vol. 2, pp. 94–95). Mr. Townson informs me that it can be observed for several miles along what is known as "Crosby's Track," and that he is acquainted with at least six separate stations. In all cases the host was *Schefflera digitata*, as is usual in the northern portion of the Auckland Provincial District. The rhizome attains a considerable size, the largest seen weighing over 6 lb. As the result of the examination of very numerous specimens Mr. Townson has definitely proved that the mature plant is monoecious, the male and female spadices being produced on the same rhizome, and often side by side. The male spadices, however, are the more numerous. All observers have pronounced the flowers to be highly fragrant, but disagree as to the nature of the perfume. Mr. Townson states that it resembles that of a "ripe rock-melon," but he also says that "like many perfumes, it may also pass into a bad smell when too concentrated." He also remarks that on one occasion he "kept a large rhizome for a considerable time in a back room, where it gradually expanded its flowers. The scent was so attractive to flies that all day long it was surrounded by a little crowd of them." No doubt this points to the fertilization of the plant through insect agency. The flowering season appears to last, at the Thames, from the middle of March to the middle of April.

Urtica ferox Forst.

Mr. T. H. Trevor has discovered another locality for this species in the Bay of Islands County, a few miles distant from the Ngamahanga *wahi-tapu* mentioned in my last contribution to this series (*Trans. N.Z. Inst.*, vol. 51, p. 89). This makes it probable that the plant may be observed in other stations north of Auckland. For a new southern locality I am indebted to *Mr. A. Allison*, who informs me that it is not uncommon at the base of the Paeroa Range, between Waiotapu and Orakei-korako.

Freycinetia Banksii A. Cunn.

I am not aware that any one has recorded the presence of curious floating roots in *Freycinetia Banksii*. My first acquaintance with them was derived from a fragment forwarded by Mr. B. C. Aston last February, which was collected by Mr. Sidney Fry in the Totara Creek, a small tributary of the Mokau River, junctioning with it about eighteen miles above its mouth. This fragment presented several unusual features, and I was consequently glad to avail myself of the kind assistance of Mr. Colin Stewart, at that time residing in the locality, for obtaining a copious supply of specimens. These consisted of slender roots, often several feet in length, in which the central axis is firm and solid, but the cortical tissue very loose and open. These roots are copiously branched, the ultimate divisions being very numerous and filiform. The outstanding peculiarity of the roots, however, which at once attracts attention, is that they are regularly girdled, as it were; with conspicuous spongy or corky whitish rings. These give the roots a very remarkable appearance, so that Mr. Fry, their original discoverer, describes them as "waving about with the disturbing currents like so many worms, their brown segmented forms, with the whitish sheaths encircling them at intervals, giving them the appearance of ringed worms."

Mr. Colin Stewart, in endeavouring to find the origin of the roots, considered that he had traced them to a tree which I have identified as *Eugenia maire*, the branches, leaves, and pneumatophores of which he sent. But this I believe to be a very pardonable mistake. A lengthened search at Birkdale, in a swampy district where both *Eugenia* and *Freycinetia* are abundant, and in which I had the assistance of Mr. F. S. Fisher and Mr. John Bishop, resulted in showing that while

it was comparatively easy to connect the floating roots with *Freycinetia*, and the pneumatophores, with *Eugenia*, all attempts to trace the floating roots to *Eugenia* failed.

The exact use of these “floating” roots in *Freycinetia* must remain doubtful until their anatomical structure has been investigated, but in all probability they may be looked upon as “breathing-roots.”

Juncus scheuchzerioides Gaud.

This is one of the species added to the florula of Macquarie Island by *Mr. H. Hamilton*, during the stay of a portion of the Australasian Antarctic Expedition on that island during the years 1911—13. It is a true circumpolar plant, having been recorded from the Auckland and Campbell Islands, Antipodes Islands, Fuegia, Falkland Islands, South Georgia, the Crozets, and Kerguelen Islands.

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Scirpus aucklandicus Boeck.

This also has been collected on Macquarie Island for the first time by *Mr. H. Hamilton*. Its existence thereon might have been safely predicted, seeing that it is the most common species of the genus on the islands to the south of New Zealand. It has also been recorded from Tasmania and from the isolated Amsterdam Island, but both these localities require fuller confirmation.

Carex trifida Cav.

Fringing swamp-holes on flats at West Point, Macquarie Island; *H. Hamilton*! Apparently not common, for Mr. Hamilton remarks on his labels that it was seen only in the locality quoted above. The geographical distribution of the species is given in the *Manual*.

Triodia macquariensis Cheesem.

"Apparently perennial, tufted, often forming dense patches, smooth and glabrous. Culms numerous, erect or geniculate at the base, 6—12 cm. long, leafy to the base of the panicle. Leaves equalling the culms or longer than them, rather narrow, 1—2 mm. broad, deeply striate, quite glabrous, flat or involute, margins thickened, tips obtuse, callous; ligules broad ovate, thin and membranous; sheaths unusually long, much broader than the blades, sometimes as much as 5 mm. across, smooth, pale, and membranous. Panicle narrow, glabrous, 2—3 cm. long; branches few, short, erect. Spikelets 6—15, 3—5-flowered, 6—7 mm. long, the lowest flower sessile at the base of the spikelet, the upper usually remote from one another. Empty glumes unequal, the lower half to two-thirds the length of the upper, glabrous, oblong, obtuse, 3-nerved. Flowering-glumes, ovate or broadly ovate-oblong, rounded at the back, not keeled, 5-nerved, glabrous or very faintly pubescent on the nerves, minutely 3-toothed at the tip or irregularly erose. Palea broad, 2-keeled, the keels ciliolate. Lodicules 2, acute.

"*Hab.*—Macquarie Island, rocks and cliffs near the coast; *H. Hamilton!* (1912—13).

"Mr. Hamilton remarks that this is a common coastal grass, found in crevices in bare rock or on the cliffs. Some of his specimens are plentifully mixed with *Tillaea moschata* or *Colobanthus muscoides*, both plants common in littoral situations. Scraps of *Callitricha antarctica* are also present. Its discovery adds another species to the list of those endemic in Macquarie Island, of which three species are now known—*Deschampsia penicillata*, *poa Hamiltoni*, and *Triodia macquariensis*. I have found it a puzzling plant to place. It differs from *Poa* principally, in the flowering-glumes being rounded on the back, and minutely 3-toothed (or irregularly erose) at the tip. It agrees with *Atropis* in the flowering-glumes being rounded on the back, but differs in habit, and in the 3-toothed tip of the flowering-glumes. Although not a typical *Triodia*, it must be kept in the vicinity of the New Zealand *T. australis*."

The above has appeared in my memoir on "The Vascular Flora of Macquarie Island," published in the *Scientific Reports of the Australasian Antarctic Expedition*. I reproduce it here to draw fuller attention to the species, which may occur in the islands to the south of New Zealand.

Festuca erecta D'Urville.

Macquarie Island, not uncommon on rocks near the sea; *Dr. Scott, A. Hamilton!* *H. Hamilton!* This is the plant described as a new species

by Mr. T. Kirk, under the name of *F. contracta* (*Trans. N.Z. Inst.*, vol. 27, p. 353). Kirk had only two very indifferent specimens to-deal with; but, fortunately, Mr. H. Hamilton secured a fair number of specimens. An examination of these proved that the plant was either very closely allied to the Fuegian and Kerguelen *Festuca erecta* D'Urville or positively identical with it. There being no authenticated specimens of *F. erecta* in New Zealand, I applied to Dr. Staph, of the Kew Herbarium, with the view of having a comparison made. This he has kindly done, with the result of proving that the Macquarie Island plant is identical with *F. erecta*. This is practically a circumpolar species, having been recorded from Fuegia, Falkland Islands, South Georgia, and Kerguelen Island.

Cyathea medullaris Swartz.

I am not aware that any actual measurements of the height of this species have been published. In books it is usually given as "from 10 ft. to 40 ft. high," but it certainly attains a much greater height. With the view of putting some definite information on record, I induced *Mr. E. Le Roy* to measure the height of two fine specimens growing in a ravine on his property at Birkenhead. He informs me that the smaller of the two is 39 ft. to the crown; the other one being 46 ft. to the crown, and 50 ft. to the top of the fronds. As I have seen taller specimens, we can safely conclude that it occasionally reaches between 60 ft. and 65 ft. in height.

Dicksonia squarrosa Swartz

Mr. Le Roy has also been kind enough to measure the height of two specimens of *Dicksonia squarrosa*. The higher one measured 23 ft. 8 in. to the crown, and 27 ft. to the top of the fronds; the other proved to be 19 ft. 6 in. to the crown and 21 ft. to the top of the fronds.

Nothochlaena distans R. Br.

The late *Mr. H C. Field*, in his book, *Ferns of New Zealand* (p. 88, and pl. xxviii, fig. 4), alludes to a supposed new *Cheilanthes* collected by Mr. A. C. Purdie near Dunedin. The description given is inconclusive, and the figure does not show sufficient detail to enable the generic position of the plant to be made out. In default of any specimens I consequently did not allude to it in the *Manual*.

Rather more than a year ago, however, *Professor A. Wall* forwarded a specimen of a fern collected in clefts in basaltic rocks at Diamond Harbour, a bay of Port Lyttelton, suggesting that it might prove to be Mr. Field's plant. In this view I concurred, but as the specimen showed no signs of sori it was impossible to fix its systematic position. Professor Wall has now forwarded an ample series of specimens in all stages, proving, as he says, that the plant is only a shade form of *Nothochlaena distans*. It usually occurred in deep crevices entirely shaded from the sun, and is consequently not so rigid nor so well covered with linear scales as the typical state, which is frequently seen in dry situations in the Auckland lava-fields. In the ramification of the frond, and in the position and character of the sori, the two plants are practically identical.

Naturalized Plants.

Eschscholtzia californica Cham.

This plant, which is sparingly naturalized as a garden escape, appears to be poisonous to stock, judging from the following particulars supplied to me by *Mr. T. H. Trevor*, of Pakaraka, Bay of Islands. He

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removed the fence from, an abandoned garden, exposing a few plants of the *Eschscholtzia*. A bull running in the paddock ate a few leaves and was seriously affected, but ultimately recovered. The plants were then grubbed up and destroyed, and no further symptoms were noticed among the cattle.

Unfortunately, it was not observed that a large number of seedlings had appeared in the neighbourhood of the old plants, so that when a number of lambs were placed in the paddock they were at once affected, half a dozen dying within an hour. At first they appeared to be silly, then lost the use of their limbs, and died frothing at the mouth.

Psoralea pinnata Linn.

Mr. R. Waters sends me specimens of this from the neighbourhood of Dargaville, where it is said to be spreading fast. I have also observed it by roadsides at Birkdale, near Auckland. The only previous record is Waipu (see *Trans. N.Z. Inst.*, vol. 46, p. 8).

Chrysanthemum coronarium Linn.

This well-known garden-plant has appeared as an escape from cultivation in several localities near Auckland. It has also established itself on the railway reclamations along the side of Auckland Harbour. It is a common plant in the Mediterranean region, extending southwards to the Azores, and has often appeared as a naturalized plant in Britain.

Senecio spathulatus A. Rich.

This species, which is allied to the New Zealand *S. laetus* Forst, has appeared in great quantities on the Harbour Board and railway reclamations fringing Auckland Harbour, and is fast making its way into waste places within the City of Auckland itself. It has probably been accidentally introduced from Australia, where it is known from several localities, and particularly from "sandy shores in Port Jackson" (Sydney Harbour). I am indebted to Dr. Maiden, of the Sydney Botanical Gardens, for asking his assistant, Mr. Cheel, to make a special report on my specimens of the plant, with which I have been somewhat puzzled. He informs me that, although it comes under the circumscription of *S. spathulatus* as defined by Mr. Bentham in the *Flora Australiensis*, all the New South Wales specimens, as well as all my own, have pubescent achenes and 2-nerved involucral bracts, thus agreeing with the description of *S. anacampserotis* DC, and differing from the type description of *S. spathulatus*, which is said to have the fruit "*linearis striatus glaber*." Mr. Cheel considers it to be an open question whether *S. anacampserotis* should not be reestablished as a species.

Juncus acutiflorus Ehr.

Moist gullies at Pukeatua, West Taupo County; *D. Retrie!* I am indebted to Mr. Petrie for specimens of this species, which has not been previously noticed as introduced into New Zealand. I understand that the specimens were identified by Dr. Stapf, of the Kew Herbarium.

Festuca fallax Thuill. and F. dura Host.

I have also to thank Mr. Petrie for specimens of these two plants, which have been identified by Dr. Stapf under the names given above—in the case of the second one with some little doubt. In a broad sense they would doubtless be treated as forms of the widespread *F. rubra* Linn.

Art. III—*Descriptions of New Native Flowering-plants.*

By D. Petrie, M.A., Ph.D., F.N.Z.Inst.

[Read before the Auckland Institute, 22nd December, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.]

Pittosporum Matthewsii sp. nov.

Planta *P. virgatae* T. Kirk affinis; differt foliis confertis, maturis linearioriblongis subacutis glabris a marginibus undulatis; capsulis longioribus subacute obovatis, ± 1.8 cm. longis, circa 1 cm. latis, valvis duabus nec canaliculatis nec latere depresso atris undique lacunosis.

A small compactly branched tree, 20–25 ft. high, with black bark.

Juvenile state: Branches and twigs slender, the latter closely covered with greyish-white pubescence; leaves rather closely placed, patent, narrow-linear, ± 2 cm. long, ± 2 mm. wide, subacute entire or slightly waved at the margins, glabrous or nearly so, little coriaceous, somewhat recurved at the edges when dried, midrib evident below, rather obscure above, the upper surface dark green and polished, paler below; very young leaves brownish-green and more or less closely clothed with white semipubescent hairs; petioles very short and slender.

Mature state: Twigs more or less closely scarred by the bases of the fallen leaves; leaves rather closely placed, linear-oblong or narrow obovate-oblong, ± 4 cm. long, 5–8 mm. wide, subacute, glabrous except the sub-floral which are closely covered with brownish-yellow tomentum, moderately coriaceous, entire, flat or more or less wavy at the margins (rarely obscurely sinuate-dentate near the tips), the lower surface paler with conspicuous dark-red midrib and veins, above more or less polished with midrib obscure and veins obsolete, edges slightly recurved when dried; petioles very short and slender.

Flowers terminal, solitary or in compact umbels of 6 or fewer, rather small, ± 7 mm. long; peduncles not longer than the flowers, densely clothed, as are also the

sepals, with brownish-yellow tomentum; sepals linear-lanceolate, acute; petals dark red, narrow-cuneate, obtuse, sharply recurved over the tips of the sepals; pistil as long as the flower, pilosely pubescent below the style. Mature capsules subacutely obovate or sub-pyriform, \pm 1.8 cm. long, about 1 cm. broad above the middle, obtuse or broadly subacute, shortly apiculate, glabrous, 2-valved, the valves nearly semicircular in cross-section and neither grooved nor ribbed, black-pitted all over.

Hab.—Kennedy Bay, Coromandel Peninsula: H. B. Matthews !

The close placing of the leaves, their linear-oblong outline, and the distinctive size and shape of the mature capsule clearly distinguish this species from *P. virgatum*. I have seen nothing to indicate any variation in the form of the juvenile leaves, but as I have not seen the plants growing I cannot be certain that such variation does not occur.

Uncinia longifructus (Kük.) Petrie sp. nov.

U. laxe caespitosa v. \pm diffusa; culmi 12–20 cm. longi filiformes teretes stricti glabri leviter canaliculati. Folia peranguste linearia plana v. \pm complicata tenuia flaccida longe vaginantia vix canaliculata, carina subtus conspicua. Spiculae breves pauciflorae \pm 1 cm. longae \pm 5 mm. latae;

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pars mascula brevissima; glumae anguste lanceolatae acutae tenues pallide virides, leviter 3-nerviae, a marginibus late scariosae, mox deciduae. Utriculi 5–6 mm. longi plano-convexi peranguste elliptici aenei politi, nervis duobus haud conspicuis distantibus a latere convexo percursi; rhacheola utriculum dimidio superans; nux oblonga triquetra apice leviter annulata.

Laxly tufted or spreading more or less freely by slender stolons. Culms 12–20 cm. long, filiform, terete, strict, smooth, slightly grooved, clothed for one-third their length by the sheathing leaf-bases, equalling or exceeding the leaves. Leaves very narrow linear, flat or slightly folded, thin and flaccid, smooth (the edges towards

the tips only slightly scabrid), long-sheathing hardly grooved, midrib evident below. Spikelets short and few-flowered, \pm 1 cm. long including the bristles, and about half as wide; female flowers 3–4 (rarely more); male part very short, of 2–3 flowers; stamens 3, long. Glumes narrow-lanceolate, acute, thin, pale green, rather faintly 3-nerved along the middle of the back, with broad scarious edges, the lateral nerves vanishing below the apex, soon falling away from the broad cupular expansions of the rhachis on which they are seated. Utricles 5–6 mm. long, very narrow elliptic, more or less plano-convex, greenish-brown, polished, with two rather faint distant nerves near the edges of the convex face, broadly stipitate below, very gradually narrowed above into a long acute beak; bristle $1\frac{1}{2}$ times as long as the utricle. Nut oblong, triquetrous, slightly annulate at the base of the style.

Hab.—Open beech forest, Routeburn Valley, Lake County, at 2,300 ft.; End Peak, Lake Hauroto, J. Crosby Smith! Clinton Valley, Lake Te Anau, in open bush.

Kükenthal has made this plant a variety of *U. tenella* R. Br. It is easily distinguished from the latter by the following characters: the thin flat flaccid long-sheathing leaves, the much longer culms, and the greatly longer and narrower plano-convex greenish-brown polished utricles. The length of the utricle of *U. tenella* is given as $1\frac{1}{2}$ lines by Bentham and as 3 mm. by C. B. Clarke, and its shape is altogether different from that of the plant here described. Kükenthal gives the length of the utricles of *U. tenella* as $3\frac{1}{2}$ mm., and those of his variety *longifructus* as 6 mm. He also states (incorrectly) that C. B. Clarke *always* found only two stamens in the male flowers of *U. tenella*.

Note on *Uncinia tenella* R. Br.

Specimens of an *Uncinia* collected by Dr. Cockayne and myself at an elevation of about 4,000 ft. on Kelly's Hill (Taramakau River), Westland, belong, so far as I can judge, to this species, the typical form of which has not so far been recorded from New Zealand. These closely match specimens of Brown's plant from (1) Southport (Tasmania), (2) Upper Yarra (Victoria), and (3) the Dandenong Ranges (Victoria), given me by the late Sir Ferdinand Mueller. In the Kelly's Hill plant the stamens were 3 in the few male flowers I could spare for dissection. In one of the Southport plants there were 2 stamens in three of the male flowers, and 3 in two other flowers. Bentham found only 2 stamens in the flowers he examined. Mr. C. B. Clarke says the stamens in the specimens seen were 2, at least most frequently—"saltem saepissime." The utricles of the Kelly's Hill plant differ in no respect from those of typical *U. tenella*. Mr. Cheeseman (*Manual*, p. 800) considers the Kelly's Hill plant intermediate between *U. tenella* R. Br. and *U. nervosa* Boott. What *U. nervosa* may be no one knows definitely. Bentham remarks that

it was founded on a single specimen, and refers it to *U. compacta* R. Br. Mr. C. B. Clarke ranks it as a variety of the latter. The *U. nervosa* in Cheeseman's *Manual* seems to me in no way closely related to the Kelly's Hill plant. The figure of Boott's species in *Flora Tasmanica* is a poor one, and affords little help in identifying it.

Uncinia caespitosa Col. var. *collina* var. nov.

Rhizoma late stolonifera culmos plurifoliosos plerumque diffusos edens. Culmi foliaque quam in typo breviores. Folia culmis breviora vel eos aequantia, 10–20 cm. alta 4–6 mm. lata, plana suberecta coriacea, in apices incrassatos longe productos abeuntia. Spiculae 4–8 cm. longae ± 8 mm. latae, subclavatae, supra densiflorae, infra floribus laxioribus; glumae femineae utriculis nonnihil longiores; nux elliptico-oblonga.

Hab.—Mount Hikurangi (East Coast), at 4,800 ft.; Ruahine Mountains, at 3,500 ft.: B. C. Aston! Tararua Mountains (Mount Holdsworth), 3,200 ft.

This is a very distinct-looking form, and has considerable claim to specific rank. It forms large open somewhat sward-like patches, and never grows in distinct tufts, as the typical form usually does.

Carex secta Boott var. *tenuiculmis* var. nov.

Var. *C. virgatae* Sol. habitu subsimilis; a planta typica differt, culmis gracillimis haud raro filiformibus, foliis tenuibus perangustis flaccidis complanatis vel apicem versus concavis (costa media parum conspicua) 40–60 cm. longis culmos aequantibus vel excedentibus; inflorescentia 6–15 cm. longa simplici ± pendula spiculis plerumque remotis parvis pauci-floris sessilibus praedita vel a parte inferiore breviter ramosa (ramis paucis brevibus indivisis); rhachide pergracili vel filiformi; utridulis breviter stipitatis vel paene astipitatis.

Hab.—Damp localities in eastern and southern Otago: D. P. Damp localities in the Hammer and Castle Hill districts, North Canterbury: Arnold Wall! Damp localities in Chatham Islands: L. Cockayne! W. R. B. Oliver!

I am indebted to Professor Wall for drawing my attention to this interesting plant,

which I had unwittingly placed in the same species-wrapper as *C. virgata*. From this it differs entirely in the structure of the utricles. A hand-and-eye examination will hardly disclose its true position. The Chatham Island specimens show only immature utricles, but I think their identity with the mainland plant cannot be doubted. They also show remarkably long leaves that greatly exceed the culms.

Poa novae-zelandiae Hackel var. Wallii var. nov.

A forma typica differt foliis coriaceis ± complanatis et a marginibus mvolutis incrassatisque muticis; panicula breviore folia haud vel vix excedente, a parte inferiore foliis ± abscondita; spiculis majoribus haud compressis; glumis florigeris latioribus trinerviis acutis haud incurvatis subcoriaceis; palea breviore ac latiore.

Hab.—Mount Miromiro (Amuri County): A. Wall ! Top of Mount Kyeburn (Maniototo County): H. J. Matthews! Mount Pisa (Vincent County).

The present plant appears to be confined to wet shingly stations, and ranges in altitude from about 3,500 ft. to 5,000 ft. or 6,000 ft. At the higher altitudes the plants are very dwarf.

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Art. IV.—*The Food Values of New Zealand Fish: Part I.*

By (Mrs.) Dorothy E. Johnson, B.Sc. in Home Science.

Communicated by Professor J. Malcolm.

[*Read before the Otago Institute, 9th December, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.*]

In all countries where procurable, fish should be made an easily accessible article of diet—*i.e.*, it should be both plentiful in quantity and reasonable in cost; but, so far, the greatest possible use has not been made of the bountiful supply in New Zealand waters. Beyond the investigation of the composition of frost-fish and

oysters by Malcolm^{*} no attempt has been made to estimate the food values of New Zealand fish.

Recognizing the necessity for the prosecution of research in the Dominion, the New Zealand Government placed funds at the disposal of the New Zealand Institute, which enabled that body to make a grant to Professor J. Malcolm for the investigation of the chemistry and food values of the New Zealand fish. This paper outlines the work done in that connection. The aim has been to ascertain—

- (a.) The percentage composition of the edible portion of the fish investigated.
- (b.) The caloric value of the fish (by calculation).
- (c.) The percentage of waste in the fish as bought.
- (d.) From the point of view of cost, to arrive at some conclusion as to the comparative values of the fish as an article of diet.

Methods.

The fish were obtained from Dunedin retail fish-dealers, with the exception of one "baby" groper, which was sent from the Portobello Fish-hatcheries, and a sample each of mullet and snapper, which were sent from Auckland by boat. With the larger fish, from $\frac{1}{2}$ lb. to 1 lb. was purchased, as would be done for home consumption. Wherever possible three samples, bought at different times, were analysed, but this was not always possible.

In a few instances there is some doubt as to the exact variety of fish bearing a commonly known name: e.g., "sea-bream" is applied to two or three different varieties of fish,[†] and exact identification would have been difficult owing to the fish being for the most part obtained in slices. It is likely, however, that in such instances the differences in composition would not be very marked—probably less than the difference between individuals of the same variety.

(I.) *Percentage of Edible Material and Percentage of Waste.*

Skin, bones, &c., were separated from the muscle, and the two portions, edible and non-edible, weighed. The flesh was finely minced and well

[Footnote] * Trans. N.Z. Inst., vol. 44, pp. 265–69, 1912.

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mixed. Then, after a portion had been set aside for the estimation of the water and protein percentage, the rest was spread in thin layers on glass plates and dried, either over a low-temperature water-bath or in an oven maintained at 52° C. Some oxidation of the fat was unavoidable in this process. The dried material was minced again, passed through a fine sieve, and the larger pieces ground in a coffee-mill. The whole powder was carefully sifted and stored in a bottle. In the case of tarakihi 1 and mullet 1 further oxidation of the fat was noticeable in that part exposed to the light.

(II.) *Percentage of Water and Solids.*

This was carried out in a hot-air oven at 65°–70° C., the average of three estimations per sample being taken.

(III.) *Percentage of Protein.*

The total nitrogen was estimated on fresh material by the Kjeldahl method, 0.2 N solutions of acid and alkali being used. The protein was calculated as total nitrogen multiplied by 6.25, and the average of two estimations per sample taken. *

(IV.) *Percentage of Fat.*

The dried powder from (I) was extracted with sulphuric ether in a Soxhlet extractor. After twelve hours' extraction the solvent was evaporated somewhat, the mixture filtered, the remainder of the ether carefully evaporated, and the oil finally dried for three hours or more at 52° C. The figure in the tables is the average of two estimations. (The water percentage of the powder was estimated, to obtain the amount of fresh material represented.)

(V.) *Percentage of Ash.*

This was carried out in the usual way with the dried material from (II) in a Davy's crucible furnace. The longer method of extracting the chlorides with distilled water after the first charring, and adding the residue after evaporation to the ash, was used at first but discontinued, as the results from the shorter method were found to vary but little from those of the longer method, and the greater accuracy seemed unnecessary, as the protein and fat estimations could only be approximate.

(VI.) *Calculations.*

From these results the following figures were calculated:—

- (1.) Calories per cent., using the factors 4.1 large calories per gramme of protein and 9.3 large calories per gramme of fat.
- (2.) The cost of 1,000 calories, and of 100 grammes of protein.
- (3.) For purposes of comparison the composition of milk, meat, and eggs was taken as given in Hutchison's *Food and Dietetics*

Results.

The results are shown in the following tables (I-VI).

[Footnote] * The use of this figure (6.25) is not quite satisfactory, as the proper factor to use with fish proteins requires investigation.

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Table L—General Table showing Percentage Composition of Fish analysed.

Common Name of Fish.	Specimen.	Scientific Name.	Date received.	Water.	Solids, by difference.	Fat.	Protein.	Ash
Groper (hapuku)	1	<i>Oligorus gigas</i>	16/7/19	70.50	29.50	20.50	1.12	
"	2	"	30/7/19	76.00	24.00 1.90	19.20	1.27	
"	3	"	11/8/19	76.10	23.90 3.40	19.34	1.08	
Baby groper (hapuku)	1	"	28/8/19	77.03	22.97 2.93	18.42	1.08	
"	2	"	11/9/19	76.41	23.59 2.32	19.75	1.10	
Sea-bream (warehou)	1	(?)	26/8/19	73.37	26.63 4.25	19.51	1.18	
Crayfish	1	[*]	5/9/19	73.13*	26.87 0.72	22.90	1.54	
"	2		8/9/19	77.45	22.55 0.52	19.78	1.55	
"	3	[*]	13/10/19	74.23*	25.77 1.30	22.35	1.40	
Snapper (tamure)	1	<i>Pagrus unicolor</i>	8/10/19	76.92	23.08 0.60	20.68	1.23	
"	2	"	27/11/19	78.67	21.33 0.42	18.93		
Mullet (kanae)	1	<i>Mugil perusii</i>	8/10/19	69.43	30.57 10.09	19.29	1.04	
Tarakihi	1	<i>Chilodactylus macropterus</i>	13/10/19	69.23	30.77 10.30	19.71	1.07	
"	2	"	22/11/19	76.00	24.00 3.05	20.31		
Blue cod (pakirikiri)	1	<i>Percis colias</i>	16/10/19	79.70	20.30 0.90	18.79	1.05	
Kingfish (haku)	1	<i>Seriola lalandii</i>	3/11/19	75.65	24.35 4.32	18.72	0.93	
"	2	"	11/11/19	74.37	25.63 4.10	19.84	1.14	
Trumpeter (kohikohi)	1	<i>Lafris hecateia</i>	28/10/19	75.86	24.14 3.31	19.37	1.01	
Moki	1	<i>Latris ciliaris</i>	28/10/19	78.00	22.00 1.63	19.12	0.93	
"	2		10/11/19	76.41	23.59 3.21	18.32	1.09	

[Footnote] * Boiled specimen.

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Table II.

Name of Fish, &c.	Kind of Sample.	Price. (Pence.)	Weight. (Grammes.)	Edible. (Percentage.)	Waste. (Percentage.)
Groper 1	Slice	4	322	82 92	17.08
" 2	"	6	316	94 62	5 38
" 3	"	6	271	97 05	2.95
Baby groper 1	"	9	283 5	87 32	12.68
" 2	Whole		3,742	39 31	60 69
Sea-bream 1	Slice	15	553	87 05	12 95
Crayfish 1	Tail	2	228.5	33.20	66.80
" 2	"	3	83	79 50	20.50
" 3	Whole	6	680	31.18	68 82
Snapper 1	"	17.5	1,544	44.37	55.63
" 2	"	30	2,735	39.56	60 44
Mullet 1	"	18	1,240	63.31	36 69
Tarakihi 1	"	30	1,895	51.44	48 56
" 2	"	9	520	53 46	46.54
Blue cod 1	Slice	21	744	47.44	52 56
Kingfish 1	"	12	498	73.30	26.70
" 2	"	15	561	78 25	21.75
Trumpeter 1	Whole	18	909	50 82	49.18
Moki 1	"	18	1,159	50.12	49.88
" 2	Slice	15	572	78 32	21 68
Egg	One	2	50	88 00	12 00
Beef	Steak	12	454	100 00	

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Table III.

Name of Fish.	Calories per 100 Grammes of Undried Edible Material.	Cost of 100 Grammes Protein (Pence.)	Cost of 1,000 Calories. (Pence.)
Groper 1		7.3	
" 2	96 39	10.5	20.8
" 3	110 92	11.8	20 6
Baby groper 1	102.78	19.8	34.4
" 2	102.56		
Sea bream 1	119.51	160	25 9
Crayfish 1	100 59	11.5	26 1
" 2	85 96	22.9	52 9
" 3	103.73	12.7	27.1
Snapper 1*	90.38	12 4	28 3
" 2	81.51	14 6	23.8
Mullet 1*	172 89	9.0	13.3
Tarakihi 1	167 45	15 6	17.4
" 2	111.64	16 0	29 0
Blue cod 1	85 40	31.7	69.7
Kingfish 1	116 93	17 6	28 1
" 2	119 47	17.2	28 6
Trumpeter 1	110 20	20.1	35 3
Moki 1	93.56	16.2	33.1
" 2	104 96	18.3	31.9
Eggs at 2s. per dozen	158 33	32.9	29 5
Beef at 1s. per pound	137.25	12.6	19 1
Milk at 3d. per pint	70 00	14 6	7.3

[Footnote] * Auckland prices.

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Table IV.—Showing
Fish in Order of Fat
Content.

Per Cent.

Tarakihi 1	10.30
Mullet	1 10 09
Kingfish 1	4 32
" 2	4.10
Sea-bream 1	4 25
Groper 3	3 40
Trumpeter 1	3 31
Moki 2	3 21
Tarakihi 2	3 05
Groper 4	2 93
Baby groper	2.32
Groper 2	1 90
Crayfish 3	1 30
Moki 1	1 63
Blue cod 1	0.90
Crayfish 1	0 72
Snapper 1	0 60
Crayfish 2	0 52
Snapper 2	0 42
Egg	10 50

Meat (beef) 5·56
Milk

Table V.—Showing

Fish in Order of
Caloric Values.

(Total calories per 100
grammes fresh
material.)

Per Cent.

Mullet 1	172 89
Tarakihi 1	167 45
Sea-bream 1	119 51
Kingfish 2	119.47
" 1	116 93
Tarakihi 2	111 64
Groper 3	110 92
Trumpeter 1	110 20
Moki 2	104 96
Crayfish 3	103 73
Groper 4	102 78
Baby groper	102 56
Crayfish 1	100 59
Groper 3	96 39
Moki 1	93 56
Snapper 1	90 38
Crayfish 2	85 96
Snapper 2	81 51
Blue cod 1	85 40
Egg	158 33
Beef	137 25
Milk	70 00

Table VI.—Showing

Fish in Order of
Cost of 100

Grammes Protein.

Pence.

Groper 1	7 31
Mullet 1	8 96
Groper 2	10 45

" 3	12 66
Snapper 1	12 35
" 2	14 64
Tarakihi 1	15 61
" 2	15 95
Sea-bream 1	15 99
Moki 1	16 21
Kingfish 1	17 22
" 2	17 56
Moki 2	18 27
Groper 4	19 78
Trumpeter 1	20 11
Crayfish 2	22 98
Blue cod 1	31 66
Beef	12 60
Milk	14 62
Eggs	32 94

Discussion.

The following points are noticeable:—

1. The percentage of water and of solids shows much the same variation that similar analyses ^{*} of American and European food fishes have shown. Further, the analyses exhibit the fact that a high fat value goes with a low water percentage, the protein percentage fluctuating but little from the mean of 19.69. In the process of fattening, therefore, the water,

[Footnote] * R. Hutchison, *Food and the Principles of Dietetics*, Clark and Almy, *Journal of Biological Chemistry*, vol. 33, p. 483, 1918.

not the protein, is replaced by fat. In a fatty fish there is an absolute gain in nutritive value though a decrease in digestibility. For example,—

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Fish	Water Percentage.	Fat Percentage.	Protein Percentage.
Blue cod	79.70	0.90	18.79
Kingfish	75.65	4.32	18.72
Groper	76.10	3.40	19.34
Mullet	69.43	10.09	19.29
Snapper	69.23	10.30	19.71

2. Table IV shows the fish in order of fat content, which is the usual order of classification for dietetic purposes. There is considerable variation from tarakihi (sample 1) with 10.30 per cent. to snapper (sample 2) with 0.42 per cent. One noticeable fact, however, is the difference between two samples of the same variety of fish, even when bought at short intervals from each other. For example,

Fish.	Date of Purchase.	Fat Percentage.
Tarakihi 1	13th October, 1919	10.30
" 2	22nd November, 1919	3.05
Moki 1	28th October, 1919	1.63
" 2	10th November, 1919	3.21

This question needs to be investigated further before definite comparison can be made of the fat content of various fish. It may be a question, say, of metabolism or of seasonal variation.

3. Table V shows the caloric values. The figures represent the total calories per 100 grammes of edible material. The presence to any great extent of fat increases the caloric value considerably, as will be seen by comparing Tables IV and V. Mullet 1,

tarakihi 1, kingfish 1 and 2, seabream 1, groper 3, and trumpeter 1 occupy almost the same positions at the head of each table, and compare quite favourably with egg, beef, and milk.

4. The cost of the fish, as shown in Tables II and VI, is the price actually paid as for home consumption. For comparative purposes the cost of 100 grammes of protein has been calculated. It will be noticed that there is considerable variation in price for the same variety of fish; fish being a perishable commodity, and the supply being erratic owing to weather conditions, the fluctuations of the market are considerable.

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Fish.	Date of Purchase.	Price.	s. d.
Groper	16th July, 1919	0 8 per pound	
"	30th July, 1919	1 0 "	
"	28th August, 1919	1 6 "	

The price, therefore, is not necessarily indicative of the food value. This is also apparent from the fact that 100 grammes of protein can be obtained from groper at 7½d., mullet at 9d., kingfish at 1s. 6d., but from blue cod the cost is 2s. 8d. Hence the popularity of the last-named fish has little

to do with its food value, but probably has considerable influence on its price. Also, a chemical analysis does not take into account such qualities as delicacy of flavour and texture, which, appealing to a buyer, exert an influence in increasing the amount he is willing to pay.

5. Table II also points out that in dealing with fish the element of waste must be considered in comparing the cost. When bought in slices the average waste is

one-sixth of the total weight, but with whole fish as much as one-half tends to be lost. There is also a further loss on cooking, but that has not been dealt with in this investigation.

6. The methods used in ascertaining the percentage of protein give the maximum figure, since part of the total nitrogen will be contained in extractives and gelatin substances. As a source of protein, therefore, a fish containing 19 per cent protein has really not the same value as meat or egg with 19 per cent protein. But, without considering this factor, with beef at 1s. per pound the corresponding prices for fish should not be greater than the following:—

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	Per 1b.	Per 1b.	Average price paid.
Groper	8½d.	instead of 1s. 2d.	
Kingfish	7½d.	" 1s. 1½d.	
Tarakihi	5½d. to 7½d.	" 7½d.	
Blue cod	3½d.	" 1s. Od.	
Sea-bream	9d.	" 1s. 3d.	
Snapper	3d.	" 5½d.	
Mullet	10d.	" 6d.	

These figures point to the high prices prevailing for a food that is naturally plentiful, and seem to indicate a state of artificial scarcity in the market. Another point which is very apparent in making these calculations is that the amount of waste (from a food point of view) is an important determinant in comparing prices: e.g., compare groper and kingfish. From the analyses (calories per cent.) the edible portion of kingfish is superior to that of groper in the proportion of 118 to 105; but the waste is 24 per cent. with kingfish, and only 7 per cent. with groper (slices). Therefore (compared with beefsteak at 1s. per pound) the housewife can afford to pay 8½d. per pound for groper, but only 7½d. per pound for kingfish.

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Name.	Calories (Percentage).	Waste (Percentage).	Maximum Price per Pound.
Kingfish	118	24	7½d.
Groper	105	7	8½d.

It is necessary to point out, however, that these deductions are based on twenty samples (eleven kinds), and more complete investigation may make modifications necessary; but it is noticeable that in many salient features the results concur with those of wider investigations carried out in other countries.

Besides acknowledging, with thanks, the constant help I have received from Professor J. Malcolm—to whom, indeed, the initiation of this research is due—I have also to thank the Council of the University of Otago for the use of their laboratories and apparatus.

All the expenses incurred have been defrayed by a grant from the New Zealand Government, through the New Zealand Institute.

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Art. V.—The Distillation of Waikaia Oil-shale.

By W. Donovan, M.Sc., and G. C. Burton.

[*Read before the Wellington Philosophical Society, 3rd December, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.*]

The following paper embodies the results of an investigation of the properties of Waikaia shale, conducted at the Dominion Laboratory during 1918, at the request of the Director of the Geological Survey.

Eight representative samples were received from various bores put down by the Waikaia Shale Company. Proximate analyses were made, and also distillation tests, to obtain the yields of oil and gas. The results were:—

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No.	Fixed Carbon.	Volatile Hydrocarbons	Water lost at 100° C	Ash.	Sulphur.	Crude Oil (Gallons per Ton).	Gas (Cubic Feet per Ton).
1	9 60	33.42	7 78	49.20	2 30	23 5	2,000
2	17 20	43 74	10 13	28 93	2 93	37.0	3,400
3	17 25	42 67	8 63	31 45	3 40	Not distilled.	

4	20 80	46.87	9.83 22.50	3 40	48 0	4,000
5	20.75	51.42	10.78 17.05	3.08	46 0	4,000
6	18 30	46 65	15 70 19.35	3.20	38 0	3,800
7	17 65	51.45	10 40 20.50	3 07	35 0	3,500
8	17 70	47.35	13 75 21.20	3 06	42 0	4,000

Note.—There was not sufficient of No. 3 for a distillation test to be made.

A composite sample, made by taking equal weights of the above eight and mixing thoroughly, was examined in greater detail, The proximate analysis was—

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Fixed carbon	17.10
Volatile hydrocarbons	43.03
Water	10.42
Ash	29.45
	100.00
Total sulphur per cent.	3.05

An ultimate analysis yielded—

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Hydrogen	5.64
Carbon	39.55
Nitrogen	0.30
Sulphur	3.05
Oxygen	22.01
Ash	29.45
	100.00

On distillation there was obtained—Crude, oil equivalent to 38 gallons per ton of shale; ammonium sulphate equivalent to 8 lb. per ton of shale; gas equivalent to 4,000 cubic feet per ton of shale.

The specific gravity of the crude oil was 0.96.

The oil was redistilled into the following fractions:—

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Below 200° C.	7.0 (naphtha).
200°–250° C.	11.5 burning-oils.
250°–300° C.	14.0
300°–350° C.	18.0 lubricating-oils.
Above 350° C.	41.0
Residue	6.0
Loss	2.5
	100.0

The distillate above 350° C. contained 14.2 per cent. of paraffin of melting-point 58.5° C., equivalent to 22 lb. paraffin per ton of shale.

If all the fractions were collected in the same vessel they would give once-once-run shale-oil, 91.5 per cent. (equivalent to 34.75 gallons per ton of shale).

The fuel values of this and of the crude oil were determined in the calorimeter, together with a crude oil from the Orepuki Shale-works, year 1903, and crude Taranaki petroleum, received in 1906 (No. 562). The sulphur was also estimated at the same time. The results were:—

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Crude Walkaia Shale.	Once run.	Crude Orepuki Shale-oil.,	Crude Taranaki Petroleum.
Calorides per gramme	9,470	10,032	10,339

British thermal units per pound	17,046	18,058	18,610	19,283
Evaporative power per pound in pounds of water at 212° F.	17 67	18 72	19 29	19 28
Total sulphur per cent.	1 80	1 76	1 79	0 21

A good fuel-oil should not contain more than 0.5 per cent. of sulphur.

The yield of ammonium sulphate, 8 lb. per ton of shale distilled, is low. It would be increased if the distillation were conducted in the presence of superheated steam, as is usual in working practice; but even if all the nitrogen were recovered in this form it would not exceed 28.3 lb. per ton.

The gas from the distillation had the following composition:—

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Carbon dioxide	18.3
Oxygen	1.0
Carbon monoxide	14.3
Methane	37.3
Hydrogen	22.3
Nitrogen	6.8
	100.0

(Sulphur compounds, which were not determined, would be partly included in the carbon dioxide.)

When purified from carbon dioxide the composition would be:—

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Oxygen	1.2
Carbon monoxide (CO)	17.5
Methane (CH_4)	45.7
Hydrogen	27.3
Nitrogen	8.3
	100.0

Calorific value, gross, in calories per cubic foot	1529
" net, in calories per cubic foot	1375
" gross, in British thermal units per cubic foot	6111
" net, in British thermal units per cubic foot	5456
" (Gas measured at 15.5° C. and 762 mm.)	

There would be about 3,250 cubic feet of such gas per ton of shale. The calorific value is approximately the same as that of good coal-gas.

Summary.

Waikaia shale would yield on distillation the following products per ton: 38 gallons crude oil, equivalent to 34¾ gallons once-run oil; ammonium sulphate, 8 lb.; gas free from carbon dioxide, 3,250 cubic feet.

After fractional distillation and refining the oil would give the following products per ton, allowing 10 per cent. for impurities and loss: Light oil (naphtha), 2.5 gallons; burning-oil, 8.8 gallons; light lubricating-oil, 6.2 gallons; heavy lubricating-oil, 12.0 gallons; paraffin, 20 lb.

(The amount of light oil would probably be increased by scrubbing the gas evolved with a suitable medium oil, to dissolve the light hydro-carbons that escape condensation.)

The shale appears to be very similar to Orepuki shale.

Art. VI.—*Sting-ray-liver Oil.*

By W. Donovan, M.Sc.

[*Read before the Wellington Philosophical Society, 3rd December, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.*]

Mr. Hoyle, of Thames, conducted some experiments in the extraction of oil from sting-ray livers, and a quantity of about 8 oz., which he obtained from the liver of

a single fish, was examined at the Dominion Laboratory in September, 1918. The sting-ray was probably *Dasyatis brevicaudatus* (Hutton).

The oil was compared with cod-liver oil, with the following results:—

Sting-ray-liver Oil. Cod-liver Oil.

Specific gravity at 15.5° C.	0.927	0.923–0.930
Saponification value	189	182–187
Iodine value	156.5	137–167
Refractive index at 15° C.	1.4796	1.4800
Unsaponifiable matter (per cent.)	3.7	0.6–2.6
Hexabromides (per cent.)	45	42.9

The oil was free from rancidity, and quite palatable. It contained some "stearine," which made it cloudy at low temperature, and which, in the case of cod-oil, is usually removed by cooling and filtering.

If the present sample were similarly treated the product would scarcely be distinguishable in appearance or composition from good cod-liver oil.

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Art. VII.—*Descriptions of New Zealand Lepidoptera.*

By E. Meyrick, B.A., F.R.S.

Communicated by G. V. Hudson, F.E.S., F.N.Z.Inst.

[*Read before the Wellington Philosophical Society, 3rd December, 1919; received by Editor 31st December, 1919; issued separately, 4th June, 1920.*]

I am again indebted to the kindness of my esteemed correspondent Mr. G. V. Hudson for the material on which the following descriptions are based.

Crambidae.

Orocrambus ventosus n. sp.

. 26–27 mm. Head, palpi, and thorax blackish, mixed with brown hairs. Abdomen dark fuscous irrorated with pale greyish-ochreous. Forewings elongate, posteriorly dilated, costa hardly arched, apex obtuse, termen slightly rounded, little oblique; dark fuscous, suffusedly mixed with brown, especially on posterior half, somewhat lighter on post-median area, veins on posterior half more or less obscurely indicated with whitish scales; a very obscurely indicated angulated darker transverse line towards termen: cilia grey, tips white, with a tendency to obscure whitish bars on veins. Hindwings grey, becoming dark grey towards termen: cilia ochreous grey-whitish, with grey basal line.

Mount Arthur, 4,200 ft., in January (Hudson); two specimens.

Pyraustidae.

Scoparia ciserodes n. sp.

. 17 mm. Head grey suffusedly mixed with white. Labial palpi 2, dark grey, base whitish, apical edge mixed with whitish. Maxillary palpi white, basal half dark fuscous. Thorax grey irrorated with white, a streak of blackish irroration on each side of back. Abdomen grey-whitish. Fore-wings elongate, narrow at base, posteriorly dilated, costa anteriorly straight, posteriorly gently arched, apex obtuse, termen rounded, rather oblique; light grey irrorated with white, with some scattered blackish scales; a short fine blackish median longitudinal line rising from a small white spot at base; lines indistinct, whitish, first slightly curved, direct (rubbed), second obtusely angulated in middle; small cloudy dark-grey spots on costa beyond middle and at $\frac{3}{4}$; orbicular and claviform indicated by some scattered blackish scales, discal spot represented by a slight 3-armed blackish mark, posterior arm edged beneath with pale ochreous; two or three dashes of blackish irroration towards upper part of termen cilia whitish, with subbasal series of well-marked grey spots. Hindwings 1, grey-whitish: cilia whitish, with very faint greyish subbasal line.

Porirua, Wellington, in January (Hudson); one specimen. An inconspicuous insect, yet quite distinct from anything else.

Tortricidae.

Tortrix sphenias Meyr.

Mr. Hudson has pointed out to me that this species (originally referred by me to *Cnephasia*), of which he has sent a second specimen from Dunedin, is very close to *fervida*, and suggested that the two are identical. This

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second specimen has veins 6 and 7 of hindwings separate; in the original type they are unmistakably stalked, but it now appears probable that this was an individual abnormality, and the presence of a costal fold (a discordant character in *Cnephasia*) and the specific affinity to *fervida* indicate that the species should be removed to *Tortrix*. After careful comparison with my seven specimens of *fervida*, however, I entertain no doubt that the two species are distinct; apart from superficial colouring, in which there is certainly some variability, the ciliations of antennae in *fervida* are obviously longer and more fasciculate than in *sphenias*.

Oecophoridae.

Borkhausenia compsogramma n. sp.

. 13–15 mm. Head, thorax, and abdomen dark purplish-fuscous. Antennal ciliations 1. Palpi grey, second joint sometimes partially suffused with whitish-yellowish. Forewings elongate; costa gently arched apex obtuse, termen obliquely rounded; dark violet-fuscous; markings ochreous-yellow suffused in disc with fulvous-orange, and with some scattered blackish scales on their edges; an oval blotch extending over basal fourth of dorsum; a narrow irregular rather oblique fascia from costa before middle, not reaching dorsum; a transverse fasciate blotch from costa beyond middle, and another inwardly oblique from costa at middle, both directed towards but not reaching a spot on dorsum before tornus; a streak along termen throughout: cilia fuscous, base scaled with ochreous-yellow along terminal streak. Hindwings and cilia dark grey.

Buller River, in December (Hudson); two specimens. At first sight extremely like *chrysogramma*, but on comparison the markings are seen to be quite differently arranged.

Izatha amoras Meyr.

This species has an elongate pale-yellow blotch extending beneath median third of costa of hindwings, sometimes nearly obsolete, and not noticed in my description, but in an example now sent from Dunedin it is conspicuous.

Lyonetiidae.

Hectacma crypsimima n. sp.

. 10 mm. Head grey mixed with whitish and blackish. Palpi dark fuscous. Thorax dark fuscous slightly speckled with whitish. Abdomen dark fuscous. Forewings elongate, rather narrow, costa gently arched, apex tolerably pointed, termen hardly rounded, extremely oblique; bronzy-brown, irregularly speckled with whitish except in posterior part of disc, with some scattered blackish scales; a very oblique blackish wedge-shaped streak from basal part of costa reaching half across wing; oblique blackish wedge-shaped spots from costa before middle and towards apex, and one from middle of dorsum; a small round blackish apical spot: cilia grey, whitish-tinged round apex, with two blackish lines. Hindwings and cilia dark fuscous.

Wellington, in February (Hudson); one specimen, "taken on black *Fagus* trunks."

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Tineidae.

Mallobathra perisseuta n. sp.

. 15 mm. Head, palpi, thorax, and abdomen dark fuscous. Antenna ciliations $2\frac{1}{2}$. Forewings elongate, posteriorly slightly dilated, costa gently arched, apex obtuse, termen obliquely rounded; 6 present; fuscous, anterior half of costa suffused with darker fuscous; a dark-fuscous quadrate spot on middle of dorsum, preceded and followed by suffused whitish blotches: cilia fuscous. Hindwings with 6 present; rather dark fuscous: cilia fuscous.

Dunedin, in October (Clarke); one specimen.

Art. VIII.—Illustrated Life-histories of New Zealand Insects: No. 1.

By G. V. Hudson, F.E.S., F.N.Z.Inst.

[*Read before the Wellington Philosophical Society, 3rd December, 1919; received by Editor, 9th December, 1919; issued separately, 4th June, 1920.*]

Plate I.

The present article is the first of a series I hope to publish from time to time on the life-histories of New Zealand insects, which to the best of my belief have not previously been recorded. The subjects will not be selected in any systematic order, but the life-histories will simply appear as they are worked out in the field. Preference will, however, be given to those orders of insects where the least is known regarding their habits, and the species dealt with will therefore mainly belong to the so-called "neglected orders." Hence species belonging to the better-known orders of Lepidoptera and Coleoptera will be excluded from the scope of these papers at present. Illustrations will be given with each paper, which it is hoped will enable any naturalist to recognize the insects in all their stages. Such structural descriptions as may be given will be extremely brief, as it will necessarily devolve on specialists in each order to give fuller details when the study of the "neglected orders" is taken up in real earnest. In the meantime the present notes and illustrations may be useful in arousing interest and in presenting the subject in an intelligible form to the general student of nature.

Order Diptera.

Family Tipulidae.

Gnophomyia rufa. ([Plate I, fig. 7.](#) .)

Tipula rufa Huds., *Trans. N.Z. Inst.*, vol. 27, p. 294. *Gnophomyia rufa* Hutton, *ib.*, vol. 32, p. 39.

This large and very handsome species of crane-fly, or "daddy-long-legs," may be found occasionally in dense forests in the Wellington and Nelson districts. It is very possibly a generally distributed species, but precise

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Fig. 1.—*Limnophila sinistra*. Nat. size.

Fig. 2.—Pupa of *L. sinistra*. Magnified.

Fig. 3.—Larva of *L. sinistra*. Magnified.

Fig. 4.—Larva of *Melanostoma decessum*. Magnified.

Fig. 5.—*Melanostoma decessum*. Magnified.

Fig. 6.—Pupa of *M. decessum*. Magnified.

Fig. 7.—*Gnophomyia rufa*. Nat. size.

Fig. 8.—Larva of *G. rufa*. Magnified.

Fig. 9.—Pupa of *G. rufa*. Magnified.

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records of its distribution are at present lacking. The larva lives and feeds in the semi-liquid vegetable detritus which accumulates in large quantities at the bases of the leaves of the well-known *Astelia Solandri*, a common and very conspicuous epiphytic plant in most of our untouched native forests. The length of the full-grown larva (see [Plate I, fig. 8](#)) is about 1½ in. It is subcylindrical, considerably flattened, with the head very minute, and eleven visible body-segments. Special oval warts armed with minute teeth are situated on the upper surface of body-segments 5 to 10 inclusive, similar larger warts being present on the underside, and this no doubt facilitates the insect's movements between the leaves. The colour of the larva is very dark slaty-brown, darker towards the extremities; the

posterior end is considerably tapered.

Apparently only one larva inhabits each space between two sheathing leaves; and only those full of the thick brown coffee-like liquid are so inhabited.

The pupa is enclosed in a rather tough, extremely elongate silken tube situated between the sheathing leaves. It rests in an upright position in the midst of the semi-liquid mass, breathing, no doubt, being effected by means of the remarkable thoracic process. The length of the pupa is about 1½ in. It is very elongate, with the head and thorax unusually small; there is a large double breathing-process on the top of the thorax, shaped somewhat like a bivalve shell. Four of the abdominal segments are furnished on the dorsal surface with special finely-toothed warts like those of the larva, the ventral surface with plain ridges. There is a horny cremaster with two recurved hooks and several other smaller processes. (See [Plate I, fig. 9.](#))

The perfect crane-fly appears from November till March. It is probable that the larva is feeding during the autumn and winter, and that pupation usually takes place in the spring, although the pupa which was actually reared was found in company with feeding larvae early in March.

***Limnophila sinistra.* ([Plate I, fig. 1.](#) .)**

Tipula obscuripennis Huds., *Trans. N.Z. Inst.*, vol. 27, p. 294; not *Limnophila obscuripennis* Skuse, 1890. *Limnophila sinistra* Hutton, *Trans. N.Z. Inst.*, vol. 32, p. 40.

This very distinct species of crane-fly is fairly common in most dense forests throughout the country.

The larva ([Plate I, fig. 3](#)) inhabits fallen tree-trunks in an advanced state of decay, forming burrows between the soft decayed portion and the harder part of the wood. It is about 1 in. in length, cylindrical, tapering towards the head, which is very small and furnished with two minute jaws and a pair of very short antennae. There are eleven visible body-segments. The extremity of the last segment is truncate and deeply excavated, the concavity being protected by five converging spines, which can be spread out or drawn inwards at the will of the insect. The orifices of the air-tubes are situated in this concavity, that of the alimentary canal being placed on the underside of the final segment, quite remote from the breathing-apparatus. Pedal warts occur on the undersides of all the segments, excepting the three immediately following the head and the terminal segment.

The pupa ([Plate I, fig. 2](#)) is about $\frac{1}{2}$ in. in length, rather stout; the thoracic breathing-appendages are about one-third the length of the wing-cases; moderately stout and strongly recurved. There are two dorsal rows of hooks on each exposed abdominal segment, and one ventral row near the terminal extremity. The cremaster is bifid, strongly recurved, and very stout. The head and thorax are dark blackish-brown and highly polished; the abdomen greyish-ochreous, darker in the middle. The cremaster and extremities of the hind-leg cases are reddish. The pupa rests in a burrow made by the larva near the surface of the log.

The perfect crane-fly appears from November till March. It is practically invisible when at rest on an old fallen tree-trunk, and it is evident that the rather unusual colouring of both the wings and body has been specially adapted to harmonize with the insect's natural surroundings.

Family Syrphidae.

Melanostoma decessum. ([Plate I, fig. 5.](#) .)

Melanostoma decessum, Hutton, *Trans. N.Z. Inst.*, vol. 33, p. 43.

The larva of this fly ([Plate I, fig. 4](#)), which is one of the so-called "rat-tailed maggots," feeds during the early spring in the liquid decay which occasionally involves certain portions of the inner bark of the cabbage-tree (*Cordyline australis*), and very possibly inhabits liquid decaying vegetable matter generally. When full grown it is about $\frac{1}{2}$ in. long, of the usual maggot type, with a long breathing-tail and two short air-tubes near the head. Although apparently very fragile and gelatinous, it is really extremely tough. Its body is semi-transparent, and the internal organs are clearly visible. The head is retracted within the second segment; there are two dark patches on each side of the head which may be rudimentary eyes. A row of hooklets extends along the outer edge of the second segment, which assists the larva in progression. It is active in habit, being almost constantly on the move.

[The section below cannot be correctly rendered as it contains complex

formatting. See the [image of the page](#) for a more accurate rendering.]

The pupa ([Plate I, fig. 6](#)) is about 5/16 in. in length, immobile, pear-shaped, flattened beneath; the segmental divisions are very indistinctly indicated. There are several obscure tubercles on the anterior portion, and two rows, of about six in each, on the flattened ventral portion. The posterior segments are strongly curved, and bear at their extremity the breathing-tube proper. The pupa rests partially embedded in the dried portion of the decayed bark of the cabbage-tree.

The fly appears in November.

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Art. IX.—*New Lepidoptera.*

By Charles E. Clarke.

[*Read before the Otago Institute, 9th December, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.*]

Hydriomenidae.

Tatosoma monoviridisata n. sp.

. 31–32 mm. Head and thorax olive-green. Antennae: proximal third olive-green, tips brownish. Palpi nearly 3 mm. Abdomen varying green above, irrorated with dark-brown scales with lateral dorsal tufts of brown-grey hairs at each segment, especially noticeable on fourth, fifth, sixth, and terminal segments. Forewings olive-green, elongate, costa rounded, hind-margin obliquely rounded, several transverse wavy dentate darker-greenish stripes, convex externally near middle, the most conspicuous being at , before $\frac{1}{2}$, and at ; a series of double dots around termen. Hindwings in small, elongate, grey, tinged with greenish terminally; an indistinct greenish band at ; lobe of hindwings in 3mm. long; all cilia light green.

The palpi of this species are shorter than in *T. tipulata*, but the lobe of the hindwing is as small as in *tipulata*

Twelve specimens were beaten from *Coriaria* on the Waitati Water Reserve in October and November, 1918, and three in 1919.

Micropterygidae.

Sabatinca lucilia n. sp.

12 mm. Head, face, and palpi covered with long bronze-brown hair. Antennae purplish tending to brown at tips. Thorax brown, densely covered with long brown hair. Abdomen grey-blackish along sides. Legs ochreous tinged with grey-blackish. Forewings ovate-lanceolate, costa bent abruptly near base, arched, apex less acute than in *incongruella*; basal area to nearly ochreous suffused with ruby banded by abrupt black transverse line; an ochreous-grey band slightly suffused with ruby reaching to nearly $\frac{1}{2}$ widening on dorsum; a dark fascia bordered blackish-grey, constricted both sides at middle and narrowed on anal margin; at another light-grey band slightly tinged with orange but broken in centre by longitudinal blackish stripe; a transverse blackish-bordered ochreous band, beyond which to apex light grey slightly tinged with orange; cilia ochreous with dark-greyish-brown bars in continuation of the dark markings on the wings. Hindwings dark grey suffused with violet, brighter towards apex; cilia dark grey with a few orange hairs.

My first specimen, rather worn, I took at the electric light at Waitomo Hotel on the 25th December, 1916. During the second week of January, 1919, I took six specimens in good condition on a sunny moss-covered clay, bank at Kauri Gully, Auckland. The season was an exceptionally late one, and normally the species would probably be at its best quite a month earlier,

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By Charles E. Clarke.

[Read before the Otago Institute, 9th December, 1919; received by Editor. 31st December, 1919: issued separately, 4th June, 1920.]

During the month of January, 1919, I made a collecting tour along the Main Trunk Railway from Wellington to Auckland, returning via Rotorua, Tokaanu, and Waimarino. I collected at various other localities *en route*—Swanson, Wairakei, Waitomo, Raurimu, Erua, Ohakune, Waipoua, the Hot Lakes district, and the lower slopes of Mount Ruapehu from Rangataua, all being included. I had originally intended climbing to the subalpine of Mount Ruapehu, but was deterred by stormy weather, which decided me to proceed to the Auckland District for a few days in search of a better climate. I there experienced good weather and collected at Kauri Gully and in the Auckland Domain, and also ascended the Waitakere Ranges from Henderson and Swanson. The best collecting of the trip, however, was made on my return journey while camping at Waimarino and Erua at an altitude of about 2,600 ft. From Erua I ascended Mount Hauhungatahi by the track, but owing to the cloud-banks enveloping the higher country I was able to collect during my visit only to a height of about 3,500 ft.

The following list contains only such species as I actually took in good condition on my somewhat hurried journey:—

- *Vanessa gonerilla* Fabr. A few at Kauri Gully.
- *Lycaena oxleyi* Murray. Very common at Auckland and at the foot of the Waitakere Ranges.
- *Chrysophanus boldenarum* White. Very common on the Waimarino Plateau.
- *Nyctemera annulata* Boisd. Generally common.
- *Heliothis armigera* Hübn. Plentiful in Auckland Domain; also netted at Rotorua.
- *Euxoa admirationis* Guen. Several at Rotorua on *Veronica* blossom.
- *Agrotis ypsilon* Rott. At sugar, Waimarino.
- *Graphiphora compta* Walk. Three netted in the Auckland Domain.
- *Leucania sulcana* Fer. Several at Waitakere.
- — *semivittata* Walk. Two specimens at Rangataua.
- — *phaula* Meyr. A few at sugar on the Mangaehuehu Stream, near Rangataua.

- *Aletia moderata* Walk. One at Waitomo.
- —— *unipuncta* Hew. Several in the Auckland Domain.
- *Dipaustica epiastra* Meyr. One at Waimarino and one at Rangataua.
- *Persectania disjungens* Walk. Some fine specimens were taken at Waimarino.
- —— *steropastis* Meyr. Two at sugar on the Mangaehuehu Stream.
- —— *composita* Guen. Several at Auckland.
- —— *atristriga* Walk. Common at Auckland and Rotorua.
- *Erana graminosa* Walk. Two only at Waimarino.
- *Melanchra exquisita* Philp. One very fine specimen taken at the electric light of Waitomo Hotel.
- —— *plena* Walk. A few at Waimarino.

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- *Melanchra maya* Huds. A few of each of these at sugar on the Mangaehuehu Stream.
- —— *diameta* Walk.
- —— *mutans* Walk. These four species were generally common.
- —— *ustistriga* Walk.
- —— *insignis* Huds.
- —— *morosa* Butl.

- — *rubescens* Butl. A few of each of these were taken at sugar on the Mangaehuehu Stream.
- — *phricias* Meyr.
- — *dotata* Walk.
- *Ariathisa comma* Walk. An exceptionally dark form was common at Rotorua.
- *Cosmodes elegans* Don. Two fine specimens were taken at the electric light at Waitomo.
- *Hypenodes anticlina* Meyr. Common at Waimarino and Erua, but in rather worn condition.
- *Plusia chalcites* Esp. Several fine specimens taken in the Auckland Domain.
- *Rhapsa scotosialis* Walk. Common in most localities.
- *Tatosoma topia* Philp. At Waimarino some very fine specimens were netted.
- — *timora* Meyr. Common at Waimarino.
- *Elvia glaucata* Walk. Waimarino; fairly common.
- *Venusia verriculata* Feld. Common at Auckland and Waitakere.
- — *undosata* Feld. Common at Waimarino.
- *Selidosema pelurgata* Walk. A few at Waitakere and Waimarino.
- — *monacha* Huds. Some fine specimens of both sexes netted at Waimarino.
- — *fenerata* Feld. A few at Kauri Gully.
- — *aristdrcha* Meyr. Two only at Waitakere.
- — *productata* Walk. Both these species common at Auckland and Waimarino.
- — *dejectaria* Walk.
- *Chloroclystis semialbata* Walk. Common at Waitakere.
- — *lichenodes* Purd. A few at Raurimu and Waimarino.
- — *nereis* Meyr. A few at Rangataua and Waimarino.

- — n. sp. A very fine unknown species was taken at Waimarino.
- *Eucymatoge gobiata* Feld. Common at Auckland and Waimarino.
- — *anguligera* Butl. Very common at Kauri Gully.
- *Hydriomena deltoidata* Walk. Some very fine varieties obtained at Raurimu.
- — *rixata* Feld. Ohakune and Waimarino; common.
- — *hemizona* Meyr. Very common at Waimarino.
- — *similata* Walk. Waimarino and Erua.
- — *callichlora* Butl. A few worn specimens at Waimarino.
- — *purpurifera* Fer. Common at Waimarino, but rather worn.
- — *subochraria* Doubl. Common at Waitomo and Ohakune.
- *Asthenes schistaria* Walk. Waitakere, Rotorua, Wairakei; common.
- — *pulchraria* Doubl. Common at Kauri Gully.
- *Euchoeeca rubropunctaria* Doubl. Common at Auckland and Waimarino.
- *Leptomeris rubraria* Doubl. Very common at Auckland and Waitakere on the roadsides.
- *Asapodes megaspilata* Walk. Common at Waimarino.
- *Xanthorhoe clarata* Walk. A few at Waimarino.
- — *obarata* Feld. Common at Waimarino and Erua.
- — *chorica* Meyr. A few very fine specimens taken at Waimarino.
- — *limonodes* Meyr. A few at Waimarino and Erua.
- — *praefectata* Walk. Some beautiful pure-white specimens taken at Waimarino.

- *Xanthorhoe aegrota* Butl. One at Kauri Gully.
- —— *lucidata* Walk. Not uncommon in the Auckland Domain.
- —— *chlamydota* Meyr. Tokaanu; one fine specimen.
- —— *semisignata* Walk. Common at Swanson, Waimarino, and Erua.
- —— *cinerearia* Doubl. Common at Auckland, Waimarino, and Tokaanu.
- —— *semifissata* Walk. A few at Waimarino.
- *Notoreas perornata* Walk. Both species common on the Waimarino Plateau.
- —— *vulcanica* Meyr.
- *Samana falcatella* Walk. Four specimens netted at Henderson and Swanson, at the foot of the Waitakere Ranges.
- *Adeixis inostentata* Walk. This species was very common at Waimarino and on the Mangaehuehu Stream.
- *Epirranthis hemipteraria* Guen. These two species occurred sparingly at Kauri Gully and Waimarino.
- —— *alectoraria* Walk.
- *Gargaphania muriferata* Walk. Common at Waitakere and Ohakune.
- *Sestra flexata* Walk. A few at Waimarino.
- —— *humeraaria* Walk. Common at Kauri Gully.
- *Azelina ophiopa* Meyr. Common at Waitakere and Raurimu.
- —— *fortinata* Guen. Very common at Waimarino and Erua.
- —— *nelsonaria* Feld. Common at Waimarino and Wairakei.

- *Declana atronivea* Walk. Common at Waitomo and Waimarino.
- —— *floccosa* Walk. Common at Auckland, Waimarino, and Ohakune.
- *Eurythecta eremana* Meyr. Common at Tokaanu.
- —— *loxias* Meyr. Four fine specimens were taken at Waimarino.
- *Catamacta gavisana* Walk. Common at Auckland and Waitomo.
- *Capua semiferana* Walk. Common at Auckland and Wairekei.
- —— *plinthoglypta* Meyr. Two only at Ohakune.
- —— *plagiata* Walk. Common at Wairakei, Auckland, Waitomo, and Tokaanu.
- *Tortrix leucaniana* Walk. A few at Ohakune.
- —— *charactana* Meyr. Common at Rangataua and Ohakune.
- —— *tigris* Philp. One fine specimen at Swanson.
- —— *molybditis* Meyr. Several at Waimarino.
- —— *postvittana* Walk. This species was very common in the Auckland Domain.
- —— *torogramma* Meyr. One only at Kauri Gully.
- —— *excessana* Walk. Common at Auckland.
- —— *orthocopa* Meyr. A few of this fine species at Waimarino and Swanson.
- *Epalxiphora axenana* Meyr. Common at Auckland, Ohakune, Wairakei; several varieties taken.
- *Ctenopseustis obliquana* Walk. Very common in various localities.
- *Cnephasia jactatana* Walk. Common at Auckland and Rangataua.
- —— *incessana* Walk. Common at Kauri Gully, Waimarino, and Raurimu.
- —— *imbriferana* Meyr. Common at Kauri Gully.
- *Spilonota zopherana* Meyr. Both these species common at Auckland and Wairakei among manuka scrub.
- —— *ejectana* Walk.

- *Eucosma querula* Meyr. Very common in the Auckland Domain.
- *Bactra noteraula* Wals. Some very large examples were taken at Taupo.
- *Isonomeutis amauropa* Meyr. A few at Waimarino and Erua.
- *Laspeyresia pomonella* Linn. One taken on a fruit-shop window in Rotorua.
- *Crocydopora cinigerella* Walk. A good series of this species was taken on the shingly beach of Lake Taupo.
- *Argyria strophaea* Meyr. Common at the side of the railway-line at Raurimu; also taken at Whakarewarewa.

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- *Gadira acerella* Walk. Kauri Gully and Tokaanu.
- *Diptychophora metallifera* Butl. Several at Waimarino.
- —— *harmonica* Meyr. Common at Kauri Gully and Waimarino.
- —— *chrysocytta* Meyr. Common at Kauri Gully.
- —— *elaina* Meyr. Very common at Ohakune and Waimarino.
- —— *aurascriptella* Walk. Common at Kauri Gully, Ohakune, and Waimarino.
- —— *epiphaea* Meyr. Two only at Waimarino.
- —— *selenaea* Meyr. Common at Kauri Gully and Ohakune.
- —— *pyrsophanes* Meyr. Waimarino; a few specimens larger than usual.
- —— *leucoxantha* Meyr. Very common at Waimarino and Erua.

- *Crambus vitellus* Doubl. Common at Rangataua and Swanson.
- —— *ramosellus* Doubl. A few at Raurimu.
- —— *helioetes* Meyr. Very common at Waimarino.
- —— *apicellus* Zell. Common at Waimarino.
- —— *siriellus* Meyr. Common at Waimarino and Rangataua.
- *Scoparia minusculalis* Walk. Common at Auckland and Waimarino.
- —— *minualis* Walk. Common at Waimarino.
- —— *dinodes* Meyr. A few at Raurimu.
- —— *pongalis* Feld. Several in the Auckland Domain.
- —— *thyridias* Meyr. Very common at Waimarino.
- —— *epicomia* Meyr. A few at the Mangaehuehu Stream.
- —— *leucogramma* Meyr. Two at Waimarino.
- —— *submarginalis* Walk. Commonest at Ohakune.
- —— *asterisca* Meyr. One at Raurimu.
- —— *feredayi* Knaggs. A few at Waimarino.
- —— *choristis* Meyr. Two at Waimarino.
- —— *indistinctalis* Walk. Common at Tokaanu and Wairakei.
- —— *illota* Philp. Two at Waimarino.
- —— *trivirgata* Feld. A few at Waimarino.
- —— *aspidotata* Meyr. Fairly common at Raurimu and Waimarino.
- —— *hemiplaca* Meyr. Two at Waimarino and two at Raurimu.
- —— *petrina* Meyr. A few at Ohakune and Waitakere.
- —— *harpalea* Meyr. A few at Ohakune and Waimarino.
- —— *philerga* Meyr. Common at Auckland.
- —— *periphanes* Meyr. Waitakere, Auckland, and Waimarino; common.

- Besides the above species of *Scoparia* an unknown species was taken at Auckland Domain and another at Tokaanu.
- *Mecyna flavidalis* Doubl. A very dark variety was common at Tokaanu and Waimarino.
- — *daiclealis* Walk. One at Waimarino and one at Waitakere.
- *Proternia philocapna* Meyr. Common in Auckland Domain.
- *Sceliodes cordalis* Doubl. Common at electric light, Waitomo.
- *Clepsicosma iridia* Meyr. Common at Waitakere and Waimarino.
- *Pyralis farinalis* Linn. One only in a Rotorua store.
- *Diasemia grammalis* Doubl. Several at Okere Falls, Taupo, and Waimarino.
- *Platyptilia aeolodes* Meyr. Common in Auckland, Taupo, Swanson, and Waimarino.
- — *monospilalis* Walk. Common in Auckland Domain.
- *Aristotelia paradesma* Meyr. A few at Kauri Gully and Auckland.
- *Gelechia monophragma* Meyr. Common at Waimarino and Erua.
- *Hieroxestis omoscopa* Meyr. Common in Auckland Domain.
- — *hapsimacha* Meyr. Common at Kauri Gully and Waimarino, attached to *Cordyline indivisa*.

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- *Pyroderces apparitella* Walk. Common in Auckland Domain.

- *Schiffermuelleria orthopanes* Meyr. Several at Waimarino.
- *Compsistis bifaciella* Walk. Common at Kauri Gully, Raurimu, and Waimarino.
- *Elachista gerasmia* Meyr. A few in Auckland Domain.
 - —— *archaeonoma* Meyr. Common at Waimarino, Auckland, and Waitakere.
- *Stathmopoda caminora* Meyr. A few at Auckland.
- —— *skelloni* Butl. Common at Auckland and Waimarino.
- *Endrosis lacteela* Schiff. Common everywhere in the neighbourhood of houses.
- *Izatha epiphanes* Meyr. Two only, at light, Waitomo.
 - —— *austera* Meyr. Common at Kauri Gully.
- —— *attactella* Walk. One found drowned in a water-butt on Ohakune Railway-station.
- —— *peroneanella* Walk. Auckland, Wairakei, and Waimarino. The Wairakei specimens taken among the hot springs had faded to a blackish-brown shade by the action of the sulphurous vapours.
- —— *picarella* Walk. A few at Waitakere.
- —— *huttoni* Butl. One only at Raurimu.
- —— *balanophora* Meyr. One at Waitomo.
- —— *copiosella* Walk. Several at Waimarino and Raurimu: one particularly large specimen has a wing-expanses of 40 mm.
- *Gymnobathra hyetodes* Meyr. A fine specimen at Swanson.
- —— *tholodella* Meyr. A few at Raurimu and Waimarino.
- —— *flavidella* Walk. Common at Kauri Gully and Okere Falls.
- —— *omphalota* Meyr. Common at Ohakune and Rangataua.
- —— *thetodes* Meyr. Two only, at light Waitomo.
- *Borkhausenia crotala* Meyr. Common at Auckland and Waimarino.
- —— *armigerella* Walk.

- —— *innotella* Walk.
- —— *chrysogramma* Meyr. Several taken at Waimarino. Much more bright than southern specimens.
- —— *hoplodesma* Meyr. Kauri Gully; one only.
- —— *basella* Walk. Several at Rangataua.
- —— *pseudospretella* Staint. Common at Auckland, Waimarino, Tokaanu, and Ohakune.
- Several undetermined species were also taken.
- *Trachypepla leucoplanetis* Meyr. A fine series at Waimarino.
- —— *lathriopa* Meyr. Common at Waimarino and Raurimu.
- —— *galaxias* Meyr. A few at Raurimu and Waimarino.
- —— *protochlora* Meyr. Several at Waimarino.
- —— *aspidephora* Meyr. Several at Kauri Gully.
- —— *euryleucota* Meyr. One large specimen at Raurimu.
- —— *contritella* Walk. Common at Waimarino.
- —— *anastrella* Meyr. A few at Raurimu.
- *Barea dinocosma* Meyr. Two at Raurimu.
- *Proteodes profunda* Meyr. A few at Raurimu.
- *Cryptolechia liochroa* Meyr. Some fine specimens at Waimarino and Erua.
- *Eutorna caryochroa* Meyr. A few at Waimarino.
- *Vanicela disjunctella* Walk. Two only at Kauri Gully.
- *Thylacosceles acridomima* Meyr. Common at Kauri Gully.
- *Glyphipteryx oxymachaera* Meyr. Common at Waimarino.
- —— *erastis* Meyr. A few at Waimarino.
- —— *leptosema* Meyr. A few at Waimarino.

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- *Glyptapteryx zelota* Meyr. A good series at Kauri Gully.
- —— *transversella* Walk. Very common at Waimarino.
- —— *achlyoessa* Meyr. Common at Waimarino.
- —— *asteronota* Meyr. A few at Kauri Gully.
- *Pantosperma holochalca* Meyr. A few on rushes at Tokaanu.
- *Coridomorpha stella* Meyr. One at Raurimu.
- *Simaethis combinatana* Walk. One at Waimarino and one at Ohakune.
- —— *microlitha* Meyr. One only at Waitakere.
- *Acrocercops cyanospila* Meyr. Two only at Taupo.
- *Batrachedra psithrya* Meyr. A few at Kauri Gully.
- *Parectopa aellomacha* Meyr. A few at Kauri Gully and the Auckland Domain.
- *Gracilaria chalcodelta* Meyr. Fairly common at Waimarino and Raurimu.
- —— *chrysitis* Feld. Three specimens of this beautiful moth at Kauri Gully.
- —— *linearis* Butl. Common, especially at Waimarino.
- *Dolichernis chloroleuca* Meyr. Common at Raurimu and Waimarino.
- *Protosynaema steropucha* Meyr. One only at Rangitoto Island, Auckland Harbour.
- *Orthenches porphyritis* Meyr. Kauri Gully and Waimarino; common.
- —— *drosochalca* Meyr. One only at Kauri Gully.

- —— *chlorocoma* Meyr. A few in Auckland Domain.
- —— *glyptarcha* Meyr. One only of this fine species at Waimarino.
- *Circoxena ditrocha* Meyr. Two of this moth at Kauri Gully.
- *Eschatotypa melichrysa* Meyr. Auckland and Waimarino; common.
- *Erechthias exospila* Meyr. Two only at Kauri Gully.
- —— *hemiclistra* Meyr. Common at Waimarino, attached to *Cordyline indivisa*.
- *Hectacma chasmatis* Meyr. Two taken in Auckland Domain.
- —— *stilbella* Newm. Common in Auckland Domain.
- *Crypsitricha mesotypa* Meyr. Common at Kauri Gully and Waimarino.
- —— *roseata* Meyr. A few at Waimarino.
- *Habrophila compseuta* Meyr. A few at Kauri Gully.
- *Endophthora omogramma* Meyr. Common in Auckland Domain.
- *Thallostoma eurygrapha* Meyr. One only at Raurimu.
- *Sagephora exsanguis* Philp. One or two in Auckland Domain.
- *Lysiphragma epixyla* Meyr. A few at Waimarino.
- *Mallobathra crataea* Meyr. Common at Waimarino.
- *Protnodes grammocosma* Meyr. Common at Kauri Gully and Waimarino, attached to *Cordyline indivisa*.
- *Porina umbraculata* Gn. Common at Ohakune.
- —— *enysii* Butl. Three fine specimens at Waimarino.
- *Mnesarchaea loxoscia* Meyr. Common at Raurimu.
- *Sabatinca calliarcha* Meyr. One only at Kauri Gully.
- —— *incongruella* Walk. Very common at Ohakune, Erua, and Waimarino.
- —— *doroxena* Meyr. Seveal at Waimarino.
- —— *lucilia* n. sp. A few at Kauri Gully and one at Waitomo.

- *Hepialis virescens* Doubl. A few in Auckland Domain and one at Waimarino.

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Art. XI.—*Notes and Descriptions of New Zealand Lepidoptera.*

By Alfred Philpott.

[*Read before the Otago Institute, 9th December, 1919; received by Editor, 31st December 1919; issued separately, 4th June, 1920.*]

Caradrinidae.

Agrotis spina Guen., *Noct.*, vol. 1, p. 269; Hamps., *Cat. Lep. Phal.*, vol. 4, p. 367.

This well-known Australian moth should be added to the list of New Zealand Lepidoptera. Dr. A. Jefferis Turner, of Brisbane, has kindly supplied me with examples, and these show that *spina* has been hitherto overlooked by New Zealand lepidopterists, having been treated as a form of *A. ypsilon*. The males of the Australian examples which I have are more ochreous than New Zealand specimens, but the females are of almost exactly the same tint. The chief difference between the species is to be found in the form of the subterminal line: in *ypsilone* this is strongly dentate, whilst in *spina* it is only slightly irregular. In *spina* also the orbicular and reniform are connected by a prominent blackish bar, this being absent in *ypsilone*. These distinctions, however, apply best to the males, the females of the species being very difficult to separate.

From Dr. Turner I learn that *Agrotis spina* is found throughout Australia, and is in some seasons extraordinarily abundant.

Aletia panda n. sp.

, 33 mm.; 36 mm. Head and palpi grey, in tinged with ochreous. *Antennae* in strongly bipectinated. Thorax grey, with dark bar on collar, crests absent. Abdomen

greyish-ochreous. Legs greyish-ochreous, anterior tarsi blackish annulated with ochreous. Forewings, costa almost straight, apex rounded, termen oblique, evenly rounded; bluish-grey, tinged with ochreous, in mixed with blackish-fuscous; a black dot on costa at base, margined broadly with whitish; first line faintly indicated, irregularly dentate, fuscous, margined anteriorly with whitish; second line from $\frac{1}{2}$ costa to dorsum, deeply and widely indented on upper half, irregularly dentate on lower half, blackish; a thin dentate fuscous presubterminal line, curving beneath reniform and closely approaching second line, thence running parallel with it to dorsum, apex of teeth margined with white; subterminal line obscure, margined anteriorly, in narrowly, in broadly, with fuscous; a series of fuscous dots round termen; *orbicular circular, pale, interruptedly margined with fuscous; claviform directly beneath orbicular, circular, half as large as, and similar in colouring to, orbicular; reniform pale, faintly fuscous-margined*: cilia ochreous with basal and post-median fuscous lines. Hindwings in ochreous-fuscous, in fuscous: cilia ochreous, in with obscure fuscous line.

Very close to *A. cuneata* Philp. in appearance, but differing in the pectinated antennae and the pale-centred stigmata. In the structure of the antennae and palpi, the new form comes nearer to *A. temenaula* Meyr. I have placed the species in *Aletia* owing to its obvious relationship to the *cuneata-temenaula* group, but the arrangement of species at present adopted for our New Zealand forms in this genus and *Leucania* seems to me to stand in need of revision.

A single pair is all the material at present available. The male was taken by Mr. G. V. Hudson on Mount Earnslaw in January, 1914, and the female was captured by myself at Routeburn in December, 1918. The types remain in the collections of their respective discoverers.

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Melanchra inchoata n. sp.

33 mm. Head, palpi, and thorax greyish-ochreous sprinkled with fuscous.

Thorax in both sexes with rather prominent anterior crest. Antennae in ciliated, ciliations . Abdomen in both sexes with the first four or five segments prominently crested. Legs ochreous, tarsi annulated with fuscous. Forewings, costa almost straight, apex subacute, termen crenate, oblique below middle; *ochreous clouded with fuscous*, in darker; a small pale apical patch; a series of four or five paired fuscous dots on costa; all lines except subterminal very obscure; basal evenly curved, serrate, fuscous; first and second almost obsolete, apparently double, fuscous; a presubterminal thin serrate dark line faintly indicated; *subterminal conspicuous, unindented, equidistant with termen, white*; terminal crenations edged with black; stigmata unusually closely grouped; orbicular rounded, whitish, dark-centred; claviform small, dark fuscous; reniform dark fuscous, obscurely white-linged: cilia ochreous, basally mixed with fuscous. Hindwings dark fuscous: cilia ochreous with dark-fuscous sub-basal line. Underwings ochreous thickly irrorated with fuscous, clear ochreous along costa and round termen of forewings; lunules and second lines of both wings fuscous.

Belongs to the *coeleno-levis* group, but is easily distinguished by the form of the subterminal line.

Stephen Island. Collected by Mr. H. Hamilton on the 9th September, 1916. I am indebted to Dr. J. A. Thomson, Director of the Dominion Museum, for the opportunity of describing this interesting species. Types, and , in coll. Dominion Museum.

Sphingidae.

Choerocampa celerio Linn.

In the *Transactions of the New Zealand Institute*, vol. 37, p. 369, Hudson, records the first captures of this species in New Zealand, four examples having been taken in the summer of 1903–4. To this record I am able to add that of a specimen taken at Te Tua, near the southern coast of the South Island. The moth was taken by a resident of the district and forwarded to the Southland Museum, in the collection of which institution it remains. It is in fine condition, so fresh as to cast considerable doubt on the possibility of its having been wind-driven across a wide expanse of ocean.

Pyraustidae.

Scoparia pascoella n. sp.

. 15–18 mm. Head and palpi ferruginous-brown, palpi ochreous beneath. Antennal ciliations $\frac{1}{2}$. Thorax ferruginous-brown mixed with white. Abdomen fuscous-grey. Legs ochreous-grey mixed with fuscous, tarsi obscurely banded with fuscous. Forewings moderate, triangular, costa almost straight, apex round-pointed, termen hardly rounded, oblique; ferruginous-brown mingled with some

fuscous and much suffused with white; first line hardly curved, unindented, white, broadly marginated with ferruginous posteriorly; orbicular and claviform dot-like, blackish, partially obscured by ferruginous suffusion, reniform X-shaped, blackish, frequently obscure; *second line irregularly bent but not deeply indented, narrow, parallel to termen, white, narrowly marginated with ferruginous anteriorly*; subterminal line obscure, interrupted at middle, widely remote from second line, white: cilia ochreous-grey. Hindwings grey-fuscous, paler anteriorly: cilia ochreous-grey with fuscous basal line.

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Near *S. organaea* Meyr., but the forewings are much narrower at the base and the costa is straighter; the second line of the two forms is quite different both in colour and form. In some examples the white suffusion is very pronounced and the markings are more or less obsolete.

I took a good series on Tooth Peaks, Wakatipu, at an elevation of about 3,000 ft., in December. The species was abundant on the moist ground near a little stream. The specific name is intended as a tribute to the memory of the late Quartermaster Merlin Owen Pascoe, who fell at La Newaille, France, a few months before the conclusion of the war. Quartermaster Pascoe did a great deal of entomological work in the Wakatipu district, and was the first entomologist to collect on Tooth Peaks.

Pyralididae.

Endotricha pyrosalis Guen., *Lep.*, vol. 8, p. 219.

Among some moths sent to me several years ago by Mr. H. Hamilton was a single example of this species, labelled "Mt. Dennan (Tararua Mountains), February, 1911." I was not at the time able to identify the specimen, and as it was not in very good condition it was set aside in the hope of obtaining further material. Having now, through the kindness of Dr. Jefferis Turner, procured good examples of *pyrosalis* from Australia, I am able to make the above record. The species has a

wing-expanses of about 20 mm. The forewings are rather bright yellow, densely sprinkled with pink, especially on the apical . The hindwings are also bright yellow, and have the termen broadly margined with pink. The patagial tufts are much elongated, reaching more than half-way to the tornus of the hindwing.

I learn from Mr. H. Hamilton that this interesting capture could not have been made by him, as he did not visit Mount Dennan on the date recorded. He suggests that the moth was probably taken by his father, the late Augustus Hamilton.

Plutellidae.

***Orthenches virgata* n. sp.**

10 mm. Head, palpi, and thorax ochreous. Antennae ochreous on basal fifth, annulated with white and black on remaining portion. Abdomen greyish-white. Legs, anterior pairs fuscous, tarsi obscurely annulated with ochreous, posterior pair ochreous-whitish. Forewings moderate, costa strongly arched, apex round-pointed, termen moderately oblique; bright ochreous with violet and purplish reflections; a brownish fascia from beneath, costa near base to dorsum at $\frac{1}{4}$; a well-defined fascia from costa at $\frac{1}{4}$ to dorsum at $\frac{1}{2}$, slightly irregular, brownish mixed with black; a similar fascia from costa at , strongly angled above middle towards termen, thence to dorsum at , where it coalesces with inwardly-oblique fascia from costa at $\frac{3}{4}$, both these fasciae having black patches at middle; a white patch margining last fascia at middle; a few black scales on central portion of dorsum: cilia ochreous, becoming fuscous round apex. Hindwings and cilia shining white.

A well-marked species, having little affinity with any other member of the genus.

The type of this interesting species was taken at Auckland on the 2nd October, 1918, by Dr. A. Jefferis Turner, of Queensland, to whose generosity I am indebted for the specimen. Mr. Charles E. Clarke was fortunate enough to secure a second example at Waitati, Otago, in February, 1919, so that the species, though apparently rare, must be widely distributed.

Art. XII.—*The Southern Maori, and Greenstone.*

By H. Beattie.

Communicated by H. D. Skinner.

[*Read before the Otago Institute, 9th December, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.*]

While I was gathering place-names from the southern Maori they gave me a little information about greenstone which may be worth recording in print. Although greenstone is not the technical name of this stone, it is the popular one, and I shall adhere to it.

In his admirable paper in *Trans. N.Z. Inst.*, vol. 24, pp. 479–539, Mr. Justice Chapman states that nowhere did the Maori get greenstone in an inland locality, and thus he considers Shortland's statement that it was procured at "Lake Wakatipua" is erroneous. The southern Maori assure me that Shortland's information was correct, and that you can still see the place where the *pounamu* was got at Te Koroka, a mountain up the Dart River. One old man said, "*Pounamu* of the *inaka* kind was found at Te Koroka, at the head of Whakatipu. It was the only place where it was got inland. *Takiwai* greenstone was found at Milford and elsewhere." Another said, "Te Koroka, where they got the greenstone, is north of Wakatipu. Taumaro is the name of the mountains between Wakatipu-wai-tai and Wakatipu-wai-maori, and Te Koroka is one of those heights."

Some of the Maori say "Wakatipu" and others "Whakatipu." It was explained to me that the word occurs in five place-names. The mountains west of the lake are called Whakatipu, and the lake is known as Whakatipu-wai-maori (Fresh-water Whakatipu). The Dart River is Te-awa-Whakatipu, the Hollyford River is Whakatipu-katuku, and Lake McKerrow is Whakatipu-wai-tai (Salt-water Whakatipu). These last three are all on the track by which the Maori went from the head of Lake Wakatipu to Martin's Bay, on the west coast.

One old Maori said, "Under Te Koroka is a place now called Maori Hill, I believe, but known of old as Puketai, after a chief of note who died there. Near this spot stood a *kaika* called Puia, and there the Maori lived when getting the greenstone.

The general name of the whole district north of Lake Wakatipu was Te-wai-pounamu." This last statement conflicts with Mr. Justice Chapman's conclusion (p. 522) that Te-wai-pounamu is the correct form of the name, although there is nothing to prevent the latter form having been applied to the rivers on the west coast. A chapter could be written on the elision or addition of "h" in the southern dialectal usages; and in any case—again to differ from the conclusions of Mr. Justice Chapman—the pronunciations of "wai" and "wahi" by a southern Maori are often so alike as to be indistinguishable save to an acute or trained ear.

Before leaving the subject of greenstone in the Wakatipu district I may add that Mr. James Cowan kindly lent me some notes he had gathered from the southern Maori in 1905, and among them are the following items of information: "Beyond the head of Whakatipu on the road to Martin's Bay, somewhere near Lake Harris Saddle, is the place where the Maori used to get *koko-tangiwai*." "Te Koroka is a bold peak at the head of Lake Whakatipu, and the Maori got a sort of coarse greenstone there."

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An old Maori said to me, "Pekerakitahi is a mountain standing by itself at the head of Wakatipu" (Mount Earnslaw). "There is greenstone in it, because Te Ariki, who lived seven generations ago, took some *pounamu* from Te Koroka and hid it in Pekerakitahi, where it went like the skin of a *tuatara*. If you break the rock you will find the greenstone inside. A mountain and creek both called Pekerakitahi are at the head of Lake Wanaka, but it is the Wakatipu mountain I mean."

In regard to how long the Maori have known greenstone, I was told that Kahue (Ngahue), who visited New Zealand thirty-nine generations ago, took some back to Hawaiki with him. One piece Kahue split into three axe-heads—one for himself, called Kapakitua; one for Kupe, named Tauira-a-pa; and one for Rata, called Te-papa-ariari. Rata sharpened his axe-head, attached a handle, and named it Aumapu. With this axe he cut down the famous tree which the "little folk" of the forest erected again, as in the oft-repeated story.

Another story has it that Tamatea-pokai-whenua, twenty-two generations ago, sailed round the South Island in search of his missing wives. Unaware that they had been wrecked off the Arahura River and turned into greenstone, Tamatea landed there, and his slave in cooking some *koka* birds burnt his fingers, which he licked. This was a violation of *tapu*, and the slave, Tumuaki, was turned into the mountain since known by his name, whilst Tamatea never found his wives, their petrified bodies furnishing the greenstone, some of which has a flaw known as *tutae-koka*, or the dung of the birds Tumuaki was cooking when he committed his thoughtless act. Mr. Justice Chapman says (p. 518), "I am unable to obtain a satisfactory meaning for *koka*. Mr. Tregear suggests *koko* (the tui), which seems probable." The bird was the orange-wattled crow (*Glaukopis cinerea*), whose name throughout the South is *koka*, although its *confrère* in the North Island (*Glaukopis wilsoni*) is there called *kokako*.

An old Maori, usually well informed, gave me a peculiar version of this tradition. He said, "I think that story about Tamatea and his three runaway wives is false. Tama-taku-ariki, often called Tama, went to Arahura in search of greenstone, which was then in human shape. He killed one, and was cooking it in an *umu*, when his companion burnt his finger and put it in his mouth. In consequence of this act the greenstone disappeared and they came away disappointed."

Mr. James Cowan writes, "The wives of Tama-ki-te-Rangi (captain of the Tairea canoe) deserted him, and he searched for them from Cook Strait to Piopiotahi (Milford Sound). The flax-like *kiekie* (*Freycinetia Banksii*), which fringes the fiord for miles, sprang, according to legend, from the shreds of Tama's shoulder-mat, torn off in his forest travels. Here he found one of his wives, but she had turned into greenstone, and as Tama wept over her his tears penetrated the very rock. This is why the nephrite found on the slopes of Mitre Peak, close to Anita Bay, is called *tangi-wai* (the water of weeping, or tear-water). If you take a clear piece of this stone and hold it up to the light you will sometimes see marks like water-drops in it. This is the true *tangi-wai*, for these are the tears of Tama-ki-te-Rangi."

Whoever the chief was who pursued his fugitive wives, it is fairly certain it was not the captain of the Takitimu canoe, who bore at various times in his own proper person the names Tamatea-ariki-nui, Tamatea-mai-Tawhiti, Tamatea-ure-kotia, Tamatea-muriwhenua, and Tamatea-pokai-whenua. This illustrious chief resided for some time in southern New

Zealand, and at least three places near Dusky Sound perpetuate the memory of his voyage of exploration in that vicinity, but his name and fame have never, that I know of, been associated with greenstone.

Mr. Cowan has given a tradition accounting for the name *tangi-wai*, but the *Memoirs of the Polynesian Society*, vol. 4, page 138, say the name was bestowed on one kind of jadeite because of the tears of Hine-ahu over the death of Tuhua, whom her jealous husband, Tama-ahua, killed. Tama-ahua, twenty-nine generations ago, led a party to get *pounamu* at Arahura, and not only was *tangi-wai* named then, but two other kinds of jadeite were named also—*kahurangi* and *kawakawa*; while through a fire that occurred the *kahotea* kind of *pounamu* was burnt, which accounts for its peculiar marking.

The same authority states that Kupe, thirty-nine generations ago, was the first to discover the jadeite, or *pounamu*. The locality was the Arahura River. The river at the time was swarming with whitebait (*inanga*), which the party proceeded to catch. Kupe's daughter picked a stone out of the river to act as a sinker to the net, and the one she seized was different from any they had seen before, and so it was called *inanga*, this remaining to the present day the name of this valued kind of *pounamu*.

I have a note as follows: "Piopiotahi was a canoe which came from Hawaiki. Kahotea was the captain and Tangiwai one of the crew, and two kinds of greenstone now bear these names."

The conflicting evidence regarding the discovery and naming of the various kinds of *pounamu* occurs because the accounts are gleaned from different tribes, who each have an explanation based on ancestral lore, although it must be admitted that all the traditions are not of equal probability and merit.

The first settlement of people of Maori blood in the South Island of which we possess reliable information is that under Rakaihautu, a chief who flourished forty-two generations ago. His people were called Waitaha, and their descendants were numerous in the South Island when the last and principal influx of Maoris occurred, twenty-two generations ago. This Waitaha people used weapons of bone and wood, and the late Tare-te-Maiharoa said of them, "They did not know

greenstone, but used a glassy stone known as *takiwai*." *Takiwai* is the southern pronunciation of *tangiwai*, said to be the most transparent variety of jade and to come from Milford Sound, so that apparently my informant did not class it as a proper greenstone, which, of course, is scientifically correct.

Pounamu was classed with fish, according to Dr. Shortland, (and there are numerous legends in this connection outside the scope of this paper, but the only reference I have to the Rapuwai people knowing any form of greenstone has a distinctly piscatorial aspect. A sub-tribe of Rapuwai known as Kati-Koko, said my informant, went round to Milford Sound, and, finding a huge piece of greenstone in the sea, set out to drive it round to Foveaux Strait. Three canoes followed it—one on each side and one behind, and yet it nearly escaped several times. They almost got it ashore at Oraka (near Riverton), but it dodged on till it settled where it is, and it now forms Motupiu (Dog Island, near Bluff). My informant added that if you went down into the interior of that island you would find it hollow and supported on three legs, or columns, of greenstone.

When the Kati-Mamoe Tribe were pushed out of the North Island some time after the arrival of the six canoes, twenty-two generations ago, they spread southward and intermarried with the Waitaha and Rapuwai Tribes

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One of my informants, a descendant of these tribes, said to me, "There are four kinds of greenstone, but the Kati-Mamoe never used them. The North Island people did not make trips for greenstone as early as they say, for the first expedition to get it went from Kaiapohia and fought the Patea people in Westland. The people of Raumano who settled on the West Coast had greenstone before either the Kati-Mamoe or Kai-Tahu Tribes came to this island."

A Maori of Kati-Mamoe descent says, "The Kati-Mamoe remained on the east and south sides of the South Island, and had no greenstone weapons until the Kai-Tahu brought these among them. In some of the old encampments at Kawhakaputaputa and elsewhere in Murihiku you can find the *uri*, or slatestone

axes, and *parahi*, or flint knives, of the old people of the Kati-Mamoe before they used greenstone."

Greenstone was brought under the notice of the Kai-Tahu Tribe in Canterbury by a woman named Raureka, who, accompanied by her dog, found a way through the dividing range between Westland and Canterbury. Both Stack and Wohlers call her a mad woman, but I should scarcely like to infer that she was, seeing she is an ancestress of an esteemed old friend of mine. She married a man called Puhou, and by the genealogy furnished me I note she flourished ten generations ago. The Kai-Tahu invasion of the South Island took place in the year 1650 approximately, and ten generations back from 1900 places the birth of Raureka as about 1650 also; so if we allow she was twenty when she made her exploring trip, we can put down a.d. 1670 as somewhere near the time when Kai-Tahu became interested in procuring greenstone.

I was told that two West Coast Maori, named Pakiha and Taka-ahi, came over to Canterbury and were acting as brigands, pouncing on solitary wayfarers, whom they killed and ate. Rakitamau killed them, but before doing so elicited information as to the route to the West Coast. He and his sons (Weka and Marama) followed the directions and arrived at a lake where was a store of greenstone, guarded just then by only an old man and woman. They killed the old couple and used them as provisions on the way back to Kaiapohia, which they entered in triumph, carrying as much greenstone as they could bring. The time of this occurrence is not stated, but I take it to be before the war expedition led by Rakitamau at the time when he killed Uekanuka.

The possession of greenstone weapons was an advantage to Kai-Tahu in their conflicts with Kati-Mamoe, but the latter gradually acquired the valued *pounamu*. It is said that one of the weapons of Marakai, one of the most valiant Kati-Mamoe, chiefs, was a *pounamu toki*. For a long time the Kati-Mamoe, *a tangata-whenua* people, were inferior to Kai-Tahu, who belonged to the conquering strain, whose achievements in Maoriland were analogous to the Norman Conquest in England. They were inferior both in weapons and prowess, but as they were pushed back from Canterbury into Otago and Southland they roused themselves, and, to quote one of my informants, they "fought like tigers," with a result that the two tribes amalgamated and were so found by the white people.

That the Kati-Mamoe possessed greenstone is evident from the traditions concerning the Otaupiri *pa*, on the north side of the Hokanui Hills. After Tu-te-Makobu killed Kaweriri at the fight of Waitaramea (also known as Tarahaukapiti) he lived at Otaupiri. Of the presence of greenstone in this *pa* I have been told no fewer than eight times. "There is, or was, a spring close to the *pa*," said the first man who told me of this famous piece of *pounamu*, "and it is, or was, covered over with a greenstone slab,

which has never been found yet." Another said, "There was a well in the *pa* of Tu-te-Makohu, and its top was covered by a celebrated slab of greenstone"; and another added these details: "I will let you into a secret. In a creek near Taupiri eight valuable *mere* are buried under a slab of greenstone which was concealed in the creek-bed. There is also in that hidden store a beautiful greenstone *taiaha*, which is said to be 3 ft. long. I have never heard of any one making a proper search for that buried treasure placed there by our ancestors."

In regard to the last remark, one old man said to me, "Several people, including the late Tame Parata, once went up to try and get Tu-te-Makohu's greenstone at Otaupiri, but the search was without result. Tu-te-Makohu died at that *pa* and was buried on a hilltop which can be seen for miles round. His *maipi* was put upright in the ground to mark his burial-place."

One old man gave some information which may refer to the foregoing, or it may be a different incident altogether: "In a creek up about the head of the Waimumu Stream, in the Hokanui Hills, is a big hole that was used in old times to get water from. Somewhere near it a noted greenstone *mere* was buried in the creek-bed. This *mere* is said to have once belonged to a great woman, and it was secreted to preserve it from falling into strange hands. It was buried by a woman who was the only one of her family left at that place, and she hid it secretly so the rest of the people would not know, and it has never been found to this day as far as is known."

The hiding of valued pieces of greenstone was quite common. Rawiri-te-Awha had once lived at Lakes Manapouri and Te Anau, and he buried some greenstone there. One of my informants was up there with Rawiri and some other Maori in 1872, and one night a companion and he went to the site of Rawiri's old *whare* and dug up the greenstone and had a look at it. They carefully replaced it, and as the party came away without it my informant considered it would be there still, although he has never been back in the locality to ascertain the changes made by the white man's occupation.

At one point near Port Molyneux, tradition says, a *whare* stood many generations ago, and that when the chief called Makatu was killed on the headland above his heart was brought down and roasted before this ancient dwelling. My informant had dug down at the spot and found traces of habitation, coming on an old bone *mere*, beautifully carved, but unfortunately half burnt. He also found a greenstone weapon of unusual design, and this he gave to Captain Bollons, of the s.s.

"Hinemoa." The hill behind the old pilot station at Port Molyneux is called Kaoriori, after a block of greenstone of this name which had been brought there and broken up to manufacture. A rivulet running from the hills near Kaitangata is called Te Waihoaka because in it, according to a correspondent of mine, "were found large quantities of a hard stone (*hoaka*) much sought after by the Maori for grinding greenstone and other stones and fashioning them into ornaments, as well as for making tools and other implements, an art in which the Maori attained truly marvellous skill."

It was natural, of course, that greenstone should be used as a medium of exchange, and two of these barters were mentioned to me. The first was that some valuable pieces of greenstone changed hands for the right to squat (*noho*) on certain lands in Otago at the time Rauparaha was raiding the people of North Canterbury. The other recorded that a fast canoe, named Kura-matakitaki, was made at Matainaka (near Waikouaiti) by Rimurapa and Horuwai some time before the whalers came. Pahi was anxious to secure it, and this he did by giving greenstone in exchange. He

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took it round south with him to Foveaux Strait. The whalers subsequently named a place (Pahi's, near Orepuki) after this chief.

Te Horo is the name of the place in Milford Sound where the *takiwai* (*tangiwai*) greenstone is got. It is a cliff-face behind Anita Bay. Piopiotahi, as I understand it, was originally the name of the Cleddau River, but is now applied to the whole sound. The Maori went round in canoes from Murihiku (Southland) to Piopiotahi to get *takiwai* up to about fifty or sixty years ago. It is said by the southern Maori

that, although the greenstone at Milford was inferior, good *pounamu* could be got at Barn Bay, some distance farther north.

One old man said to me, "In 1841 Anglem, Gilroy, Stirling, and others started trading with Sydney in flax, and they also opened up greenstone-quarries about Milford. The flax was properly dressed (*whitau*). They had natives getting greenstone at Piopiotahi, and they took this greenstone to the North Island and exchanged it for plenty of flax, which they could sell at Sydney for £70 or £80 a ton. While getting the *pounamu* at Milford a boat, overloaded with the stone, capsized and sank between two rocks."

Some years ago I had a chat with Mrs. Gilroy, who was a daughter of Captain Anglem, and was born on the west coast, near Puysegur Point, about the year 1832. She narrated: "After taking flax to Sydney my father came back and took one lot of greenstone to China. The stone was got at Piopiotahi, or Milford, and neither Stirling nor Gilroy had anything to do with it. My father was living at the Bluff then. Captain Waybone(?), of the schooner 'Success,' was washed overboard one stormy night off the Bluff, and the vessel came in and lay here five or six weeks. Johnny Jones, who was part-owner, got my father to take the schooner back to Sydney. My father came back in a brig, 'The Royal Mail,' and, picking up all the old natives here, he took them round to Milford to get greenstone. I was a girl at the time. The owner of 'The Royal Mail' came over in the 'Anita' and sailed round to Milford, and after they got a cargo of greenstone both vessels proceeded to China." Here the narrative unfortunately ends. I was gathering Maori place-names—Mrs. Gilroy gave me a long and valuable list—and did not pursue the subject of greenstone further.

One thing that has always struck me is the great number of greenstone tools, weapons, and ornaments that has been found in Otago, and also the very wide extent over which the finds range. Either the population was much larger at one time, or the limited number of inhabitants worked unceasingly to produce such a quantity of manufactured stone. Then, again, the Maori must have been very happy-go-lucky or indifferent in their care of possessions so valuable to a people in the Stone Age. Although much may have been buried with the dead or hidden in the earth for safety and left there through the owners dying, yet a large quantity has been found lying on the ground as if carelessly thrown down by travelling parties and left unretrieved and forgotten. As already inferred, these greenstone articles ("curios," the *pakeha* calls them) have been found in most parts of Otago. Among other localities where such have been found, I see I have a note that an axe-head was picked up on the top of the Old Man Range, near the Kawarau end. Many farmhouses throughout Otago possess greenstone curios picked up in the neighbourhood, and if the whole could be gathered in one place, together with museum collections and private collectors' hoards, it would, I am sure, make an array of astonishing extent. Several days ago, too, at a place near where I am writing in Gore, a big adze-head was dug up, and much more may still be found.

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Addenda.

The testimony of the southern Maori that greenstone was got a [*unclear:*] head of Lake Wakatipu raises the query, What is the correct for [*unclear:*] the name Wakatipu? Shortland gives the name as “Wakatipua” [*unclear:*] two maps in his book, *The Southern Districts of New Zealand*, and [*unclear:*] page 205 also spells the name with a final “a,” but at page 35 he refers to the lake as “Wakatipu.”

Its correct form is one of the conundrums in Maori nomenclature. The difficulty is threefold: Should there be an “h” in the name, or a final “a,” or both? I referred the matter to the best-informed of the southern Maori, and have nine opinions regarding it, but cannot say much further ahead.

Two of the old men said the name was Wakatipu, and meant “growing” canoe”; but why it was growing they knew not, except it was a sort of magic canoe. Another also said the first part of the name was *waka*, not *whaka*. He had never heard the reason for the name, but considered it was a canoe to cross the lake. An old woman said she had heard no traditions to account for the name, but the old people she had known usually called the lake by the name of Whakatipu-wai-maori. An old man said, “Whakatipu means ‘to grow,’ ‘to nourish,’ and the reason the name was given was because the Waitaha and Kati-Mamoe tribes when beaten in war retired there to rear families.” But against this one of the best authorities on southern history says it is a Waitaha name given long before the Kati-Mamoe appeared in the south. The Waitaha, he says, were descended from Toi, Rauru, and Rakaihautu, and why they named the lake “Whakatipu” is not known, but, as far as he knew, it was not after any chief or ancestor. The late Tare-te-Maiharoa said he did not know who named Wakatipu, nor why. It was a Waitaha name, and its origin had been lost in antiquity. Another usually well-informed man said he had never heard the origin of the name, nor did he even know the correct form of the word. The last opinion I got was from a man who gave me numerous place-names of the lake vicinity, and he said the Waitaha bestowed the name Whakatipu. The word *whaka* (or, as the North-Islanders

would say, *whanga*) meant "a bay," and *tipu* meant "growing," but he had never heard why the Waitaha applied the name.

In regard to information derived by Europeans from Maori sources, Mr. Henry P. Young, who got his information at Colac Bay, wrote in 1903, "Wakatipu should be Wakatipua, the *waka* or hollow of the *tipua* or demon from the well-known legend." Mr. Henry E. Nickless, writing in 1898, said that Hoani Matewai Poko, a son of Te Waewae, told him the proper name of the lake was Whakatipu and not Whakatipua. Mr. H. M. Stowell (Hare Hongi), in 1898—the year the stamp was printed with "Wakitipu" on it—wrote that the name should be Whakatipu; and he was followed by Mr. S. Percy Smith, who wrote, "Mr. Stowell may be right about Whakatipu, although Tare Wetere assures me that it should be Whakatipua, and I am inclined to think that the name should be Wakatipua." Halswell in his 1841 map spelt the name "Wakatopa." James F. Healey, writing in 1898, said that the Waitaki Maori in 1856 gave him the name as Whakatipu, and said it was a mighty lake [*unclear*:] existed near a greenstone river. A white settler told me that the [*unclear*:] had told him the name was Waka-tipua because a phantom can [*unclear*:] to drift on the lake. In Mr. Cowan's notes was one—"Whaka [*unclear*:] was the name of a canoe in which the Maoris went to fetch the [*unclear*:]

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[*unclear*:] wai from across Lake Whakatipu." Mr. Cowan says in his *Maoris* [*unclear*:] *New Zealand* the full name of the lake is Te-roto-whakatipu-whenua.

The late Mr. W. S. Young, of Otakeho, writing to me regarding his [*unclear*:] trips in 1857–59, said a very intelligent old Maori, Kawana by name, told them he used "to live at a large lake called Wakatapu, the only place where greenstone could be obtained. Opposite their settlement on the shore of the lake was a great cliff, which occasionally broke away, when the chief would launch his sacred canoe, Wakatapu—hence the name given to the lake—and, paddling across, obtain pieces of greenstone and distribute them among the tribe. Ultimately the northern Maori came after greenstone and destroyed the lake tribe... When or how the name first degenerated from Wakatapu to Wakatipu is more than I can

tell. Had we lived in southern Otago I think the lake would have been called Wakatapu (sacred canoe)." Mr. Young saw the lake and a slip in a cliff from the top of the Shotover Mountains; but as he soon after removed to the North Island he never saw at close quarters the Roto Wakatapu and the Pari Pounamu (greenstone cliff) described by old Kawana.

In a letter to me Mr. S. Percy Smith says he is inclined to think the name should be Whaka-tipua, and that is also my conclusion. An old legend says the lake-bed was formed by a giant ogre or *tipua*, called Kopu-wai, being burnt there. Shortland wrote *wakapapa* instead of *whakapapa*, so he may also have written "Wakatipua" for "Whakatipua." The tradition of a canoe crossing the lake for greenstone will probably be true, but it has become grafted into or intermixed with the older story that the great hollow in which the lake lies was formed by the ashes of the giant. Hence we find the conflicting opinions already recorded. The matter cannot be regarded as settled yet, but it is hoped that the foregoing information may help towards a solution.

The question as to whether the name is rightly Wai-pounamu or Wahi-pounamu is an interesting one. The southern Maori was almost as bad as the cockney for deleting and adding the aspirate. Dozens of examples could be given, but one will suffice here. There is an island east of Stewart Island, and its name is Wahi-taua, but it is usually called Wai-taua. Even in Mr. Justice Chapman's paper there are two illustrations of this trait. One kind of greenstone is called *auhunga* on page 513, and on page 515 it is called *hauhunga*. On page 509 an ear-pendant is termed *kapehu* and also *kapeu*. One of my informants found a *kapeu* on Pigeon Island (Wawahi-waka), Lake Wakatipu, in the year 1864. It must be very old, as it was worn white. As far as I know, he has it still in his possession. To revert to Wai-pounamu and Wahi-pounamu, I think it is probable both forms were used—the former for the rivers of Westland, where *pounamu* was got in the water, and the latter for perhaps Piopiotahi and Te Koroka, where it was procured from cliffs or mountain-sides.

Mr. Cowan gives the kind of greenstone that was found at the head of Lake Wakatipu as *koko-tangiwai*, but I was told it was *inaka* (or *inanga*). I heard recently that a European resident in that locality had come across what he considered to be an old greenstone-quarry. If that be so, we should be able to ascertain something more than we know at present about this traditional *pounamu* hunting-ground.

Art. XIII.—Nature-lore of the Southern Maori.

By H. Beattie.

Communicated by H. D. Skinner.

[*Read before the Otago Institute, 9th December, 1919; received by Editor, 31st December, 1919; issued separately, 4th June, 1920.*]

In collecting the traditions and place-names of the Maori of Otago and Southland I have gathered a great mass of information, some of which has recently been published elsewhere. There remains, however, a considerable quantity of material which has never been printed, and some of this relating to nature may be of interest. It must be understood that I am not trying to deal exhaustively with the various phases of this extensive subject, but simply to record what the southern Maori have occasionally said to me about it. The Maori gave me some nine hundred place-names hitherto unrecorded by the *pakeha*, and it was while giving these names that they mentioned the following facts. Where the terms "North" and "South" are used, reference is made to the districts north or south of Timaru, Canterbury.

The Kanakana, or Lamprey.

The general name for the lamprey is *piharau* in the North and *kana-kana* in the South. One of my informants said that there are at least four different kinds of *kanakana*, or, if counted as all one species, the Maori had names for them at four separate stages or at different sizes. These names are—(1) *Te-ika-tukituki-wai*; (2) *te-ika-totoe-wai*; (3) *matua-iwi-papaho*; (4) *te ru*. Some rivers might have all four kinds, and other rivers fewer. They went up certain rivers only, and they shunned others for no apparent reason; but evidently something in the water, either in taste or in plant or animal life, or in the situation of rocks, &c., attracted or repelled them. My informant added that the *kanakana* would not come up the Karoro Creek, but swarmed up the Molyneux River, whose mouth is about two miles distant. They proceed up the rivers until they find their passage barred by rocks, and to these rocks they cling with their sucker-like mouths and are easily caught. One of my informants combated the statement that the *kanakana* lived

on whitebait, saying that its food was the *kohuwai*, a green mossy growth which adheres to the rocks.

The most famous of the spots where the Maori assembled every October and November to catch the lampreys was Te Au-nui (Mataura Falls). Only certain *hapu* (families) had the right to fish there, and each family had a strictly defined *pa* (fishing spot), the right to which had been handed down from their ancestors. The names of some of these *pa* were (1) Wai-kana, (2) O-te-hakihaki, (3) Rerepari, (4) Mataniho-o-Hukou, (5) Mupuke-a-Rahui (6) Otautari. The names of the others are forgotten.

The falls on the Pomahaka River named Opurere were also a celebrated *kanakana* fishery. An old man tells me that the people used to go there every October and November, and after catching all they could they would return to their homes to plant potatoes. There were six *pa* (fishing-allotments) at Opurere, and, beginning from the south side, the names were (1) Mataniho-o-Muka, (2) Tu-kutu-tahi, (3) Te-awa-inaka, (4) Patu-moana (this is a small island), (5) Rau-tawhiri, (6) Te Rerewa.

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Other places at which *kanakana* might be caught were Te Rere-o-Kaihiku (Kaihiku Falls), Hehetu a small fall where the Orawia runs into the Waiau, Waipapa-o-Karetai, on the Silverstream, and elsewhere.

It must not be thought that persons entitled to take the lampreys from a certain section of rock could proceed to do so at haphazard. It was a matter that had to be gone about with *karakia* (incantations) and due observance of time-honoured customs. Each of the falls was protected by a guardian *taepo*^{*} (spectre), and if a person offended against tradition, woe betide him. The *taepo* of the Mataura Falls was a magic dog. It was explained to me as a rock which stuck out of the water about where the Mataura Freezing-works are, and, although it looked like a rock at ordinary times, to one who was guilty of desecration it would miraculously change, and appear as an ogre possessing a dog's head, paws, and body, but with

a fish's tail. The luckless wight who saw it thus was doomed to disaster unless he could invoke powerful charms to ward off the evil.

The *taepo* of the Pomahaka Falls was also an uncanny thing to provoke. It frequented the tiny island known as Patu-moana, and took the shape of a giant eel. These spectres did not trouble those who proceeded to take the *kanakana* in the correct manner as prescribed by ancestral usage.

To supplement what the Maori told me about the *kanakana*, I may add that the late Mr. N. Chalmers, of Fiji, writing to me in 1910, said, "I reached Tuturau in September, 1853. This was in the *kanakana* season, and I was much interested in the way in which the Natives caught the lampreys. On the top of the falls there are—or were at that time—three large potholes about 6 ft. deep, and full of stones. These were cleared out and strong stakes put in each; then as the *kanakana* came crawling up and clinging to the rocky wall of the falls the Maori, leaning on the stakes, reached out their hands and, grasping the fish, put them in the *korari* eel-pots handy. It took them only about ten minutes to fill one pot, when another took its place. The superstition of the Maori is very marked, for Reko told me that if an enemy or any one threw a firestick into the falls, then the *kanakana* would desert the locality; so, needless to say, I was very careful to avoid hurting their feelings... When I was at Hokanui in 1858 I had a stockman called George, a Sussex man, who came to the house one afternoon with a face as white as a sheet and swearing he had seen an eel at least a mile long at the Longford (now Gore). I got on my horse and went with him, and when I saw the phenomenon I was not surprised at his statement; for I saw a column of *kanakana* more than a mile long, swimming in a round mass exactly like a large eel, so beautifully were they keeping a circular shape." Mr. F. L. Mieville, who stayed at Tuturau in 1854, writes, "The natives were very good to us and supplied us with potatoes, also *kanakanas* much resembling leather with a strong flavour of train-oil—they were dried and very hard."

The Maori Dog.

The question of who introduced the Maori dog to New Zealand has aroused discussion at various times. Maori tradition says that some of the canoes which came here from Hawaiki A.D. 1350 brought dogs; but some people consider that the inhabitants of New Zealand before that time had dogs. Thus in the story of Kopuwai (one of the oldest legends in the South Island annals—it must be much over a thousand years

[Footnote] * ? *taipo*. Williams says *taepo* is not used by the Maori.—Ed.

old) we are told he had a pack of ten two-headed dogs. Be that as it may, we know that when the *pakeha* came to New Zealand they found Maori dogs extant. In Otago and Southland these dogs roamed the interior, living on the countless flocks of native birds that thronged everywhere. The animals made inroads into the runholders' flocks and were hunted down and exterminated. Some white men considered that these dogs were descendants of ones liberated by Captain Cook or of those that had got away from the whalers, but there is no doubt whatever that they were genuine Maori dogs. They had woolly hair, sharp-pointed noses, pointed ears, and never barked, the noise they made being a long, melancholy howl. According to European observers, some of these dogs were pure white, others black-and-white, and others fawn. The Maori called them *kuri*, and several places in Otago and on Stewart Island bear names reminiscent of these animals. Asked concerning these dogs, two of the old Maori said the *kuri* was usually of a black-and-white colour, and another old man said they were often reddish-tan. One said, "It had long hair, a bushy tail, a short, sharp nose, and a small head. They were very wary, but could be caught by tying up a bitch (*uha*) and leaving it, when the wild ones would come round it. These dogs were in New Zealand long before Captain Cook came, as our traditions show; but when they began to run wild I cannot say."

Another said, "The *kuri* was the Maori dog. The reason why one lot of Maori came to New Zealand was because some of them who were not high-class people stole a dog and ate it. Through this they were forced to leave Hawaiki. Before the *pakeha* came our people used to sometimes castrate (*whakapoka*) these dogs and then fatten and eat them. They had long hair, and their skins made fine mats called *topuni*, and rugs. When I was a boy I remember a fine *kuri* belonging to a native called Koati in Westland. It had a big body and short legs. A man named McDonald bought it as a curio for £2; but he tied it up and it jumped the fence and was strangled."

Another said, "I never heard how the *kuri* came to New Zealand. The skins were cut into strips and made into rugs. I once saw a *kakahu* (garment) made of them—it was a *taniko* cloak. Its colour was white and black, and some of the hair had been stained red with dye from a tree like the *miro* but whose name I forgot."

A shepherd speaking of wild dogs on Knapdale Run in 1858 said, "A family of red

ones seemed to frequent the lower flat, while those on the upper flat were yellow."

The question of the *kuri*, or Maori dog, still requires much investigation.

Lizards And Tuatara.

Having read that the Maori had a superstitious awe of lizards, I asked about them, but got little satisfaction. One old man said, "I know three kinds of lizards. The one which lives in the cracks in rocks is *karara-papani*, the greenish one is called *kakariki*, and the common one is *karara-toro-pakihī*. I know nothing of the *tuatara*." Another said, "The kind of lizard known as *mokakariki* was perhaps so called because its colour was like the plumage of a parakeet. The general name was *karara*. I have never seen or heard of *tuatara* down here, but I have seen a lizard about 2 ft. long. It was on top of one of the Hokanui Hills and, because I had had a bad dream the night before, I killed the *karara* with a big stone, lit a fire, and burnt it. It was the biggest lizard I ever saw. A wise old

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man told me afterwards that it was a good job I had killed and burnt the lizard and so stopped any evil coming to me because of my dream. Some of the old Maori used to eat lizards. You could tame them for pets so that they would come when their names were called and they would lie and sleep alongside you. One such pet, Te Horo-mokai by name, was kept at Motu-kai-puhuka (village near Kaitangata), but it was lost, and although it was seen later eating *tutu* it was never caught again." Another said, "*Tuatara* were down on Auckland Island, and Mrs. Cameron, of Riverton, got two from there. They had fins on their heads and backs. I reckon the Maori had been down there before the Europeans came, and had a look round but thought it no good and never settled there." My last informant on this subject stated that legend averred that at Mason's Bay, Stewart Island, some people saw *tuatara* eggs and broke them; the *tuatara* came after them and they killed it. The names of two small islets in Lake Wanaka commemorate lizards—viz., Taki-karara and Te Pae-karara. "Only the big kind of lizard was called *karara*" (see *Trans. N.Z. Inst.*, vol. 7, p. 295).

The Maori Rat.

Some people have expressed abhorrence of the idea of eating rats, but my Maori friends were careful to explain that the Maori rat was an altogether different creature from the filth-eating European rat. The Maori rat was a fruit-eater and a cleanly animal. One old Maori told me that once a party of white whalers was wrecked in the West Coast Sounds and walked overland. They were glad to eat the Maori rats, which were then feeding on the fruit of the *kowhai*, and were big and fat. "Long Harry," one of the party, told my informant that the rats were "very good." My informant added that some of these rats had hair like the opossum, and that the general name for the rats was *kiore*, but one kind was called *pouhawaiki*. Another old man said the Maori rat was not found on Stewart Island, although it was plentiful on the mainland. It was a fruit-eater, and was snared. An old song mentioned that Tawera, near Oxford, in Canterbury, was the best place to go if one wanted a feast of *kiore* (rats). A well-informed *kaumatua* (elder) said that the Maori rat was called *kiore-tawai*, and was once very plentiful. It was grey, but not like the colour of our present rodents. It would not eat flesh, but only fruit and berries. *Pouhawaiki*, he said, was the name of the introduced, or European, rat.

Near the mouth of the Molyneux is a bank called Te Rua-koi, which I was told meant "a hole made by the rats." When they were fat the Maori would go and dig them out. My informant was certain that was the correct name of the locality, and that the getting of the rats out of their lairs was why it was so named. Another Maori, well versed in nature-lore, said he had never seen the Maori rat (*kiore maori* he called it), although a very old white settler had told him of seeing it many years ago in that district. According to what he had heard, this rat liked to live in mossy places in swampy ground. It made holes in the moss, and the nest was known as *rua kiore*. That this creature existed before the *pakeha* came he knew from tradition; also the ancient name of a creek near, Otaraia was Tapiri-*kiore*, which meant "two rats walking together." In fact, there were two creeks with this name. Leaving Poupoutunoa (Clinton) and going through the Kuriwao Gorge you come to Tapiri-*kiore-tuatahi* (*tuatahi* = first), and then to Tapiri-*kiore-rahi* (*rahi*= big). Then you cross Te Kauaka-o-Waipahi (the ford of the Waipahi), and go on to Te Au-nui (Mataura Falls).

The pioneer runholders on the Waimea Plain found "futtahs" (*whata* = storehouse) left by former Maori inhabitants. These *whata* were erected on the top of two stout, high posts, each of which had a nick round it about 18 in. from the ground to prevent the rats from getting up to the provisions, so evidently the Maori rat had some sort of predilection for Maori food, notwithstanding it was reputedly frugivorous.

Settlers of the late "fifties" speak of the plague of rats that overran Otago, but I presume these were European rats. On the subject of the *kiore*, or Maori rat, like that of the *kuri*, or Maori dog, we could do with much more information.

The Mutton-birds.

The *titi* (mutton-bird) is a favourite item of food with Maori and *pakeha* alike. The edible qualities of this bird were, I was told, unknown to the Waitaha and Kati-Mamoe Tribes. It was the first two Kai-Tahu visitors to Ruapuke who discovered that the *pi-titi* (young mutton-birds) were good eating. Ruapuke was then uninhabited, and these two chiefs, Potoma and Rerewhakaupoko (two of the *titi* islands are named after them), visited it, and on the small adjacent island of Papatea saw *rua* (holes) and inserted their hands and pulled out the plump young *titi*. It is said that they preserved the mutton-birds and some human flesh in alternate layers in a *poha* (bag) made of *rimu* (kelp), and that those to whom it was given as a *kaihaukai* (gift of food) relished it exceedingly. This was, as far as can be ascertained, about two hundred years ago, and since then *he poha-titi* (a kelp bag) has always been the receptacle to hold these birds, fat being poured over the contents and acting as an efficient preservative.

A very old Maori said to me, "March is the season for mutton-birds, and I went after them many years ago although I have never been inland after *weka*. *Titi* was the general name for mutton-birds. but a small kind was called *koruri*, and there were other kinds whose names I cannot recall."

Another said, "There are three principal kinds of mutton-birds. The chief one is a black bird, and is simply called *titi*; another kind is black-and-white, and is called *titi-wainui*; and another kind is *titi-ariki*. This is a grey bird, and is very scarce."

Still another remarked, "I know no legends about the *titi* and its catching, killing, or preserving. A small kind is called *korure*, and the kind known as *wainui* is rather rare." This informant went on to say that some of the larger *titi* islands were divided into *manu*, or bird-preserves, for different families. For instance, on Herekopare Island there were five *manu*—viz., Te Tihi, Kuri, Te Upoko-o-Tamairaki, Hotunui, and Te Ahi-o-Pere.

There was evidently some etiquette observed about taking the *titi*, as an old and respected-Maori of the South received his name from the following circumstance. It was the rule that one party arriving on an island before the other parties entitled to do so should wait until the arrival of all before starting operations. In this case the first party caught some birds at once and were roasting them when another party came. High words led to blows, and my informant's mother joined in the *melee* with a *kohiku* (a skewer or stick used to roast birds before a fire), and in consequence when he was born a few months later he was called-Kohiku Titi.

I was told that the general name for the islands round Stewart Island was Mai-kai, meaning that they were places to come to for food. (Perhaps this name should be Mahika-kai.)

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Eels (Tuna).

An old Maori said to me that there were three kinds of eels that he knew. The *horepara* is a light green, with white belly and white underjaw, and is good for eating. The *rokehe* is a) black eel, with big head, strong jaw, thick skin, and does not taste very good. Owing to the thickness of its skin another name for it is *kirirua* ("two skins" or "double skin"). The *tunapou* is still bigger in the head than the *rokehe* and tapers to a very small tail. It has the same kind of skin as the *kirirua*, and is not eaten by the Maori but thrown away when caught.

All or nearly all fish spawn in salt water, may informant thought, but he was not so sure of eels. Lots of eels are cast up on the bars at the mouths of rivers, and the old

Maori would say these were aged breeding-eels, which were done. It was only breeding-eels which came down to the sea and then went back up the river. When they came down to spawn you would not see them unless they were cast up on the beach. This was about June. You could catch them in the rivers from August to May, but not many in the latter month, as it was too cold for them. In the town of Wyndham there is a lagoon called Pipi-a-Manawa, and it is fed by a spring called Matatiki, and he remembered old Tangatahuru-huru telling him this spring was a winter retreat of the *tuna* (eels). You could see the hole in the ground from which the spring came, and it was almost blocked with eels in winter, the reason being that spring water is warmer than river water. In the Otu Creek just before it enters the Mataura River there is a hole which is another winter resort of the eels. They used to congregate thickly in that spot, and if you threw in a stone they would swarm out in great agitation. There was a season for catching everything, continued the old man, but eels could be caught the whole year round in some places, although from a food view the best time to catch them was from Christmas-time to February, as the flies were not so bad then, and the eels could be dried (*tauraki*). Hang them up for three weeks, then put in *aumu* (earth-oven), cook, and put into a *poha* (kelp bag), which can be bound with *totara* bark and flax, and there you have your delicious eel-flesh preserved for an indefinite period.

Eels from the rivers, continued my informant, are not so good as those from the lakes, as the flesh is not so firm. The eels in the lagoons were all right if one just wanted a few eels for daily use, but there were not enough eels in the lagoons, as a rule, to make it worth while to fish for them for preserving purposes. The lakes known to the Maori as Roto-nui-o-Whatu and Kaitiria—but now called by the white settlers Lake Tuakitoto and Lake Kaitangata—were great eeling-places, but to be truly successful one had to be careful to say the right *karakia* (invocations) before starting operations. The eels were usually caught in eel-pots (*rohe-wainui*), the basket or cage part of which was called *hinaki*. A smaller kind of eel-pot, called *hinaki-kanakana*, was used for catching *kanakana* (lampreys); and, strange to say, eels will not go into this, and, *vice versa*, *kanakana* will not go into the ordinary eel-pots. There was one kind of net to catch one size of eel, as a rule, but there was another mesh which could be used to catch all sizes. Eel-pots were sometimes made of flax in the South, as it took a lot of work and manipulation to make them of the *toraro* vine.

All the foregoing information was from one man, but I have still three further notes. One man said, "At Manawapore (Upper Mavora Lake) there is a stone eel-trap. Old Rawiri told us, if we went there, to block

the end, to lift the stone and take out the eels, then go up forward and lift the next stone door and take out more eels. It is a very old trap, and is partly natural and partly made."

Mr. James Cowan collected the following note from southern sources: "At Little Mavora (Hikuraki) there is an artificial stone *hinaki* with a door for eels to get in. It was built by the old Ngati-Mamoe" people—they put a stone cover on. The two notes evidently refer to the same "stone eel-pot," but its discovery has never been reported by white men.

Another old man speaking about eeling said, "A fine place to get eels is at Miki-oe, near Dr. Menzies' old run, near the Mokoruta River, now miscalled Mokoreta. It is a spring and creek where the eels go in the winter-time because the water is warm."

A large number of place-names in Otago and Southland perpetuate the ancient Maori love for the toothsome *tuna*. There are a number of places called Kaituna and Waituna (eel-stream), one of the latter being in the West Coast Sounds region. A lagoon near Gore is called after a man, Tunarere; and Taieri Lake, in central Otago, was named after a chief, Tuna-heketaka. Of nomenclature which does not bear its significance on its face two names occur to me. A tributary of the Waiau is Kaipurua Creek, and I was informed the name meant a pair of eels eating at one bait or "two eels on one bob." Murikauhaka was an ancient village at the old mouth of the Mata-au (Molyneux), and I was told the name means—*muri*, "the end"; *kauhaka*, a hole in a bank where an eel has its quarters."

The figurative name for the Canterbury seaboard is Ka Poupou a Te Rakihouia, because that chief, over a thousand years ago, erected posts and built *pa-tuna* (eel-weirs) at the mouths of the rivers. These weirs were continued until comparatively recently, but I have no description of them as yet.

Mr. F. L. Mieville, writing of his experiences with the Maori in Otago in 1853 and 1854, says, "The Maoris have a very good way of cooking an eel. They clean it, but do not skin it. Like them, I now think it is a great mistake to skin an eel. Next they impale it with a stick pointed at both ends, running it through from the tail to the head. The stick is then stuck slantingly into the ground close to a good fire, and

when one side is cooked the other is turned. The eel is then served up—*i.e.*, the stick is placed upright in the earth amidst seven or eight Maoris, and each one pulls off a bit with his fingers."

The Small Fry.

The season for whitebait (*paraki*) was October and November, said an old Maori wise in these matters. The *patete* was another kind of whitebait, and was good, to eat after it leaves the sea, but as it proceeds up the rivers inland it picks up stones and gets rubbish inside and is then no good for food. *Waharoa* (long mouth) was a big kind of whitebait. You could catch it with a hook baited with a worm. It had bones and its flesh was coarse. *Mata* was the very small whitebait, and it was caught with Maori nets (*kaka*) which were sometimes a chain long. *Inaka* is the name of the little minnows—they are black, with white bellies. My informant reckoned they came down to the sea to spawn, as Wai-whakarara, near the mouth of the Molyneux, was a great place to catch them. If not caught before spawning they were no good, and would go up the river again in long columns, leaving the water white with spawn at the mouth of

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the river. The name of the crabs in inland creeks is *papaka*, and of the crayfish *koura*. "The native trout, known to the settlers as cockabully, is called *kokopu*, and the mountain-trout is called *kokopara*," said my informant, adding, "both these fish are various-coloured, but they are of different shapes."

Another of the old men said, "The correct name of the cockabullies is *kokopara*. They are still to be found in the creeks at Stewart Island." In the early days of Otago settlement the name of this fish was spelt "kokobula," or sometimes "cockabulla." I have a note, "Mata-inaka was a lagoon near Waikouaiti where the Maori got very small whitebait; hence its name." A fish called *puaihakarua*, which was caught in some streams, I have no particulars of, nor of a small fish called *ikamaru*.

Sea-fish.

An old Maori said to me, "Our name for the barracouta is *maka*, and the proper name of the place the white men call Titri is Kaimaka (to eat barracouta). We caught these fish with a rod (*matere*), using a jigger (*pa*) worked with string (*tau*). When the flesh of the *maka* was preserved by drying it was called *moe*. The jigger was made of wood, and whenever possible of *towai* wood. One of the best places in Otago to get this kind of wood was at a bush called Oreheke, north-west of the Tapuaenuku Range—now called Tapanui—and near the head of the Pomahaka River. This bush was full of *towai* timber. On days when you cannot see a barracouta, and you are getting no bites, use a *towai* jigger and you will get plenty of fish. The reason for this is because a particular bird once settled on this tree; but I do not know which bird it was, nor the story about it."

Another old Maori, in speaking of sea-fish, said, "We called the blue cod, *rawaru*; rock-cod *moeanu*; red cod, *hoka*; ling, *rari*; soles, whose jaws are more bent than flounders, *horihori*; butterfish, *takakaha*; white-fish, *tarakihi*. The name of the falls in the Owaka River near the township is Taheke-*aua* (Mullet Falls). The reason of the name is that the mullet (*aua*) ran up the river from the sea until stopped by the falls, and that was a great place for catching them." A stream near Taieri Lake was Te Awa-kai-*aua* (eat mullet), but I do not know why it was so named.

I have a note, "At Moeraki the fish principally caught are *hapuku* (groper), *rawaru* (blue cod), and *mangaa* (North Island name of barracouta)," but I am sorry I omitted to get details of ancient fishing methods or of the huge flax nets of pre-European days.

Seals and Sea-lions.

In regard to the larger denizens of the sea, the southern Maori name for seals generally was *pakake*; the fur-seal was *kekeno*; the porpoise, *terehu*; the sea-leopard, *rapoka*; and the sea-lion, *whakahau*. A number of place-names in the South reveals the Maori interest in these mammals, such as Whakawai-pakake (to entice seals), Tangi-pakake (when the mother seals were killed the young ones would *tangi* and shed tears), Ara-kaki (the path of a female seal), &c. One old man said, "The two hind flippers of a seal are called *ka-kautaua*, and two rocks near Ruapuke are called this name because of their shape." Another said, "The bight below Lord's River, Stewart Island, is called Pupuri-kautaua (Hold on to the flipper) because here a chief named Kahu surprised a *whakahau* (sea-lion) and caught hold of its flipper and held on till his men could kill it. He

was a big, powerful man, but it must have been a young *whakahau* or he could not have held it." Another narrates that when a boy he copied some white boys and made bow and arrows, and he got into sad trouble for shooting an arrow into a *poha* of *kekeno* flesh suspended to the roof. The *poha* was opened, and he says the seal-flesh made good eating, although fat. The Maori method of killing the seals, &c., is said to have been by clubbing, but more particulars would be welcome.

Whales in the South were called *kewa*, and the traditions frequently mention them, chiefly as miracle-workers; but the Maori would occasionally find stranded whales, when they would enjoy a course of whale-flesh.

Bird-hunting.

So much has been written about the sparing and catching of birds by the Maori that the collector will not say much on the subject except to add a remark or two made by, the old people.

The southern Maori trained their *kuri* to catch birds such as *weka*, *kakapo*, and *tokoeka*. The last-named bird I was told had big "paws" (toes) and was able to kick the dogs, so there was a certain knack in catching them. In catching woodhens (*weka*), the art, as I understand it, was for the huntsman to entice the woodhen near enough for the dog to seize without letting the bird *whakakeokeo* or alarm the rest. *Keokeo* is the short sharp cry of the *weka* when alarmed, and to prevent it the hunter would *turutu*, or imitate the cry of the bird, and so coax it quite close, when the dog would spring at it; but not many of the present Maori have been *weka-catching*. *Weka* were also captured with a noose.

Wild ducks were snared in the creeks with a flax net or snare, called the *kaha*. I was also told that a Maori who was a fast swimmer could catch moulting ducks, which in common with unfledged young are called *maunu*. An old and respected white settler tells me that in 1859 he was invited by the Maori at Henley to take part in a "duck drive" on Lake Waihola. They started out at daybreak in canoes and dug-outs, and rounded up great numbers of young and moulting paradise ducks unable to fly. They ran these *maunu* into a corner and slew them with

waddies. They returned in triumph to the "kaik" with six or seven hundred birds, cleaned them, and hung them up in rows, to be subsequently stored in the *whata* (food-storehouses). My informant added that one of the best feeds he ever had was an eel taken out of the *whata* one day he chanced to call.

Ducks, said one of my informants, were caught in long nets, into which they swam, and the more they struggled to withdraw their heads the tighter the mesh became on their necks. He had never heard of the Maori swimming under the birds and pulling them down by the legs, as was done in some parts of the world. There was no need to do so, as they were so plentiful, and they were very tame and would come close to you. There were no guns to scare and make them afraid and wild, and all the killing of them done by the Maori was done quietly and orderly.

Another said that the place-name Pomahaka should be Pou-mahaka, meaning posts to which the snares for catching ducks were attached.

The season to catch *weka*, said one old man; was from April to July, when they were fattest; after July the birds became thin. Sometimes the Maori would go out at night and blow (or *whakataki*) on flax held between the lips. If two *weka* had been answering each other this call would bring them. Two birds calling each other were called *puhuka*, or

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weka-puhuka. The call of the male bird was slow—*tore, tore*—but when the call was quick and agitated—*tore, tore*—that was the female bird. The former was called *toa* (a *toa-tautahi* was a fat male *weka*) and the female bird was called *uwha*.

I have a further note to the effect that there is a kind of woodhen on the islands round Stewart Island known as *miuweka*.

One of my aged friends said he could go into the bush and get *kaka* by the drinking-trough method, or the rush-hut and decoy-bird method, or by the aid of ordinary *manuka* spears. He could get *tui*, pigeons, parra-keets, &c., in the same

manner; there was no fuss, and no one need starve if he knew the bush-lore. I neglected to get fuller details from him, but hope to do so later on.

Experiences of Weka-hunters.

Winter being the best season to catch the *weka*, the parties who went inland then sometimes had rough experiences. I was told of one tragedy of the long-ago through this cause. A man named Weka, his wife Nuku, and their two children set out from Tuturau up-country on a *weka*-hunting expedition. They camped on the hill on which East Gore is now built, and here the woman busied herself gathering *taramea* (spear-grass) from which to extract scent (*kakara*). Resuming their journey, they went to Nokomai, but much to their disappointment the *weka* were scarce, so, under the shadow of the mountain called Karu-a-hine, Weka made a *pahuri* (shelter) for his wife and family while he went on to Kimiakau (Arrow River) and Kamuriwai. (My informant said, "Kamuri-whenua is the *pakihī* (plain) from Oamaru to the Waitaki but not across that river, while Kamuri-wai is the *pakihī* near Foxe's (Arrowtown) on the Arrow.") This was a noted *weka* ground, and he had fair success and started to return, but was delayed several days by a violent snowstorm. He crossed the Kawarau on a *moki* and struggled through the deep snow to Nokomai. There was no trace of his wife and children, but when the snow melted a bit he found their dead bodies. With some difficulty he buried them and sadly came down-country. Camping on the hill between the Mataura and Waikakahi (Waikaka) Rivers, memories of his wife gathering the *taramea* came over him and he composed a song, which is still preserved. From this circumstance the hill is called Onuku in memory of her. Weka continued his journey to Tuturau, where, it is said, he died of grief shortly after.

Another aged Maori told me of a party, among whom was Rakitapu, his informant, who went *weka*-hunting, their objective being Okopiri, a wooded gully north of Heriot, I was told. There were no runholders there then. The party were on the Otuparaoa Mountains one fine moonlit night, when all of a sudden snow came on. It proved to be an exceptionally heavy fall, and the *weka*-hunters had a rough time. That snowfall is now known traditionally as Kaipahau, a name which implies that the party, or such of them as sported whiskers, ate the snow off their beards. It was in July, the month that the *weka* are fattest, that this great snowstorm occurred.

A noted place for getting *weka* was Mikioe, up the Otamatea (now called Otamita, or Otamete) in the Hokanui Hills. Here there was a clump of *mikimiki* shrub, of the berries of which the *weka* are fond. I was told that *miki* meant the shrub and that *oe* denoted the shedding of its berries or leaves. My informant once saw some *weka* so eager to get the berries that they had clambered on to a matted mass of *mikimiki* and were perhaps 2 ft. off the ground. The sight interested and amused him.

It is said the Maori named the woodhen from its cry, “*we-ka, we-ka*”; but a European who is well acquainted with the birds renders this cry as “*kea-week, ka-week*.” This is just another illustration of the difference between Maori and *pakeha* ideas in regard to onomatopoeia.

The Weather.

The foregoing accounts of the rough weather sometimes experienced by the Maori in winter afford an appropriate opportunity of giving some stray remarks made to me by the old men. One said, “Our word for spring is *kana*; summer, *raumati*; autumn, *kahuru*, a word meaning ‘ten,’ or ‘plenty’; and winter, *makariri*, which means cold. The old people did not like the winter. If snowflakes came they would shiver and say ‘*Kai te oka te huka*’ (The snow is falling). We used the word *huka* for snow generally, *huka-wai* for snow and rain or sleet, *huka-taratara* for hail, *huka-nehunehu* for fine dry snow, *huka-kapu* for flakes of snow, *kopaka* for ice, *ua* or *awha* for rain, and the name for frost I cannot recollect.”

Another said, “The mountains north of Gore are called Te Rau, and when the natives of Murihiku heard thunder from the north or north-west they said that was Te Rau praying for snow, and if the thunder was from the south-west they said that was Hautere (Solander Island) praying for snow.” My informant added that he had heard the green *tui* or *koparapara* chattering that morning, and that this was not a good weather sign. The *koparapara* is the bell-bird (*korimako*, or *makomako*, in the North). The Maori also foretell the seasons by observing trees and plants, but I have no particulars of this.

Maori traditions tell of great floods in the Aparima, Mataura, and Clutha Rivers, and debris was found by early white settlers at a height which has never been approached since. A vast flood in the Clutha is known as *Wai-mau-pakura* (“Water which carried the swamp-hen”—so called because it swept many nesting-birds out to sea), and at the recent Rivers Commission the date was surmised to be 1800. The question arises, Was the climate wetter before European settlement?

Birds.

My Maori friends did not have very much to say about the avifauna. One remarked, "In days gone by the bush swarmed with native birds; now we see scarcely any. We had the *kakaruai* (robin), *miromiro* (tomtit), *titakataka* (fantail), *tatariki* (canary), a very small bird without a tail called *titiripounamu* (rifleman), *kakariki* (parrakeet). We had a black bird with red wattles, *koka* (native crow), and a bird with a yellow-mark over its back, *tieke* (saddleback). Both these birds had beautiful notes—they could whistle like a man. Then we had two birds which came only in the summer, the *pipiwharauroa* (shining cuckoo) and the *koekoea* (long-tailed cuckoo)."

Another said, "Our name for the *tui* was *koko*. Away behind Seacliff Asylum there is a bush called Potae-rua, and a creek there is Waikoko (Tui Stream). Our trees fruit about six weeks later than the North Island, and the *tui* are fat in April and May. A man could hit them with stones [sic] and fill his basket; hence the name of that place. A ridge between Waikaro and Te Akaroa, near Measly Beach, is Paekoko, which means 'the *tui's* resting-place.'"

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One of my old Maori friends went to the Wakatipu diggings in 1862. He says, "When in Moonlight Gully my dog caught some big moreporks in the rocks there, and we called the place Kohaka-ruru (nest of more-porks). These birds were not the small bush-owls known as *ruru*, but the bigger open-country ones known as *ruru-whenua*. They were big and fat, and when cooked the whole party ate them, and they tasted so good that even the white men smacked their lips over them." I have never heard of the Maori eating owls except this instance, it being generally supposed they regarded the bird with a good deal of awe. A place-near Colac Bay is Ruru-koukou ("the cry of the morepork"—*ruru* being the bird and *koukou* its call).

In securing Maori nomenclature I ascertained that many place-names in the South are reminiscent of birds. The native lark is *pioioi*, and the name of Dunback

Hill is Te Awapioioi; the native quail was called *koreke*, and a range of hills between Milton and the sea is Whatu-koreke; the kingfisher is *kotare*, and a hill near Nuggets Point is Taumata-kotare; the teal duck is *patake*, and a creek near Invercargill is Te Awapatake; the seagull is *karoro*, and an island in the Mataura River above Gore is Pokai-karoro; the parrakeet is *kakariki*, and a place near Charlton was known as Pokai-kakariki, while a beach near Fortrose is Kakariki-taunoa; and so on.

One of the aged men said to me, "There used to be a small bird at Roto-nui-a-Whatu (now called by the white people Lake Tuakitoto). It was about the size of a redbill (*torea*), and had a white breast and a black back. We called it *pouakakai*, but its European name I do not know."

The common name of the swamp-turkey in the South was *pakura*, and a swamp near Balfour was called Kai-pakura (to eat swamp-hens). The bird was also called *pukaki* because of a habit it has of stretching up its neck when alarmed and so bulging its throat. The North Island name of this bird is *pukeko*, and how often has one heard it said, "Look at those awful Southerners massacring the beautiful Maori language ! Fancy them corrupting the word *pukeko* into *pukaki*!" This is not so; it is only one of the numerous instances where northern and southern names differ.

The native pigeon is a celebrated bird in southern estimation. My Maori friends laid great stress on its connection with the story of Maui. It is commonly called *kereru*, but is also known as *kukupa*. When Maui was a boy he went down into the underworld to find his father, and he painted his mouth and legs red and put on a white *maro*, or kilt, and transformed himself into a pigeon. One of my informants said, "The white on the breast of the *kereru* is the napkin, or *maro*, Maui was wrapped in as a babe." Maui in the shape of a pigeon flew on to the handle of the *ko* (spade) of his father, who spoke to the bird; but all it could do was to nod its head and answer, "Ku, ku." Any one familiar with the bird knows the way it wags and nods its head—this is in memory of Maui—and all it can say is what Maui answered his father, "Ku, ku."

Speaking of Maui reminds me that legend says it was the mirth of the *titakataka* (fantail) which caused his death. One of the old men said the word *titakataka* meant "flitting about," and the bird was so named because of its restless disposition. The correct name of Akatore, in Otago, is Aka-torea, and it means "the harbour of the redbills (or, oystercatchers)." The North Island form of the name would be Whanga-torea. The southern Maori used the ordinary *manuka* to make bird-spears, and I have a note that the clump of *manuka* called Pokai-kakariki, near Charlton, was celebrated in this connection.

The Moa.

As a rule, my informants frankly admitted they knew nothing about the *moa*. One man, however, said the last *moa* was killed on the Waimea Plains about five generations ago, and gave some very plausible details. There is just a possibility that one of the smaller kinds of *moa* may have survived long after the big birds became extinct, or that a very large *kiwi* was killed, but I do not place absolute reliance on the tradition.

One man said, "Just a few chains below the Mataura Falls is Te-kohaka-a-moa (the nest of the moa). It is a round depression on a flat rock, and the old people thought it resembled a *moa*'s nest. They also found *moa* bones about it. Near Clinton is the hill Te-kohaka-a-pouakai (the nest of the *pouakai*). The *pouakai* was one of the kinds of *moa* that lived in this land. A small sea-bird is now called *pouakakai*: but do not mix the name. The *pouakai* has not been seen for many generations; the *pouakakai* is quite common yet." From this it appears that the southern Maori recognized that there were different species of *Dinornis*.

The late Tare-te-Maiharoa, than whom there was no greater authority in recent years, was positive the *moa* was extinct when the Maori came, a.d. 1350. They were killed out in the South Island by the Waitaha, who called the birds *pouakai*. The name *moa* was given by the latest comers who saw the bones lying about. "The Moriori of the Chatham Islands," said Tare, "were related to the Kati-Mamoe, but left New Zealand very long ago."

This accounts for the *poua* bird of Moriori traditions. It is simply the *moa* of New Zealand, which was probably on the point of extinction or already extinct when that people left this country. The last Maori note I have on the *moa* runs, "I have heard a song which says the *moa* was killed out by *karakia* (*tau-whaka-moe-tia*) because it was a dangerous bird, but how long ago I cannot say."

Insects.

I understand that the question has recently been raised whether the flea was brought into New Zealand by European ships. I did not know of this inquiry in

time to ask my Maori friends what they knew of the matter, but may say that on Ruapuke Island there is a place known as Te Awatuiau (Flea Channel). Shortland in 1843 said *tiau* was the southern name for the flea, the northern name being *puruhi*. One old man noticed a statement that the Maori name of the mosquito was *waeroa*, and said to me, "Its name in the North might be *waeroa*, but in the South it was always known as *keroa*." Noticing some insects as I was conversing with an old Maori, he supplied me with the following names: "Our name for the bluebottle-fly was *rako*, and for its eggs and maggots *iro*. Spiders were *pukau-were-were*, and grasshoppers *tukarakau*. The daddy-long-legs' name was *te tatau-o-te-whare-o-Maui* (the door of the house of Maui), but I do not know how it got this name. A green kind of butterfly, a sort of cricket, was called *kikiwari*, while the black and spotted butterflies are *mokarakara*. [He pronounced this *mokalakala*.] Then we used to have *peka-peka* (bats) in plenty, but I have not seen any of them for a long time." The sandfly was called *namu*, and there is a place near Waiau mouth called Kai-namu (eat sandflies) because these pests were so numerous as to get into the mouth with the food that was being eaten. I have a further note that in the South the name of the ant was *upokorua*.

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Mushrooms.

One of my informants said, "One of the raids made by the southern Maori northward is called Kai-whareatua. It is not the name of a fight but of a war expedition, and Tare Wetere te Kahu was in it. The Southerners had gone up to fight the North-Islanders and were returning, when they ran ashore, and were wrecked at the mouth of the Rakitata River. In the capsized all the food was lost, and the party found mushrooms and ate them. Hence the origin of the name Kai-whareatua (eat mushrooms). The word *whareatua* means a 'devil house' and that is the old Maori name of the mushroom." Another old man remarked, "Tare Wetere was in the Taua-iti raid on Te Rauparaha, but I do not think he was at the Kai-whareatua raid, as, according to my information, it was before his time." This opens up the interesting question, Were mushrooms indigenous or introduced? I consulted a lot of New Zealand works without result, and I asked old settlers. One

says that probably mushrooms were native, as they were to be found in the early days among the tussocks in the backblocks, but others consider that they will not grow without horse-manure. This belief *Chambers's Encyclopaedia* classes as unreliable, and says that mushrooms were found growing over nearly all the world a very fine edible variety being native to Victoria, Australia. If this be so, why not in New Zealand? It is said that although the North Island Maori have plenty of names for fungi growing on trees they have none for field fungi—at least, so I understand. I therefore interrogated my aged Maori friends in the South, with the following results:—

“Yes, there were mushrooms, but I forgot their names.”

“The name of the mushroom was *whareatua*, but I cannot say if they were here before the *pakeha* came.”

“Mushrooms were not here all the time. You could see them only in their season. Their Maori name was *whareatua*.”

“There were three kinds of mushrooms. One was very small and thin in the bush and was called *harore*, and the others were called *whareatua* and were all sizes up to almost as big as a hat. One of these kinds was good to eat. Another thing like mushrooms was called *weho*, and was also good to eat. They all belonged to the ground. The Waitaha people brought fern-trees and fern-roots to eat, but no one brought the mushrooms. Another thing to eat came out of the ground after thunderstorms. It was called *poketara*. You would come out in the morning and see it. It was a round-like ball, and sometimes almost as big as a small football. It was wonderful how it grew so quickly. It had to be eaten at once—after a day it was no good. It could be cooked on the fire and tasted like a mushroom.”

“The *whareatua* was a mushroom on a long stalk and with a deep body. I am not sure if it was here before the white people. The *poketara* was a big, round thing, a sort of mushroom, but it had no opening; it was all covered. It lasted only a short time, and then it would go into dust. I do not know the history of the raid known as Kai-*whareatua*.”

“*Whareatua* was the name of the mushroom. I do not know who brought them to New Zealand, but they were all over the country. They were like an umbrella in shape, but in late years I have seen what is a new sort to me, with thick stems and bunched tops, and for which I know no name. It is said the *poketara* comes down in thunderstorms. It has no opening at all, and is white and round. When it becomes old the stuff inside turns into a powder and blows away. It sometimes grows as big

as your two fists together, but some remain quite small. There was also a small, round thing about the size of your thumb, white or somewhat darker. An old fellow said it was good to eat, but I cannot think of its name. I once tried it. I placed it in a *whena* (roll) of bush flax and cooked it in an *umu* (oven). It had no taste, and was soft like a jujube."

This represents the information I gleaned about fungi. The/*poketara* is possibly our "puffball," but that, and other queries, is now presented for discussion.

Fern-trees and Fern-root.

Mention of the southern Maori eating mushrooms leads me on to the question of how they wrested an existence from Nature, whose moods are sterner down here than in the more enervating North. They say the *kumara* did not flourish farther south than Banks Peninsula, but a northern opinion that they must have subsisted mainly on fern-root and fish did not meet with the approval of one old Maori, who told me that by the system of *kaihaukai* they could exchange *titi* (mutton-birds) and other things for *kumara* from Canterbury, and even get *taro* and *hue* from the North Island. In regard to the natural products of Otago he said, "We had different kinds of fern-trees. The *mamaku* was not in this district, although it was over on Stewart Island; but we had the *poka*, *wheki*, and *katote*. The leaves of the *poka* are white underneath, the *katote* leaves are green on both sides and softer, while the leaves of the *wheki* are very rough and its stem very black. The *aho* (heart) of the *katote* is good to eat, but that of the others is bitter. I remember that three of us had a good feed of the heart of a *katote* at Opiriao (Sandy Bay, near Catlin's). Perhaps *katote* heart might make good jam—it had a sweet taste.

"Our name for fern-root was *aruhe*, and the leaves of the fern were called *rau-aruhe*. I remember once, at the south end of the Koau on Inch-Clutha, at a place called Pekeihupuku—the *ihupuku* was a big kind of seal and *peke* means its shoulder—eating fern-root. It was during the big flood of 1868, and we went back to the reserve and got fern-root and beat it on a big stone with a piece of iron. In the old days it was beaten with sticks and wooden clubs. When it was mashed we picked out the fibres and ate the rest, and it tasted good. It used to be mixed with

whitebait, these tiny fish being beaten into it; the name of the resulting mash was *kohere-aruhe*. Mr. Hay, an early settler, used to eat fern-root occasionally, both when he was among the Maori and at his own home."

Relative to eating tree-ferns, one of my informants related, "In the whaling days the brig 'New Hampden' was wrecked at the Bluff. She was known to the Maori as 'Kai-mamaku' (to eat fern-trees) because once she ran into Te Ana-hawea (Bligh Sound) for shelter, and, food becoming short, the crew went ashore and cut some *mamaku*, which they ate."

Some localities were renowned for the excellence of the fern-root growing there, one such place, I was told, being Pau-upoko, near Port Molyneux.

Various Foods and Drinks.

The old Maori who spoke to me about fern-trees and fern-root continued, "But we had another vegetable food too, and that was the *kauru*, the cooked root of the *ti* (cabbage-tree). Sometimes these trees had a side shoot, and that was the proper *kauru*; when it was taken the tree did not die, as it did if its root (*more-ti*) was taken. If the *kauru* you were eating

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was called *more-ti* you would know it was from that root only. Sometimes the people would leave a bit of the root in the ground and in a few years another tree would grow in its place. The root could be cooked at an open fire or in an *umu* (oven). In the old days the *umu* in which the *kauru* was baked was often called a *puna-ti*, *puna* meaning a hole and *ti* being the cabbage-tree. It would cook quicker at an open fire, and its rough skin prevented it from charring, but it did not taste its best unless placed in an *ipu* (basin) and soaked in flax-honey (*wai-korari*). Or the *kauru* could be taken and laid flat, and the flax-honey dripped on it, when it would absorb it. Then if you were travelling and were thirsty you could up-end your *kauru* root and let the moisture trickle down your throat. This was called *unu-wai-korari*, and it was a good sweet drink.

"Another food of the ancient times was prepared like this: Secure some kelp (*rimu*), the same as that dried for the *poha-titi*, and take it up-country to a place where *tutu* is plentiful. Gather *tutu* berries and put them in a *putoro*, a small flax bag very closely woven so that the seeds of the *tutu* cannot get through. Squeeze the bag, and the juice comes through and forms a good drink, called *waitutu*. Take an *ipu*, or wooden trough, put the kelp and *tutu* juice in it and boil by putting hot stones in. You can tell that the kelp is boiled enough by poking a stick into it and it falls to bits. Leave it till it is cold, and the result is a black-coloured jelly, called *rehia*, which was often eaten by the aid of an *akapipi* (mussel-shell).

"*Waitutu* was a good refreshing drink, although sweet. I remember once at Tuturau another Maori and I had a good drink of it. We held the *putoro* over our heads and wrung them and let the juice drop into our mouths. I never heard of any other drinks among the old people except *waikorari*, *waitutu*, and water. Besides the foods I have described we had berries of various kinds, such as the *hua-kotukutuku* (fuchsia), which were eaten raw, and *mako* berries, which came in their season. I also remember long ago eating snowberries in the Hokanui Hills. I think our name for them was *tapuku*."

Near Colac Bay is a small lagoon called Okoura, and I was told it was named after a man who was killed there. Bulrushes grew in the lagoon, and their roots were gathered and eaten with the flesh of Koura. Bulrush-roots were called *ko-areare*; they were mashed and formed an article of diet with the old-time Maori.

An old Maori said to me, "In the North Island the fuchsia-berry was called *konini*, but down here both tree and fruit bore the same name—*kotukutuku*."

I have a further note that a berry which grows in swamps is called *te rerewa*, but I cannot say if it is edible.

The Tuturau Reserve.

Recently I was at the Tuturau Maori Reserve to see my old friend Mrs. Gourlay (Toki Reko) laid to rest in the burial-ground there. That evening Mr. Gourlay, a European, a keen observer of nature, told me some of the methods he had seen the Maori at Tuturau adopt in getting food. He has been fifty years in the district, the last forty-five of them in his present location, and following is a summary of his information.

In rain or high winds the pigeons kept low in the bush, and the Maori speared them with bird-spears made of *manuka* or *horoeka* (lancewood). The end of the spear was sharp-pointed and burnt hard, and seemed to go right through the birds if skilfully thrust. There was nothing attached to the spear.

Ducks were snared by placing nets across streams at the height to intercept the birds' heads as they swam along. One morning Mr. Gourlay saw a duck and all its brood caught in one. Some years ago he got his wife to make him an old-fashioned net for snaring ducks, and it was quite efficacious. There was no fuss nor worry with the snare—the gun was simply not in it with the noiseless net.

The Maori used to go down to the swamp at Menzies Ferry and catch *matuku* (bittern) by laying snares for the birds' feet on the paths they had made through the rushes. The bitterns made a booming noise at times, and the Maori said the birds did this when catching eels. The Maori caught *pukuki* (swamp-hens) in the same manner.

He had never seen, or heard of, the Maori catching *kotuku* (white heron), as that bird was so rare, but it could no doubt be caught in the same way as the bittern.

Snares were also laid on the feeding-flats of the paradise ducks at certain times. When the birds were moulting and could not fly the Maori would get into the swamps after them and run them down.

He had seen the Maori catch *tui* by covering a pool with branches, leaving an open space for the birds to drink. Snares were set round this open place and *tui* aplenty were bagged in a good season.

To catch *kaka*, a square, 8 ft. by 10 ft., say, was thatched over, the fowlers waiting underneath with a decoy *kaka*. The cries of this bird brought many others, and as they settled on the corner posts the snares affixed thereto made them captives. These were not killed at once, but added to the collection below. The bird could gnaw through green flax, so their legs were fastened with dry flax amid an appalling din. When enough were caught the birds were killed and preserved in kelp bags. To save the fat for this purpose the birds were cooked in a wooden trough with hot stones. *Weka* were often cooked in the same way.

Various Birds and Fishes.

Weka (woodhens) were caught by the familiar red rag and snare method. The

snares sat still, and, as he caught each bird he bit the back of its neck to kill it and threw it behind him. This saved him wringing its neck, and was not only quicker, but it did not alarm or disturb the other birds.

The Maori also killed the *titi*(mutton-birds) by biting the neck. There was a knack in catching them. He had heard that these birds would tear your hands to pieces with their beaks and feet if you tried to wring their necks.

Kiwi were never at Tuturau, although they had frequented the Hokanui Hills. He had heard it said that the Maori would wait behind trees, and as the bird came pecking along he would hit it on the head with a stick.

By the Mataura River, in the South Wyndham Bush, there used to be a shagery, and he had seen a Maori bring away about two or three hundred young shags caught just before they were ready to fly. The big birds were too rank to eat. The Maori would not touch hawks—they were probably too rank also.

In regard to fish, the Maori caught *kanakana* (lampreys) in the river at Tuturau. They built a wing-dam of logs, stakes, branches, and scrub across the river, except for a few feet where the “pot” was. The dam was anchored with big stones and the material woven with flax so as to stand-big floods in the river. He had seen a “pot” 8 ft. wide by 3 ft.

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or 4 ft. deep, and when full of lampreys it had taken as many as six people to haul it out. It was made of fine flax, with vines as bows to strengthen it. This dam was quite close to the *kaika*, and during many years the people did not go to the falls at all, as they could get all the *kanakana* they wanted so handy.

He had seen a Maori put an eel-pot in the Upoko-papaii Creek and get as many eels as his horse could carry—probably 2 cwt. of eels. The Maori also caught eels with bobs (*mounu*). These were made by sticking strips of flax through rushes (*wiwi*) and threading worms (*noke*) on. Eels cannot wriggle fast on dry grass, so this was spread by the fisher, and as the eels took the bob they were hauled on to

the spread grass, where they were seized and threaded through the gills on to a flax line ready to be carried away. He had seen old Pi catch eels by hand. The spring was blocked with tussock (*patiti*), and the water was to her hips, but she caught the eels round the gills and handed them out one by one. The eels the Maori ate were not the silver-bellies, which they thought too poor, but the big black fellows.

The Maori did not like the *kokopura*, as it had too many bones. *Koura*, or crayfish, were caught by turning over the stones in creeks, and they were roasted on the embers. *Kakahi*, or fresh-water mussels, were found in some streams.

In the Mataura River at certain seasons the Maori would net *patiki* (flounders) on the beaches. *Mata* (whitebait) were caught in baskets of flax very finely woven. *Inaka* (minnows) were caught at the falls, and were spread on flax mats and sun-dried. When properly done they would last a long time.

The *kiore*, or native rat, was nearly cream in colour, and was caught with a bent stick and loop. The rat would chew a string to get at a bait, and this released the stick and the loop caught them. They were rolled in mud and baked in the fire, the mud bringing the skin off. Most Maori would not touch the *pouhawaiki*, or European rat.

Tuturau was a very rich *kaika* in the old days. The bush swarmed with birds and the creeks with fish; but, strange to say, the proper fern-root did not grow here, being brought from Otama and Tokanui. It was dug with the Maori spade. This was of wood, about 5 ft. long, and had a sort of scoop at the business end and a stick stuck out on one side for the foot of the digger to press. They were square at the end, and dug fairly well, being very vigorously used; in fact, Mr. Gourlay thought that many an English spade would break if the same energy was used on it.

When he came to the reserve half a dozen trees were held to be sacred. These were all *matai* (black-pine), and it was perhaps because of the edible berries on them that they had been originally "tapu-ed." You could shoot or spear pigeons on them, but you must not put an axe near them. *Pikiraki* was the name of the red mistletoe on the *tawai* (beech); but the white mistletoe on the *rata* was called *puawai*. The Maori at Tuturau got mud from a swamp at Waimumu, and this made an excellent fast black dye.

When eels were put out to dry and rain threatened, a shelter of tussock or *ti* leaves was thatched over them. This shelter was called an *uhī*. One kind of *whāta* (storehouse) was built up high, and you went up an *arawhata* (ladder) to reach it.

He would eat Maori preserved food even if it had mildew on it, as it would cause no harm; but food preserved by Europeans was apt to go

bad quickly and might poison any one not careful. The Maori food was naturally cured, kept well, and tasted sweet and good.

The above is the essence of Mr. Gourlay's information; but a granddaughter added that she had recently visited the Bay of Plenty and noticed the following differences between the names of shell-fish there and in Southland. What is called the *pipi* in the South is there called *kuku*, and what they call *pipi* is like a cockle, only with an oval shell and flatter, and they dig in the sand for it as the tide goes out. This shell-fish is called *toheroa* in the South. There is also a big, heavy shell like a very large cockle, which is called *kuakua* in the North Island, but down round Foveaux Strait is known as *whakai-a-tama*.

A *pakeha* who was brought up at Riverton writes, "Eels were taken with a spear. The fishermen waded and sought for the fish by poking about in the silt with their bare feet. When an eel was located by the Maori's toe it was immediately secured with the spear, which was unerring in Maori hands. The Maori also used eel-pots in capturing their winter's food-supply. These traps were made of *manuka* sticks, bound together with *whitau* (scraped flax), and made in cylindrical form, about 5 ft. long; a netting of prepared flax, with an opening in the centre, was placed at each end of the cylinder. The two nets were attached to each other by means of a flax cord passing down the centre of the eel-trap. The fish, attracted by a bait of worms, pork, flesh, or fish of any kind, suspended midway in the eel-pot, were led by the sloping net to the entrance, passing in and becoming prisoners. The eels, after capture, were cleaned and dried in the sun, and then stored away for future use."

Plant-life.

Strolling through the bush and clearings one day with a venerable Maori, he gave me the names of a few of the plants. The shrub known to the white people as the pepper-tree is called *ramarama*; that known to the northern Maoris as *koromiko* is known in the South as *kokomuka*, while the bush-lawyer is named *tataraihika*, and a kind of bramble is *tataramoa*. The cutty-grass of the settlers was to the

southern Maori known as *matoreha*, the biddy-bid as *piripiri*, and the nettle as *okaoka* (the island Pukeokaoka, near Stewart Island, simply means "Nettle Hill." The common native grass, he said, was called *ma-uku-uku*, the native mountain-grass *pouaka*, and the ordinary swamp-rushes *wiwi*.

The southern Maori say that the *patiti*, *ake-rautaki*, and other vegetation growing on the Takitimu Mountains have a peculiar scent of their own. A visitor took some to an old Riverton chief, who sniffed at it and said "Ah! 'tis Takitimu." A legendary account says that the celebrated chief Tamatea brought these plants from Hawaiki in his canoe, Takitimu, twenty-two generations ago, and that he planted them on this mountain-range.

Kohuwai, also known as *kohuai*, said one of my informants, is a green sort of weed or moss in the bottoms of streams, and a small creek between Waikawa and Chasland's is called Wai-kohuwai because of its bed being so covered with this moss.

After the Europeans introduced smoking the Maori would smoke a weed called *kopata*. They would, said an old man, make a bowl for a pipe out of wood, insert as a stem a reed of *pukakaho*, and puff away. This kind of smoking was called *tiniko*. Over at Stewart Island there is a plant called *punui* with a leaf like a pumpkin. A boy dried and smoked

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this leaf, and, gravely added the narrator, his mouth was turned inside out. These leaves deceived another lad, too. He came from the North, and when he saw the leaves thought he was going to feast on pumpkins, but he was disappointed.

Haumata was the name of what are now called Maori-heads, said one old man, and *upoko-takata* was the name of a plant, possibly the snow-grass of the early settlers. *Papaii* was a kind of spear-grass, and the name is perpetuated in Upoko-papaii ("Sam's Grief," near Tuturau). *Pukio* was the Maori name of "niggerheads," and there is a stream beyond the Waiau known as Wai-pukio. The grass-tree was called *nei* in the South, and Mantell, writing in 1852, says they formed so constant

a part of the "mosses" or vegetation in swampy valleys—comprising mosses, lichens, sundews, grasses, shrubs—that the Maori called these mosses *nei* also.

Legend says that the *pikiraki* was the last plant remaining in the kit of Tane, the forest god, when he sowed the forest. He looked at it tenderly and said, "I cannot let my last child lie on the ground," and that is why it is a parasitic plant perched high up on the big trees, a kind of mistletoe with red flowers.

The common bush fern is *turokio*; another kind of fern is the *piupiu*, and it is said the *kakapo* (ground-parrot) will bite it off at the base and hold the frond over its head to shield itself from observation. And this leads us to an interesting bit of folk-lore.

A Folk-tale.

The *kakapo* and the *toroa* (albatross), said my informant, had a dispute as to who was to be "boss" of the land, and finally they agreed to decide the question by a test. They were to take turn about at hiding, to see which had the greater success at finding the other. A piece of open land with very little cover was selected, and the *toroa* hid first, but his white plumage was too conspicuous and he was found almost at once. "I will hide again," he cried, "and this time you won't find me." But alas for his hopes ! his opponent found him with very little trouble. Then the *kakapo* took his turn at hiding, and lay down on a bare place with a *piupiu* fern over his head. Search as he might, the *toroa* could not find his wily rival until the latter laughed aloud, the sound disclosing his whereabouts. "I will hide again," he said, "on that bare patch over there, and this time you won't find me." The cunning bird again used *piupiu* to avoid detection, and again the *toroa*, search as he might, failed to discover his rival. He flew backwards and forwards over the place as low as possible, but all to no purpose—his quest was in vain. Having been so unsuccessful, the other birds decided that the *toroa* was not a fit and proper bird to dwell on land, so in deep disgrace he was banished to the wide oceans and there he is now to be found.

Potatoes and Introduced Plants.

Potatoes, introduced by Europeans, were early grown in the South, for in the late R. McNab's *Murihiku* we read that in 1813 there was "a field of considerably more than 100 acres which presented one well-cultivated bed, filled with rising crops of various ages, some ready for digging, while others had been but newly planted." This was inland from Bluff Harbour, and it was also recorded that "a spike nail would buy a hundredweight of potatoes" from the Maori. One of my old Maori friends said,

“*Horeta* was the name of the old variety of potatoes which the whalers brought. A black variety was called, I believe, *mangumangu* in the North, but we called it *tatairako* in the South. A potato which was veined inside was named *ropi*, while our name for the Derwent was *pikaukene*.” I was also told about Te Puoho's raiders reaching Tuturau in 1836—“It must have been about Christmas, for the early potatoes were just ripe enough to eat and the invaders had a fine feed after their starvation trip.”

The early settlers in Otago found “Maori cabbage” growing wild. The Maori gave me the name of this as *pora*, and further said that a kind of turnip had grown wild in Central Otago, their name for it being *kawakawa*.

One old Maori said, “In 1869 I was eeling at Longford (now Gore) and was engaged to help harvest 30 acres of oats. Among it I saw a jaggy plant and I wondered what it was. It was the first time I had ever seen thistles.”

An old settler tells me the “Maori cabbage” was simply a degenerate swede turnip. The leaves were turnip-leaves; the body was a thin wiry root and uneatable—it was the leaves which were eaten. From the description of the *kawakawa* it is surmised to have been kohlrabi growing wild but not yet degenerated.

Shell-fish.

I did not get very much information about shell-fish, although we know that, judging by the middens left by the Maori, such were eaten with avidity. The correct name of the Waikaka River, I was told, was Waikakahi, so called because of the number of *kakahi*, or fresh-water shell-fish, in its waters. The names of salt-water shell-fish are perpetuated in the place-names Hakapupu (in northern dialect Whanga-pupu—“periwinkle Harbour”) and kaipipi (“eat shell-fish”—the kind usually called the cockle). Hakapupu is the Maori name of Pleasant River, near Waikouaiti, and Kaipipi is at Stewart Island. A kind of mussel (*kutai*) is mentioned in one tradition as furnishing the relish (*kinaki*) for a cannibal feast. The eating of the *pawa* or *paua* (mutton-fish—a univalve) is also mentioned in the history. One of my informants said there was a thread in the limpet (*kaki*), and

this was said to represent the line which Maui was using when he fished the North Island out of the deep.

One old Maori mentioned oysters, and he thought they had been brought by Captain Howell to Port William, and from there had spread to Foveaux Strait. The story runs that about 1839 Howell brought over some sacks of oysters from Australia as a treat to his men at Riverton, but adverse weather compelled him to toss the sacks overboard off Bluff, and that this was the nucleus of the extensive bed, there now. I should like to know if oysters propagate sufficiently fast to render this account feasible.

Paints and Dyes.

Looking through my notebooks, I see casual references to paints and dyes, but really so little it is scarcely worth mentioning. One of the old Maori said that, some of the people who came on the Arai-te-Uru canoe, about twenty-seven generations ago, were skilled workmen—at cultivating the kumara, at carving, &c. One in particular brought red paint with him, but in exploring the land he dropped it in the hills east of Lake Kaitangata, and hence those hills are famous to this day for yielding the haematite stone from which the Maori got their red paint. It is said that

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one of these hills bears quite a big hole made by generations of Maori in search of *maukoroa* (also known as *horu*—red paint). One old man said, “The Kati-Mamoe used to put red paint on their faces. They knew only two paints—*maukoroa* (red) and a blue paint whose name I forget. The red paint and the *hoaka* (stone used as a grindstone) were brought to this land from Hawaiki.” I am sorry I did not get a description of how the paint was made. I was also told, “*Maraki* is a red-yellow clay found at Waikouaiti and used for seaming canoes.”

An old woman said, “*Kiakia* is the name of a creek at Woodside, near Outram, and it runs into Lee Creek. It is so called because of the *kiakia* which grew there. The

kiakia is a small bush-like spear-grass or grass-tree, and the Maori went there to get it. They soaked it with the bark of the *pokaka* tree and a dye resulted."

"There is a swamp near, Paterson's store at Port Molyneux called Tukoroua," said another of my informants, "and that little spot is famous for the dye it produces. The Tukoroua Swamp is the only place in South Otago where the proper kind of *paruparu*, or black mud, for dyeing *whitau* (prepared flax-fibre) can be found. The mud found elsewhere would turn the *whitau* red or rusty looking, but the Tukoroua mud made it a beautiful black. You could wash it with the best soap and you would never get that black out. Such a reputation had this place that people would come down from the North to get their mats treated with the dye from this swamp."

A creek in Southland is called Opani because on its banks the Maori got earth suitable for making red paint (*pani*), and the name of the hill north of Kaitangata where the red ochre was procured is Te-horo-maukoroa. I was told that a tree called *makatoatoa* was no good for timber and that the Maori extracted the sap from its bark for dye, but I do not know what its European name is.

Introduced Animals.

One or two of my Maori friends casually mentioned some of the animals introduced into this land. It is well known that the southern Maori call the mouse *hinereta* (henrietta) because a vessel of this name ("Elizabeth Henrietta"—1823) introduced these little creatures to their notice, but why they call a cat *naki* I could not ascertain.

Some of the old people are not pleased with the introduction of vermin to Maoriland. They blame the ferrets, weasels, and stoats for largely helping to kill out the native birds, and the fact remains that although Stewart Island has been settled by white men, with their dogs roaming about too, for many years, bird-life is still fairly plentiful. Thus in 1918 in Oban, the principal settlement, I saw the *kereru*, or native pigeon, and heard the *weka*, or woodhen, calling. One old man said that if any one attempted to take vermin to Stewart Island he hoped he would be caught; and he further expressed the bloodthirsty wish that the delinquent would be slowly done to death in boiling oil.

It is generally conceded that Captain Cook introduced the pig to New Zealand, but the late Tare-te-Maiharoa told me they knew the animal traditionally, and they called it *poaka*. He said it was mentioned in the history very far back. I have read that *poaka* is a corruption of the English word "porker," but against this we must remember that those Polynesians who had pigs when Cook visited the South Sea islands called

the animals *puaka*. A European who went pig-hunting with the Maori in the "fifties" says their custom was to get astride the pig and stick it upwards.

Detached Information.

I find I have a collection of stray notes which I do not seem able to incorporate with the other sections of this paper, so will include them here.

Koura.—The crayfish found in inland streams and in the sea were both called *Koura*, as far as I know. A stream north of Gore is Kai-koura (to eat crayfish) and Wai-koura is quite a common place-name. The Maori had a peculiar method of treating crayfish. They would place them across a stream of fresh running water as tight as they could pack them, having them so fastened they could not escape. After they were dead some time the crayfish were, I understand, taken out and dried. A small creek in the gorge of the Taieri River near its mouth was described to me as a place where crayfish had been thus treated in the old days. A place near Tautuku is called Hiri-koura, and I was told it meant the place where crayfish were fastened. The usual meaning of *hiri* (or *whiri*) is to plait or twist.

Kaio (or, as called by the northern Maori, *ngaio*) is a well-known curiosity—half plant, half animal—that was eaten by the Maori. Wharekaio is the name of a beach and landing-place near where the "Tararua" was wrecked, near Fortrose. My informant said, "The *kaio* fastens one end of itself to the rocks and the other end is like a spud. You take this knob and soak it all night and eat it." A European who has boiled and eaten them says, "They taste like a boiled egg flavoured with oil, and have a very good flavour. The taste must, however, be acquired."

Nets.—Although I have very little information about nets, I append the few items gleaned. Lovell's Creek was known to the Maori as Tuakitata, after a kind of fishing-net. This style of net (*tata*) was made in the shape of the cockle-shell called *tuaki*. Other kinds of nets were called *kaka* and *houka*, whilst two kinds of snares for netting birds were called *mahaka* and *here*.

Primitive Appliances.—When the southern Maori finally abandoned their old methods and adopted European ones I cannot exactly say, but here are some

notes concerning the Maori at Tuturau in the "fifties." In 1852 old Reko was working at a pine log, 25 ft. long, with a stone adze, trying to hollow out a canoe. Then he got an old chisel from some white man, but was not making much progress, and finally two Europeans completed the dug-out for him. In 1853 Mr. Chalmers left Tuturau with Reko and Kaikoura on an exploring trip, the white man carrying a gun, and the two Maori had eel-spears and a stick about 6 ft. long with a big fish-hook tied to one end. They carried no provisions, but lived on the country they traversed. The three walked the whole trip in *paraerae* (sandals) made of flax and cabbage-tree leaves, the latter far and away the more durable. In 1854 old Reko would go eeling with a large-hook tied to his wrist and lying on the palm of his hand so when his hand felt an eel he had only to pull it forward to have the eel hooked. Writing in 1854, Mr. Mieville says, "Old Reko scorned matches, and had a light from his firesticks nearly as quickly as I did. He rubbed a pointed stick in a groove in another stick. I never could get fire, but the Maori does so at once."

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Maori Cooking.—One of my informants said he greatly preferred food cooked by the old Maori methods to those introduced by the *pakeha*, although he had not enjoyed the former for years now. European cooking, he said, took the strength out of flesh or fish, whereas the *umu*, or earth oven, preserved all the natural virtue and flavour. What better than to wrap the food in nice green flax-leaves and let it steam in an *umu*? He considered even the method of toasting food before a fire on a *Kohiku* or stick was preferable to frying in a pan or roasting in a stove. Some of the superstitions connected with cooking continued after the white people came, and the operation would be done outside, the women who had been cooking changing their dress before coming in and eating.

Preserving Food.—The same Maori went on to draw my attention to the excellence of Maori methods of preserving food. Anything cooked was called *paka*, and you could get *paka-weka*, *paka-titi*, and so on. These birds have been cooked and then preserved in their own fat. The great receptacle for these preserved foods was kelp which had been made into the familiar *poha*. My informant considered that kelp

possessed some special quality in preserving the taste of what it held, and said he had heard there was a proposal to send butter away in kelp bags. He thought if such was done the butter would keep its taste and quality better in hot weather than under the present system.

Not all food was preserved- in the foregoing manner, some being dried uncooked. The *hapuku*, or groper, was sometimes cut into strips and treated this way, the flesh being then called *maraki*. One' old man gave me some *maraki* to chew, but my tastes were not sufficiently educated in what pleases the Maori palate for me to ask for a second helping.

The Maori Quail.—One of my informants mentioned the *Koreke*, or Maori quail, but unfortunately I omitted to ask how the Maori caught them. These birds were teeming in Otago when European settlement began, and it is hard to realize the countless numbers of them that existed; yet when the diggings broke out this beautiful bird vanished as if it had never been. An old settler who has eaten dozens of them says he never found berries inside them; they had no gizzards, and apparently lived on beetles and insects.

Bob Fishing.—One of the old Maoris mentioned catching eels with a bob. Some frayed strips of flax were attached to a stick, and large worms were threaded on the flax strands, which were looped up, and then the baited mass was dangled in the water. If a tug is felt the fisherman flicks out the eel before it can disentangle its teeth from the bob. I have not learned whether the Europeans copied this from the Maori, or *vice versa*, but somebody may be able to supply the information.

Medicinal.

An old Maori said to me, "A good remedy for colds and sore throats is to steep *goai* (kowhai) bark in boiling water and drink the infusion. It has to be taken fresh, as it will not keep, although perhaps spirits would act as a preservative. The bark is taken only from the sunny side of the tree, and its removal does not kill the tree. My neighbours and I all keep a stock of the bark handy." A well-known Maori remedy for diarrhoea is the leaves of the *Kokomuka*, or New Zealand veronica, and it is used by both races now. It is said that in the old days the Maori who suffered from toothache—a rare complaint among them—stuffed the gum out of

the flax into the holes in the offending molars as a palliative. According to a southern Maori, a water-plant called the *runa* was applied to the skin of sufferers from ringworm. It is said to be a sort of water-lily, and the Wairuna Stream derived its name from it.

The ancient people of the South Island, said one Maori, were skilled in the use of shrubs and herbs. They had known a cure for consumption, but now it is so much needed the shrub cannot be found—the white man's fires and cultivation seem to have destroyed it. This shrub is said to have grown on the Canterbury Plains.

I was reading lately of a herb, called "dortza," which the American Indians asserted would cure influenza, pneumonia, and incipient consumption. Tests by medical men were to the effect that it had done remarkable work in many cases

The claim by southern Maori that they had once known such a herb seemed to me a noteworthy one, and the fact was told to me years before the fame of dortza got spread by the Press.

The Old Order Changes.

A thoughtful old full-blooded Maori, in saying adieu to me last time I visited him, remarked, "The Maori knew how to gather his food from of old, and it suited him, and he raised a vigorous race. Look at him now! There are few middle-aged and few young people! Why? It is largely ignorance of food-values. It takes a lot of food to maintain a Maori in health. In the old days he could eat as many fish and birds as he wanted, and all beautifully cooked in the earth-ovens. Using European foods, he does not know how much to use, or how to cook it properly. He eats it half-prepared or in insufficient quantities, and by not keeping his strength up throws the way open to consumption and wasting diseases. The hope of the Maori is education. The old people had not learned through generation after generation to be farmers or roadmakers and they could not settle to work as the young can. I always urge the young to learn to read and write and get knowledge. A young woman in the 'kaik' had a little boy ill and gave him coastor-oil; and this not working quickly enough, she gave him Epsom salts. The boy became worse,

and a friend raised the money to take the boy to a doctor, who said the two medicines combined formed a poison, and that if the boy had not been brought then he would soon have died. The doctor gave a corrective remedy and the boy recovered. In the same way I reckon want of knowledge is causing many Maori to eat wrong food or to prepare it wrongly and so to slowly poison themselves, or, at any rate, to undermine their constitutions. I have often told the people this, but my words have received little attention. ' It is impossible to go back to native foods, as these have been mostly destroyed by civilization, so the people must read the proper books to learn how to thrive on the proper European food. The Maori girls should all be taught housekeeping, the proper value of food and how to cook it, as I am convinced this is the only way to save our race."

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Art. XIV.—*The Mission of the "Brimont" at Akaroa, in August, 1840.*

By Johannes C. Andersen.

[*Read before the Historical Section of the Wellington Philosophical Society, 20th May, 1919; received by Editor, 19th June, 1919; issued separately, 10th June, 1920.*]

The British Government, though constantly urged by the New Zealand Company, had persistently refused to recognize New Zealand as a British colony, or even as a possession of the Kingdom. The company, therefore, in order to force the hand of the Government, despatched the "Tory" for Port Nicholson (afterwards named Wellington) on the 12th May, 1839, for the purpose of purchasing land from the natives and forming a settlement, the first colonists to follow almost at once. This forced the Government into unwilling action, and an Imperial Proclamation was issued on the 15th June, 1839, extending the boundaries of New South Wales so as to include portions of New Zealand; and on the 13th July of the same year Captain Hobson was appointed Lieutenant-Governor "of any territory which is or may be acquired in sovereignty by Her Majesty in New Zealand." Among other instructions issued to Captain Hobson by Lord Normanby was one to the effect

that he should endeavour to persuade the chiefs of New Zealand to unite themselves to Great Britain; he was also to establish a settled form of civil government, with the free and intelligent consent of the natives expressed according to their established usages; to treat for the recognition of the sovereignty of Her Majesty over the whole or any part of the Islands; to, induce the chiefs to contract that no lands should in future be sold except to the Crown; to announce by Proclamation that no valid title to land acquired from the natives would thereafter be recognized unless confirmed by a Crown grant; to arrange a commission of inquiry as to what lands had been lawfully acquired by British subjects and others; to select and appoint a Protector of Aborigines.

Captain Hobson left in the "Druid" for Port Jackson, where he arrived on the 24th December, 1839. On the 14th January, 1840, Sir George Gipps, Governor of New South Wales, administered the oaths to Captain Hobson, making him Lieutenant-Governor of New-Zealand. He also, in accordance with the instructions of Lord Normanby, issued three Proclamations—the first extending the boundaries of New South Wales to include any territory which then was, or might thereafter be, acquired in sovereignty by Her Majesty in New Zealand; the second appointing Captain Hobson Lieutenant-Governor; the third declaring that all purchases of land from the natives thereafter would be invalid unless supported by a Crown grant.

The new Lieutenant-Governor arrived in the Bay of Islands on the 29th January, 1840, where he next day read his commissions before the people assembled. As a first step towards establishing the sovereignty of Her Majesty he called together the natives, and on the 5th February, 1840, were commenced the negotiations which, on the following day, resulted in the Treaty of Waitangi being signed by forty-six principal chiefs. Others signed it, or authorized copies' of it, in various parts of the Islands at later dates, the aggregate number of signatures obtained being 512! Being

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attacked by paralysis, the Lieutenant-Governor was disabled from travelling to

obtain the signatures personally, and he deputed Major Bunbury to visit parts of the North Island, and also the Middle and Stewart Islands, for that purpose. Major Bunbury sailed in H.M.S. "Herald," with instructions, dated 25th April, 1840, to obtain signatures at all places possible, and to visit such places as he might deem most desirable for establishing Her Majesty's authority.

In reporting the results of his mission Major Bunbury stated that he had, on the 5th June, 1840, proclaimed the Queen's authority, by right of discovery—no natives being there met with—at Southern Port (Stewart Island); and at Cloudy Bay (Middle Island) on the 17th June, the sovereignty at this place having been ceded by the principal chiefs signing the treaty.

Writing on the 25th May, 1840, to the Secretary of State for the Colonies, Lieutenant-Governor Hobson concluded his despatch by saying that without waiting for Major Bunbury's report he had, on the 21st May, 1840, proclaimed the sovereignty of Her Majesty, owing to affairs at Port Nicholson pressing him so to do, over the North Island in accordance with the consents given by the natives in the treaty, and over the southern islands by right of discovery. This despatch was acknowledged and approved by Lord John Russell, and the Proclamations making the islands subject to Her Majesty were inserted in the *London Gazette*. New-Zealand was at the time promised a charter of separate government, which charter was sent on the 9th December, 1840. Lest, however, the proclamation of sovereignty over the Middle Island "by virtue of discovery" should be considered either insufficient or illegal, the Queen's authority was again proclaimed over it by Major Bunbury on the 17th June, 1840, by virtue of the Treaty of Waitangi. This same proclamation was also made, at Cloudy Bay, and Captain Nias, of H.M.S. "Herald," landed with a party of marines to honour the occasion, twenty-one guns being fired from the ship.

Sir George Gipps, writing to Lord John Russell on the 24th July, 1840, reported that Major Bunbury appeared to have carried out his instructions very satisfactorily. He, says, *inter alia*, "One of the places visited by the 'Herald' was Banks Peninsula, the spot at which it has been said that a settlement is about to be made by a company formed in France. Of this company, however, and of its proceedings I know nothing, save what I have derived from English newspapers." The French discovery-ships "Astrolabe" and "Zélée" were at Banks Peninsula in April, 1840; they knew of no project for forming a settlement there, and, indeed, thought the locality a disadvantageous and undesirable one for such a purpose.

Strong feeling had been excited in France by the publication in London of the instructions to Captain Hobson when he was sent out as Lieutenant-Governor to New Zealand. The French Press teemed with calls on their Government to take steps similar to those the British Government proposed to adopt, and to take a share in the colonizing of New Zealand, as a country open to all nations. Mr. E. Gibbon Wakefield, giving evidence on the 17th, July, 1840, before the Select Committee on New Zealand affairs, stated that he had received as many as forty

different French newspapers containing comments on Captain Hobson's instructions. The French Chamber of Commerce also petitioned the Government, and from all this excitement sprang a project for sending French colonists

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and establishing a French colony in New Zealand. Matters connected with this project were conducted by a company calling itself the Nanto-Bordelaise Company. A certain Captain Langlois had, on the 2nd August, 1838, made a provisional purchase from Tuaanau and other natives, of the greater part of Banks Peninsula, paying a deposit in commodities valued at £pD6, further commodities to the value of £pD234 to be paid at a later period. They were so paid, but not until the arrival of the French colonists in August, 1840. Consequently, owing to the Proclamation of Governor Gipps above referred to, the purchase was, strictly speaking, illegal, and need not have been recognized by the Crown at all. Captain Langlois sold part of his interest to the Nanto-Bordelaise Company, and on the 9th March, 1840, sixty-three emigrants left Rochefort in, the "Comte de Paris," an old man-of-war given by the French Government for the purpose.

Another man-of-war, the "Aube," under Captain Lavaud, was sent as escort, and also to take possession for the French Government and protect the colonists on their arrival. The captain, in order to consult the Roman Catholic bishop resident there, sailed for the Bay of Islands, arriving on the 11th July, 1840. Certain proceedings took place subsequently to her arrival, which have given rise to the romantic account of the "taking possession" at Akaroa. It is said that the captain in an unguarded moment revealed the object of his presence in New Zealand waters, whereupon the "Britomart" was secretly despatched to forestall the French by taking possession of the South Island at Akaroa. Lavaud was obliged to make some mention of his mission in order to explain his presence in the bay, and was placed in an extremely awkward position when he was told that the whole of New Zealand, including the South Island, had been proclaimed a possession of the British Crown. At the time he left France New Zealand was still a No Man's Land; and he had had two separate instructions—one to protect the French whaling industry in the southern waters, the other to prepare Akaroa for the reception of

the emigrants by the "Comte de Paris," part of such preparation being the annexation of Banks Peninsula or further territories on behalf of France. He knew nothing even of the appointment of Hobson as Lieutenant-Governor, and he was at first disposed to refuse recognition of his authority.

Hobson appreciated his difficulty; and in order partly to safeguard such British interest in the peninsula as had been established, partly to convince the French that the territory was undoubtedly regarded as British, he despatched Captain Stanley with two Magistrates to hold Courts at Akaroa and other places on the peninsula. The following is a copy of the instructions, to Stanley: they are printed in part in Rusden's *History of New Zealand*, though not in the printed collections of official documents:—

Government House, Russell,
Bay of Islands, 22nd July, 1840.

Sir,—

It being of the utmost importance that the authority of Her Majesty should be most unequivocally exercised throughout the remote parts of this colony, and more particularly in the Southern and Middle Islands, where, I understand, foreign influence and even interference is to be apprehended, I have the honour to request you to proceed immediately in H.M. sloop, under your command, to those islands.

On the subject of this commission I have to request the most inviolable secrecy from all except your immediate superior officers, to whom it may be your duty to report your proceedings.

The ostensible purpose of your cruise may appear to be the conveyance of two magistrates to Port Nicholson, to whom I will elsewhere more particularly refer.
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real object to which I wish particularly to call your attention is to defeat the movements of any foreign ship of war that may be engaged in establishing a settlement in any part of the coast of New Zealand.

There are various rumours current that Captain Lavaud, of the French corvette "L'Aube," now at anchor in this port, is employed in the furtherance of designs such as I have before mentioned. From some observations that fell from him, I discovered that his intention was to proceed to the southern islands, being under the impression that the land about Akaroa and Banks Peninsula, in the Middle Island, is the property of a French subject. These circumstances, combined with the tone in which Captain Lavaud alluded to Akaroa and Banks Peninsula, excited, in my mind, a strong presumption that he is charged with some mission in that quarter incompatible with the Sovereign rights of Her Britannic Majesty, and which, as I have before observed, it will be your study by every means to frustrate.

If my suspicions prove correct, "L'Aube" will no doubt proceed direct to Akaroa and Banks Peninsula, for which place I have earnestly to request that you/will at once depart with the utmost expedition, as it would be a point of the utmost consideration that, on his arrival at that pert, he may find you in occupation, so that it will be out of his power to dislodge you without committing some direct act of hostility.

Captain Lavaud may, however, anticipate you | at' Akaroa, or (should he be defeated in his, movements) may endeavour to establish himself at some other point. In the event of either contingency occurring, I have to request you will remonstrate and protest in the most decided manner against such proceeding, and impress upon him that such interference must be considered as an act of decided hostile invasion.

You will perceive by the enclosed copy of Major Bunbury's declaration that independent of the assumption of the sovereignty of the Middle and Southern Islands, as announced by my proclamation of the 21st May last (a copy of which is also enclosed), the principal chiefs have ceded their rights to Her Majesty through that officer, who was fully authorised to treat with them for that purpose; it will not, therefore, be necessary for you to adopt any further proceedings. It will, however, be advisable that some act of civil authority should be exercised on the islands, and for that purpose the magistrates who accompany you will be instructed to hold a court on their arrival at each port, and to have a record of their proceedings registered and transmitted to me.

You will by every opportunity which may offer forward intelligence of the French squadron's movements, and should you deem it necessary, to the Secretary of State for the Colonies through the Admiralty and to His Excellency Sir George Gipps, Governor of New South Wales.

Mr. Murphy and Mr. Robinson, the magistrates who accompany you, will receive a

memorandum of instructions for their future guidance, which you will be pleased to hand to them when you arrive at your destination.

As your presence in these islands will be of the utmost importance to keep in check any aggression on the part of foreign Powers, I have earnestly to request that, should you require any further supply of provisions the same may be procured, if possible, at Port Nicholson, or at any of the ports on the coast, without returning to Sydney.

I have the honour to be, Sir,

Your most obedient servant,

W. Hobson,

.
The instructions to the Magistrates are not copied by Rusden; they and the above were, however, discovered in the Public Records Office in London by Mr. Guy H. Scholefield, London correspondent of the Press. The instructions, were addressed to Mr. Murphy, whose name appears first in Stanley's instructions, he, not Robinson; being apparently the senior-officer. They were as follows:—

Memo. of Instructions to be attended to by Mr. Murphy. P.M.

You will, at every port that H.M. sloop "Britomart" touches at, act in your magisterial capacity, and, as it is requisite that the civil authority should be strictly exercised, should no case be brought under your notice, you will adjourn from day to day, and a careful record of your proceedings be registered, a copy of which you will transmit to me.

Under any circumstances that Captain Stanley may call upon you for assistance you will, of course, render it, and co-operate generally with him in the advancement of any measures he may think it expedient to adopt.

Dated at Russell, 21st July, 1840.

The following is a copy of Captain Stanley's report, dated 17th September, 1840:—

I have the honour to inform your Excellency that I proceeded in Her Majesty's-sloop under my command to the port of Akaroa, in Banks Peninsula, where I arrived on August 10th after a very stormy passage, during which the stern boat was washed away and one of the quarter-boats stove. The French frigate "L'Aube" had not arrived when I anchored, nor had any French emigrants been landed. August 11th I landed, accompanied by Messrs. Murphy and Robinson, police magistrates, and visited the only two parts of the bay where there were houses; at both places a flag was hoisted, and a court, of which notice had been given the day before, held by the magistrates. Having received information that there were three whaling-stations on the southern side of the peninsula, the exposed positions of which afforded no anchorage for the "Britomart," I sent Messrs. Murphy and Robinson to visit them in a whale-boat. At each station the flag was hoisted and a court held. On August 15th the French frigate "L'Aube" arrived, having been four days off the point. On August 16th the French whaler "Comte de Paris," having on board fifty-seven French emigrants, arrived. With the exception of M. Belligni, from the Jardin des Plantes, who is sent to look after the emigrants, and who is a good botanist and mineralogist, the emigrants are all of the lower order, and include carpenters, gardeners, stonemasons, labourers, a baker, a miner—in all thirty men, eleven women, and the rest-children. Captain Lavaud, on the arrival of the French emigrants, assured me on his word of honour that he would observe strict neutrality between the English residents and the emigrants, and should any difference arise he would settle matters impartially. Captain Lavaud also informed me that, as the "Comte de Paris" has to proceed to sea, whaling, he would cause the emigrants to be landed on some unoccupied part of the bay, where he pledged himself they would do nothing which would be considered hostile to the Government, and that until fresh instructions were received from our respective Governments the emigrants would merely build themselves houses for shelter and clear away what little land they might require for gardens. Upon visiting the "Comte de Paris" I found she had on board, besides agricultural tools for the settlers, six long 24-pounders, mounted on field carriages. I immediately called on Captain Lavaud to protest against the guns being landed. Captain Lavaud assured me that he had been much surprised at finding guns had been sent out in the "Comte de Paris," but that he had already

given the most positive orders that they should not be landed. On August 19th, the French emigrants having been landed in a sheltered well-chosen part of the bay, where they could not interfere with anyone, I handed over to Messrs. Murphy and Robinson the instructions entrusted to me by your Excellency to meet such a contingency.' Mr. Robinson, finding that he could engage three or four Englishmen as constables, and having been enabled, through the kindness of Captain Lavaud, to purchase a boat from the French whaler, decided upon remaining. Captain Lavaud expressed much satisfaction when I informed him Mr. Robinson was to remain, and immediately offered him the use of his cabin and table so long as the "Aube" remained at Akaroa. Mr. Robinson accepted Captain Lavaud's offer until he could establish himself on shore. On August 27th I sailed from Akaroa to Pigeon Bay, where, finding no inhabitants, I merely remained long enough to survey the harbour, which, though narrow and exposed to the westward, is well sheltered from every other wind, and is much frequented by whalers, who procure a great number of pigeons. From Pigeon Bay I went to Port Cooper, where Mr. Murphy held a court. Several chiefs were present and seemed to understand and appreciate Mr. Murphy's proceedings in one or two cases that came before him. Between Port Cooper and Cloudy Bay I could hear of no anchorage whatever from the whalers who frequented the coast. I arrived at Port Nicholson on September 2nd, embarked Messrs. Shortland and Smart, and sailed for the Bay of Islands on September 16th. I have the honour to enclose herewith such information as I was enabled to procure during my stay at Banks Peninsula, and also plans of the harbours.

One enclosure is an interesting table of ports and whaling-stations in the peninsula visited by Captain Stanley, but as it does not bear on the subject it is not copied; from it is gathered, however, that the European population at the time of Captain Stanley's visit numbered over eighty.

It will be observed that no note whatever is made of "taking possession." The log of the "Britomart" is equally reticent. A copy of the log was obtained by Mr. Guy, H. Scholefield in London, and from it the following particulars are gathered. The sloop-of-war "Britomart," Captain

Stanley, left Sydney on the 17th June, 1840, and came to anchor at Koro-rareka, or Bay of Islands, on the afternoon of the 2nd July, H.M.S. "Herald" having worked into the bay just a head of her. She lay in the bay for nine days, "cutting brooms," watering, &c., until on Saturday, the 11th July, "arrived the French ship of war 'L'Aube,' and revenue cutter 'Ranger,' with the Governor. Saluted the French flag with 21 guns." Routine work went on as before, but on the 22nd the company of the "Britomart" was employed making preparations for sea. The log of the following day, commencing at midnight on the 22nd, is interesting: "2 a.m. received on board per order of his Excellency Lieutenant-Governor Hobson; Mr. Murphy and Mr. Robinson, magistrates; 8, loosed sail, short'd in cable; 11 weighed and made sail. Working out of Kororareka Harbour; tacked occasionally." The vessel was busy all the afternoon working out of the Bay of Islands, and at daylight on the 24th Cape Brett lay on the lee bow distant ten or twelve miles. The passage to Akaroa was a thoroughly bad one, and the ship suffered considerably from the knocking-about she received. At midday on the 25th, the first day out, the vessel was off the Great Barrier. The following morning the foretopmast was found to be chafed through, and in the afternoon the foretopsail was split. On the 27th much time was occupied in bending new sails; in the afternoon two ports were stove in by the heavy sea. Cape Wareka [? Wharekahika] was 218 miles distant at noon on the 28th. On the 29th and 30th there was a heavy head swell, which made the 120 miles to East Cape a good deal more. However, the wind veered round, and the "Britomart" rounded East Cape before midnight on the 31st. In the afternoon the hold had 14 in. of water, and thereafter the pumps were going almost continuously. On the 2nd August "Akoroa" was 306 miles distant, and there were 17 in. and 18 in. of water in the hold through the afternoon. At 2 o'clock on the morning of the 3rd a sea was shipped which stove in the lee quarter boat and washed away a port. The ship was twelve miles farther from her destination at noon on the 4th than on the previous day. Again, in the early morning of the 5th, a sea stove in a weather port. Land was seen on the port bow at 10 a.m. on the 6th'; it was somewhere near Flat Point, or Te Awaite, in the North Island. In the afternoon the sea split the foretopmast-staysail. Next day the weather moderated, and sea-water was pumped into the empty tanks. Land showed on the lee. bow at 7 in the evening, and next morning, the 8th, Cape Palliser was four or five leagues distant. On the morning of the 9th, Sunday, the crew was mustered and the Articles of War were read. This was a proceeding of quite a routine nature. There

was land on the beam, and a run of eighty-three miles to Akaroa. This is the narrative of the 10th: "4 a.m. bore up for the land; 12.30 calm, with a heavy swell; out sweeps and swept ship; 1.30 a breeze from the nor'ward; in sweeps, trimmed and swept into the harbour; 4.30 shortened sail and came to with S.B. in 6 $\frac{3}{4}$ fathoms; furled sails, &c." At daylight on the 11th the boats were out and the ship was made snug. There is no reference to any incident outside the ordinary routine of the ship. On the 12th the boats were sent out to survey and cut wood, and they were so employed for the next few days, completing on Friday, 14th. On the following day, 15th August: "5 p.m., sent boats to assist towing the French ship-of-war 'L'Aube'; 8, anchored do." Sunday was marked with the usual Divine service. On Monday, 17th—"p.m., arrived the French ship (merchant) 'Count de Paris,' with emigrants. Lent the cutter with a party to haul the seine." There is nothing but routine entries until the 22nd, when the company was employed making preparations for sea.

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The "Britomart" ran down the harbour on the 26th and came near the entrance, when she spoke the British merchant ship "Speculator," just arrived. Sails were loosed on the 27th, and further preparations made for sea. At 8 a.m. Captain Stanley "discharged Mr. C. B. Robinson, police magistrate," and at 9 made sail down the harbour, coming to at the anchorage. Putting to sea the following day, the "Britomart" spoke the schooner "Success," of Sydney, from Port Cooper, and another sail. On the 29th she shaped her course for Pigeon Bay, where she came to and sent a boat to survey and get water. On the 30th she sailed for Port Cooper (now Lyttelton Harbour) and anchored there. On the 1st September the "Britomart" was again under sail, and a cable was passed to the merchant ship "Africane," but in getting under way in the squally wind the hawser parted, and the "Britomart" touched bottom. She made a good passage to Cape Palliser, which was in sight at daylight on the 2nd, and in the afternoon she was working up to Port Nicholson, where she anchored at 5 p.m.

Lieutenant-Governor Hobson sent a copy of Captain Stanley's report to Governor Sir George Gipps, saying, "I transmit a copy of Captain Stanley's report of his

proceedings while at Akaroa. The measures he adopted with the French emigrants are, I think, extremely judicious, and the whole of his conduct evinces a degree of zeal and intelligence which, I trust, you will consider worthy of the notice of Her Majesty's Government." There is no note of "forestalling" the French; and the first apparent note of anything that might be construed into pleasure at such forestalling is found in Governor Gipps's despatch to Lord John Russell: "I have already transmitted to your Lordship copies of the instructions which have been given to Captain Stanley, of H.M.S. "Britomart," by the Lieutenant-Governor of New Zealand. I have now the satisfaction to inform your Lordship that Captain Stanley preceded the French

Even in the French Chamber of Deputies the position seemed to have been clearly perceived; for later, on the 29th May, 1844, the following remarks were made in that chamber by M. Guizot, Minister of Foreign Affairs: There are two Proclamations, one on the 21st May, the other on the 17th June. Both are anterior to the arrival of Captain Lavaud, of the 'Aube.' Of these I have carefully read only that of June 17th, relative to the taking possession of the southern island. Here is the English text—I translate literally: 'Taken possession, in the name of Her Most Gracious Majesty the Queen of the United Kingdoms of Great Britain and Ireland, of the southern island of New Zealand. This island, situated in [here follows latitude and longitude], with all its woods, rivers, ports, and territory, having been ceded in sovereignty by different independent chiefs to Her Most Gracious Majesty, we have taken solemn possession of it, &c.'

There was a diary in existence, and may still be, though its whereabouts is not known—the diary of C. B. Robinson, one of the Magistrates sent with Stanley. Thanks to the foresight of the late Mr. S. C. Farr, of Christchurch, important extracts from it are printed in *Canterbury Old and New*, as follows:—

August 3rd, 1840. Appointed by Captain William Hobson, Lieutenant-Governor of New Zealand, with all necessary instructions and a proclamation signed "William Hobson," and dated August 3rd, 1840, at Government House, Russell, Bay of Islands. Also signed by Willoughby Shortland, Colonial Secretary. Instructions were: "To proceed with all despatch in H.M.S. (brig) 'Britomart,' Captain Owen Stanley R.N., Commander, to Akaroa, Banks Peninsula, and hoist the Union Jack, which will be given to you, on a spur jutting out a little more than half-way up the harbour, on the east side, and marked in red on the map you take with you."

Here followed the Proclamation, which was not copied. The diary continued:—

"We sailed that evening with a fair, strong wind a good passage was made, and we anchored in Akaroa Bay on the morning of August 11th. We at once proceeded to make preparations for the formal ceremony. A log of wood, old and dry, was procured from the bush by some of the crew, and was hewn by the carpenter eight inches square. A hole was dug in the ground at the spot selected, the post put in, and the earth well rammed down round it. A spar had been brought from the vessel, rigged with pulley and halyard for hoisting the flag; this was lashed to the post, and every-thing, made ready by 5 p.m. on August 15th. The next morning, at 12 o'clock noon, I Charles Barrington Robinson, deputed by the Acting-Governor, hoisted the Union Jack in the name of Her Majesty the Queen Victoria, and in the presence of Captain Stanley, his officers, some of the crew, about a dozen natives (Maoris), and the only Englishman then in the bay, Mr. Green, with his family. There was no demonstration other than my reading the proclamation, three cheers for Her Majesty, and the National Anthem.

The next note made was: "August 18th. The French man-of-war 'Aube,' Captain Lavaud, arrived in the bay."

"Now compare these statements with the log of the "Britomart." The Proclamation signed "William Hobson" was, it is said, dated 3rd August. On that date the "Britomart" was actually being buffeted at sea, south of East Cape, and somewhat over three hundred miles from Akaroa! Mr. Robinson says, "We sailed that evening [August 3rd]... a good passage was made... and we anchored on the morning of August 11th." The log shows they sailed on the morning of the 22nd July, and made anything but a good passage, anchoring in Akaroa at 4.30 p.m. on the 10th August. Mr. Robinson says he hoisted the flag at noon on the 16th, and the "Aube" appeared on the 18th August; the log shows that the "Aube" came to anchor on Saturday, 15th August. Again, the report of Captain Stanley shows that the flag was hoisted and a Court held at two places in the bay on the 11th August, and at three other bays where there were whaling-stations during the succeeding days, so that during the time Mr. Robinson says they were busy preparing the pole, &c., the report shows that he and Mr. Murphy were visiting the whaling-stations in a whaleboat.

These discrepancies are extraordinary, and cannot but give colour to a suggestion already made in the voluminous newspaper, correspondence on this subject—that the diary was not begun until some time after the event, and then written up from memory, or from faulty notes.

On the late Dr. R. McNab visiting England towards the end of 1909 the writer of this paper wrote to him, in December of that year, urging him to secure, if possible, logs of the "Aube" and "Comte de Paris," also the instructions to Captain Lavaud, and Lavaud's despatches to his Government. The writer had already sent him a precis of what had been gathered by him up till that date, and Dr. McNab was successful in obtaining copies of a great deal of matter—so much that he intended making it the subject of a book. This his lamented death unfortunately prevented.

The following are translated extracts from a letter written by Lavaud to the Minister of Marine, at the Bay of Islands, on the 19th June, 1840:—

On the 29th of June I sailed round Van Diemen's Land; at that time there was a S.E. wind shifting to the east, a fine breeze but contrary to the course to be travelled to get to the south of New Zealand: I decided to sail into the Bay of Islands, where I hoped to see the Bishop of Maronae. ... Your Excellency was kind enough to allow me the latitude to change this part of my course, and I sailed to the north, directing the "Aube" to the Three Kings Islands, the first land I caught sight of

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since the 25th of March and it was on the 8th of this month at 1 o'clock in the morning. On the 9th I recognized the Cape Maria van Diemen. I left the North Cape the same day at night, and on the 10th, in the morning, I was at the entrance of the Bay of Islands, which I could only reach in the night on account of the calm and the strong land breezes which did not permit me to go ahead. I met the vessel H.B.M. "Britomart." The Captain came to see me as soon as I had cast anchor. We exchanged the usual salutes of politeness and remained very good

friends. I immediately visited the Bishop.

On my arrival I heard of the taking possession, in the name of the Queen of the United Kingdom of Great Britain and Ireland, of the three islands composing the group known under the name of New Zealand. The British flag flies two miles from the anchorage of Kororareka, on the River Karra-karra, on the site of Fort Russell-Town, the name of the town to be built there. A Lieutenant-Governor, Mr. Hobson, is established there with a large administrative staff and a garrison of 130 men, commanded by a field officer of the land forces, who has three other officers under his command. Three warships seem to be attached to the British colony. The corvette "Herald," which belongs to them, recently made a voyage round all the islands where Englishmen are established, visiting the principal places.... Akaroa is at present also occupied by an Englishman, whose cattle graze there. The corvette "Herald" went there, and I heard that about two months ago, there, as well as everywhere where she found no Europeans, the declaration of British sovereignty had been written on a paper, enclosed in a bottle, and hidden in the earth...

The property of Banks Peninsula has been constituted by a Mr. Clayton, who lives in the Bay of Islands and who has heard from the whalers long ago that Mr. Langlois had acquired it; but as I thought, in such a state of affairs, I ought at present to conceal the mission I was charged with, this statement did not come to me in an official way.

The position has greatly changed since my departure from France; British jealousy has made great steps forward and is running fast. I shall avoid to compromise the Government of the King; I will act with great caution; but, on the other hand, so far away from Your Excellency, and ignoring what has happened between the two Governments, after France has been notified that the full sovereign power lies in the hands of "Her Majesty Queen Victoria, her heirs and successors," as stated in the Proclamation dated the 21st of May—I repeat, so far away, I cannot deviate from the orders I carry, and, having above all to preserve the honour of my flag, I shall declare officially to the representative of Her Britannic Majesty on the island, Captain Hobson, that for the present I protest against any measure, coming from the British Government, which might result in infringing the French property duly acquired from the free and independent natives, till the moment in which the Government of the King will be pleased to recognize British sovereignty over these islands.

I fear that the "Comte de Paris," which, according to what her captain wrote to me before I left France, has put into port at Senegal, at the Cape, at Hobart Town, and at the Bay of Islands, before returning to Akaroa, will keep us waiting for some time, which will be very regrettable. There ought to be more than one warship here, for I shall not be able to leave Akaroa when I get there, and yet I will entirely ignore there what is happening around me. We must not conceal from ourselves that everybody here will try and hinder us, and I will be all the more unprepared

to avoid the pitfalls of our neighbours because I will have no information from the outside.... I hope that the official news received in France the last few months will appear to Your Excellency to be of such a nature that fresh instructions will be sent me, and that perhaps also the sea forces will be increased...

I add my letter to Captain Hobson... who, as Your Excellency will see, refused to enter into explanations with me if I did not previously recognize his title as Governor of the Islands of New Zealand.... I tried to make him understand that I could not see why he should keep silent about the object of my letter [concerning properties acquired by the French in various parts of the Islands], having only as a reason that I did not recognize him as Governor of the Islands of New Zealand. I also pointed out to him that large French properties existed in the Islands, especially in the Middle Island, which we call in France the South Island, and that I could not admit the rights of sovereignty of a foreign Government over this property; but he very well explained to me that there was a distinction to be made here—that he did not contest the property of the French on the Islands; that the chiefs when selling had only sold the land, but not their authority, which they abdicated in favour of Britain; that only after this abdication the British sovereignty had been declared. Then I handed him a letter telling him that the contents would make him understand my last word. He read it with great attention, and told me that in my place he would

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have acted as I had done, and that he thought it was the surest way to avoid a conflict which might have had very unpleasant consequences for both Governments, in breaking out so far away. I insisted upon knowing if the contents of my letter had been well understood. He told me, Yes, that he understood the whole sense and the whole situation; that he would send a copy to the Governor-General at Sydney, who would take his orders from the Government of the Queen; and that in the meantime he would use his whole persuasive influence with this same Governor-General, so that the Committee should not be obliged to inquire about the validity of the French title-deeds until the two Governments had come to some arrangement. After that I added that I was going to the South; that several

landowners and colonists were already established there, and others would go there to establish themselves; that the measures I claimed were to be extended to them also, and that there, too, they were to feel the protection of their Government, and consequently should be able to occupy the land, work on it, sow and reap without being worried. Mr. Langlois will take possession of Banks Peninsula and will give over to me the land which he is to transfer to the French Government, which will not appear in the matter, unless it were to judge that it ought not to give its adhesion to the sovereignty of Queen Victoria over the Islands of New Zealand of which Banks Peninsula is a part; and in case that I were to receive orders to declare that this sovereignty was not recognized I should proclaim that of France over the peninsula. I say only Banks Peninsula because all the rest is invaded and occupied by the British. There is even a Magistrate at Cloudy Bay. Well, Minister, things are so advanced that it is too late to stop them, and being persuaded of this I wish to let the King's Government act freely without urging or compromising it in anything. The same motives have made me avoid placing myself in the position to be obliged to fire the first cannon-shot, the signal of war, knowing that if, on my departure from France, Your Excellency could have seen the position in which I find myself at present you would have sent me off with different instructions from those I have; you would not have let the "Comte de Paris" sail, and would not have left me the choice of war or peace....

Later, in July, Lavaud received information of other claims than that of Langlois to land on Banks Peninsula; and he writes to his Minister—

Your Excellency will see that, as I had already heard, the ownership of Banks Peninsula has been partially or totally claimed by several people, who every one of them pretend to be the legitimate owners and to possess title-deeds. I have had the honour of mentioning to you, among others, Mr. Clayton, who lays claim only to a part. Further I may name to you the firm of Cooper and Levy, of Sydney, who, as well as Monsieur Langlois, claim the whole peninsula; they have already brought timber to close the isthmus of this peninsula, and the herd of oxen which is in the bay of Akaroa belongs to this firm....

I shall concert with Monsieur Langlois to see what can be done; perhaps it would be suitable to come to some arrangement with the claimants, of whom at least two, Messrs. Clayton and Cooper, bought prior to him.

In any case, we shall settle at Akaroa, awaiting your orders.

The Middle Island (Tawai-Ponamoo) is to-day, as I had the honour of telling you, nearly entirely in the possession of foreigners. We can no more think of acquiring from the natives, who possess only the land reserved for their habitations and plantations; we could only buy from the British, but they are so numerous that I regard it as very difficult to proclaim the sovereignty of France there, as the company, according to all appearances, can actually only claim a part of this peninsula. Through negotiations, I believe it to be quite possible to make the

Britannic Cabinet disown Governor Hobson's first Proclamation, as he, in declaring the Queen's sovereignty, relies on a right of discovery which cannot be acknowledged by the nations.

It seems to me that it is impossible that this pretended right can be invoked to-day, so long after the discovery of these islands by Captain Cook; besides, the right of discovery can only be exercised in uninhabited countries, but not in those where the land is trodden by those to whom it naturally belongs and ought to belong. The independence of the Middle Island, under the protectorate of France, would be, I believe, what would henceforth suit you the best. The freedom of the ports of this Island would lead to great commercial movement, which would strike a big blow at the colony of the North Island, soon to be subjected to Customs duties. Your Excellency will appreciate, from all that I have had the honour of communicating to you, the obstacles I have had to encounter and the delicate position in which I find myself. Nevertheless, in a conversation I had yesterday with Mr. Hobson, I thought fit to tell him that French colonists, landowners in the Middle Island, had just arrived, and

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that I was going there to protect them when they would take possession of their lands. His letter of the 23rd will perhaps lead me, if I find difficulties in Akaroa, to return to Sydney, when I have settled Monsieur Langlois, for I see that Mr. Hobson can or will not settle the question. In this state of affairs, if the Britannic Government has not got the signatures of the chiefs of Banks Peninsula—that is to say, their consent to recognize its sovereignty—I will make every possible effort to convince the chiefs that they must not abandon their land to any nation, but preserve it for themselves and their descendants by accepting the patronage of 'France and its' Government. It is also in the direction of independence, I believe, that we ought to act with Britain.

But, sir, there is no time to be lost to enter into an explanation with the Britannic Cabinet: everything goes very quickly in this colony, and the powers given by Lord Normanby to the Government of Sydney give him all the more latitude, because

what he will decide to do concerning these islands has been applauded in advance...

A later letter is dated Akaroa, 19th August, 1840. In it he informs his Minister what he found at Akaroa:—

I have the honour to announce to you the arrival of the "Aube" in the Bay of Akaroa on the 15th instant.

I found several British established there, and the Proclamation placarded by the corvette "Herald" last May posted on the house of an Englishman placed in charge of these Proclamations...

The brig "Britomart" is sailing along the coast and visiting the different ports with two Magistrates, having to go everywhere where any offence has to be investigated and punished. I suppose that my presence is somewhat the reason of these cruises. A boat from this brig, which was lying outside the bay on the 17th instant, came alongside the "Comte de Paris," which, on entering, had fired guns; in this boat were officers and the two Magistrates I just mentioned. Believing that this gun-fire was to call their boat, these gentlemen came on board. They noticed carriages for coast-guns which were on deck; they seemed astonished, but, however, did not say anything about it. Various remarks thoughtlessly made by Captain Langlois also made them feel uneasy, and have been the subject of an explanation between the British captain and myself. I promised to follow the line of conduct that I had traced for myself in the Bay of Islands, and to maintain what I had written, until the British and French Cabinets had decided the question of occupancy in one way or another.

As I have had the honour of informing Your Excellency, I had officially announced to Captain Hobson that I was returning to Akaroa, where the surrounding land, as well as the whole of Banks Peninsula, belonged to French proprietors, who had sent out cultivators from France to clear the land and make it productive... My surprise was great when, on the arrival of the "Comte de Paris," I heard, in the most positive way, that Monsieur Langlois had never negotiated with the chiefs of this part, that he possessed nothing there, and that we had, in fact, no right of ownership we could put forward. The chiefs gathered around me declared to me, through the voice of M. Comte, a missionary priest of Monseignor Pompallier, who speaks the language of the natives, that Monsieur Langlois had negotiated for a part of the land of Port Cooper, Tokolabo Bay, for which he had paid one part, but that there never had been any question of the port of Akaroa, in which they had sold to a Mr. Rhodes a certain part for grazing or cultivating, and that in the same way they had sold the bay of Pyreka and other bays forming the southern part of the peninsula; and, finally, that that they had never signed a contract of sale, drawn up between Monsieur Langlois and the tribes, of the north-west and west of the peninsula.

In such a state of things, how am I to execute the orders of the King? How to take possession... even tacitly, in case of an arrangement between the Governments of France and of Britain, of a land that does not belong to the company? In one word, how to execute the treaty of the 11th October, 1839, made in Paris between the Government and the Nanto-Bordelaise Company? Really, sir, I am travelling on such a winding and dark road that I only walk by groping my way.... If Monsieur Langlois had not heard of my presence he would have treated the acts and the official doings of Britain as a joke; he would have hoisted the tricolour flag, would have saluted it with 101 guns, and he would have taken possession in the name of the King of the French; while I, for my part, have tried every day in my conduct to avoid binding my Government, and especially not to compromise the dignity of Royalty. Fortunately, the whaler "Pauline," which I met at sea, by making my presence here known at Port Cooper, prevented a demonstration of this kind, for the ceremony of which several officers and masters of whalers had already been convoked.

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From to-day [21st August] a British Magistrate has been appointed to reside at Akaroa and will establish himself there. I suppose it is the arrival and the landing of our colonists that has called forth this measure. I had a conference on this matter with him, and I could see a certain fear concerning my intentions; nevertheless, I am pleased at his presence, because, together with mine, it might avoid misunderstandings between the established British and our colonists....

In ending this despatch I must repeat to Your Excellency my whole idea: No colonization possible in these seas if we do not obtain the withdrawal of these Proclamations and declarations as to the island of Tawai Poenamou (Middle Island); and then, apart from the inconvenience of the neighbourhood, one would have to make a better choice of emigrants than those brought out by the "Comte de Paris."

There is a voluminous essay written by Lavaud, entitled "Voyage and Attempted Colonization of the South Island of New Zealand, undertaken by the Corvette

'Aube,' commanded by Commander Lavaud," which gives more detail than the official papers, but is hardly more to the point.

It will be admitted that Lavaud was placed in a very difficult position through the change of circumstances that had taken place since he left France; that he, as representative of that country, bore himself in a courteous if independent manner, and that both he and Hobson acted with admirable mutual forbearance; that there was no race, the French objects having been defeated whilst Lavaud was still at sea and in ignorance of events; and that Lavaud, whilst accepting the defeat with difficulty, did so with dignity; that his action was the best he could have taken, both for the continued amity of the two nations and for the comfort of the emigrants.

In conclusion, it is a pleasure to be able to express this respect for one who represented a nation with whom we have often been at variance, but between whom and ourselves a bitter war against a common foe has, we trust, consummated an enduring friendship. The French did not prosecute their claim; upon inquiry, the New Zealand Government, in view of the fact that a large number of emigrants had been sent out in good faith, at a cost of £pD15,125, made the company a grant of 30,000 acres, and the company finally ceded all its rights on the peninsula to the New Zealand Company for the sum of £pD4,500.

Many contemporary versions have appeared of what was supposed to have taken place at Akaroa in August, 1840; and it was the great discrepancies among these, and the reading of Stanley's report, that awoke in the writer a suspicion that the ceremony performed was not one of taking possession, but merely one of exercising civil authority in virtue of possession already taken; and that more facts were to be gleaned from the dark fields of the past.

It is to be hoped that the whole of the official correspondence, both English and French, may be made generally available by publication.

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Ecology, and the Bearing of these upon certain Geological and Phylogenetic Problems.

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Historical.

Ranunculus paucifolius was “raised to specific rank” by Kirk (1899, p. 11), who separated it from *R. chordorhizos* Hook. f.

The notable points in his description are: “Leaves 1 or 2”; “Scape equalling the petioles”; “Achenes few, turgid, with a straight subulate beak”; “flowering season, December.”

Under *R. paucifolius*, Cheeseman (1906, p. 16) says, “Much more complete material is required before a good description can be given of this curious little plant. It is very close to the preceding species, but seems sufficiently distinct in the less fleshy and more coriaceous habit; fewer leaves, which are broader, and much less divided; longer scape, and broader petals. Only one flowering specimen has been obtained.”

From Hooker's account of *R. chordorhizos* it is evident that *Ranunculus paucifolius* was first collected by Haast before the publication of the *Handbook* (1867), though its discovery is accredited by Cheeseman to Enys (1906, p. xxxiii), where it is stated that Enys's work in New Zealand began in 1874.

Comparison of *Ranunculus chordorhizos* and *R. paucifolius*.

R. chordorhizos.

In 1918 I obtained flowers of *R. chordorhizos* from two plants in my garden at Christchurch brought from Mount Hutt (at c. 4,000 ft.) in 1917. One of those also flowered in 1919. The flowering-date in Christchurch (sea-level) was September. The flower is from 1 in. to 1½ in. in diameter. The petals are from 5 to 8, and even more.



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Photograph of *Ranunculus paucifolius* *in situ* showing five leaves and root.



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Fig. 1.—Photograph of *Ranunculus paucifolius* showing six leaves.

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The most striking feature of the flower (hitherto undescribed) is the form of the sepals, which are lobed like the radical leaves, and one of them in each flower is much larger than the rest, lobed and appearing like the cauline leaves which form a sort of involucre in *R. Haastii*, but attached so much higher that it should rather be termed a bract. The edges of the petals are also lobed shallowly. The colour of the sepals is dark like the leaves. I obtained one head of ripe achenes from my plants. The description of the achene in Kirk and Cheeseman seems to be quite exact.

Specimens of the plants here used were sent to Kew for identification; there are no flowering specimens there, but my plants were identified as *R. chordorhizos*. The locality (Mount Hutt) is not far from Mount Somers (the original locality), and the plant has been collected by Laing at Mount Winterslow, between Mount Somers and Mount Hutt.

R. paucifolius.

I visited Castle Hill on the 8th November, 1919, and obtained specimens. There had been a heavy fall of snow on the 1st and 2nd November, and most of the flowers were much damaged. Between twenty and thirty blooms were observed. The flowering-date is late October and November, not December (Kirk, Cheeseman). I was able to get about a dozen specimens which had flowered after the disappearance of the snow. No buds were coming on, and the season was rather backward than otherwise.

The flower is large and showy, averaging about 1½ in. in diameter when fully expanded. I measured one exactly 2 in. in diameter.

The number of petals is from 5 to 8 or even more; the most usual number seemed to be 6. The sepals are 5. Most of the plants bear one flower only, but several were observed with two. The scape is very short, not more than 1 in. in any of my specimens. There are no cauline leaves as in *R. Haastii*; the sepals are pale yellow and have nothing of the peculiar character of those of *R. chordorhizos*. The edges of the petals, unlike those of *R. chordorhizos*, are entire or very nearly so, the margin being very slightly wavy.

I obtained ripe achenes at Castle Hill in December, 1918. The description in Kirk is inexact, and the achene is not distinguishable from that of *R. chordorrhizos*.

I may add that I have in cultivation seven plants brought from Castle Hill in 1918. All are thriving, but none flowered in 1919.

The two species having been grown close together, the following points of comparison may be noted. The general coloration of the two is very similar and very curious; *R. chordorrhizos* is, however, a little darker than *R. paucifolius*. The leaf of *R. chordorrhizos* has the segments distinctly recurved; those of *R. paucifolius* are nearly flat. *R. paucifolius* is a good deal the larger plant in every way. The leaf of *R. paucifolius* is pitted, but not so deeply as that of *R. chordorrhizos*. The leaves of both species are pitted when fresh, not only "when dry" (Kirk, Cheeseman).

To summarize the new facts resulting from these observations:—

- (1.) *R. chordorrhizos* has recurved leaves, pitted while fresh.
- (2.) *R. chordorrhizos* has a flower about $1\frac{1}{2}$ in. in diameter (not "1 in.")
- (3.) The sepals of *R. chordorrhizos* are lobed, and have something of the character of a cauline leaf or bract.
- (4.) The number of petals of *R. chordorrhizos* is from 5 to 8 or more.
- (5.) The edge of the petals of *R. chordorrhizos* is lobed or crenate.

- (6.) One of my plants in cultivation has 9 now. Six is quite usual. The name *paucifolius* is a misnomer.
- (7.) The scape of *R. paucifolius* is not always solitary.
- (8.) The number of petals of *R. paucifolius* is 5–8.
- (9.) The flower of *R. paucifolius* is larger than described hitherto, being from 1½ in. to 2 in.
- (10.) The flowering-date of *R. paucifolius* is late October and November, not December.
- (11.) The achene of *R. paucifolius* is exactly like that of *R. chordorrhizos*; the style is curved, not straight.

Conclusion from these Facts.

I have been tempted to think that *R. paucifolius* hardly deserves specific status, and that it should be reduced to the rank of a variety of *R. chordorrhizos*; but in the light of the above observations I am compelled to decide that it should be upheld as a distinct species. While the differences in the cutting and the colour of the leaf, the size of the plant and of the flower, the edging of the petals, the pitting of the leaf, might be considered trivial, yet the character of the sepals of *R. chordorrhizos*, constituting a distinct link with *R. Haastii*, would seem to be important enough, taken in conjunction with the other differences, to warrant the retention of the species. Until flowering specimens of *R. crithmifolius* have been studied it is not possible to tell how the group may ultimately be treated.

Habitat and Distribution.

General.

The only known locality for *Ranunculus paucifolius* is a rock-bound hollow behind the farm buildings at Castle Hill, in the Trelißick Basin, about a mile and a half from the homestead of the late J.D. Enys, upon whose property the farm was situated.

A full account of the general geological features of the district is given by Speight

(1917), with a map showing the Castle Hill itself (p. 323), and plates, of which Plate xxi, fig. 1, gives a view of the small hollow from above.

The locality of the species is a small synclinal basin forming a kind of amphitheatre. Its main direction is north-east and south-west, the north-east end being the higher. It is bounded on the south and west by the steep grassy slopes of Castle Hill, with frequent outcrops of limestone (seen in [Plate IV](#)), and on the north and east by piles of limestone rocks from 80 ft. to 100 ft. high, which are weathered into the usual fantastic shapes. It is entered from the eastern side by a gap in the limestone barrier about 100 yards broad; a small but constant stream rises on the south-west side of the basin, and flows through this gap on to the flat cultivated plains of the Castle Hill farm, which are overlooked by the steep limestone rocks. Except at this point the basin is surrounded on all sides by limestone rocks or steep slopes of grass upon a limestone soil. The weathering of the rocks by frost and wind produces a great amount of debris, which is blown far and wide by the strong winds of the Southern Alps, and this debris collects in the basin owing to its enclosed character. Within the basin a small dune-system is produced by the action of the wind, so that its floor is diversified by small


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Photograph of locality from south-east, showing open formation


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Photograph of locality from north-east, the white patches showing the limestone debris in which grows *Ranunculus paucifolius*.

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ridges and shallow hollows of dune type. The south-west half of the basin is clothed with tussock grassland, and does not concern us. The north-east half, at the south-west end, shows first (moving from south-west to north-east) a small area, about 120 yards by 100 yards, of open debris formation which does not harbour this *Ranunculus*. The upper (or north-eastern) portion consists of a larger area of limestone debris, about 350 yards by 100 to 150 yards, of which some parts are clothed with a half-closed tussock formation, others with an open formation, including the *Ranunculus paucifolius*, while some considerable portions are entirely barren. The bottom of this part of the basin is occupied chiefly by a belt of half-closed tussock formation; the eastern side has rapid slopes of coarse debris below the limestone rocks; the western side (shown in [Plate IV](#)) has a gentler gradient, and the grass-covered slopes of Castle Hill here ease off gradually into the central basin. Tongues of half-closed tussock formation, on this side, occupying higher ground or ridges, separate roughly circular or semicircular areas of the open formation well seen in Plate V, within which most of the plants of *Ranunculus paucifolius* occur.

The debris itself is of a flaky character, but is reduced, over most of the area, to a

fine uniform powder. The colour of the bare patches is thus a pale yellow, deepening to brown in certain places, owing apparently to the volcanic element present in the limestone itself in varying quantity. The debris on the steep eastern slopes is much of it very coarse and rough, and very large flakes of the stone lie thickly here.

At the extreme north-east corner a dune formation is being broken up. Here are semicircular breaches of the higher dune, whence masses of very loose debris come down. At the top the slope is steep and the material deep and soft; hardly any vegetation can grow, and the line separating the tussock grassland from the perfectly barren space is sharp and clear.

Possibly all parts of the basin have at one time or another been thus closely covered, the covering being subsequently stripped away or buried, while a certain area must always have remained sufficiently open somewhere in the area for the calciphile community to exist.

Digging at a spot where several plants of *Ranunculus paucifolius* grew close together showed that the limestone debris was here exactly 18 in. deep. At that depth a more consolidated subsoil was reached. Down to this depth the material was perfectly uniform, fine and incoherent, and the roots of the *Ranunculus*, about 10 in. or 12 in. long, do not reach beyond this layer, which seemed fairly damp throughout at the end of a period of about a fortnight's fine weather. In a really dry season this material must, of course, become extremely dry.

Details of Distribution.

The following are the main results of the careful search of the whole, or nearly the whole, of the area, in which I had the assistance of Messrs. R. Speight, A. E. Flower, and Dr. W. P. Evans.

(1.) Most of the plants grow on the more gently sloping north-west side of the basin, and are most thickly congregated on two areas, each about 60 yards by 40 yards. The whole area within which all the plants (except three or four) were found is about 300 yards by about 60 yards—roughly, between 3½ and 4 acres.

(2.) Nearly all the plants were found on ground sloping at an angle of from 6° to 8°. Few were found on quite level spots, and none at all on very steep places.

- (3.) Where several plants occur in a line, from 2 ft. to 4 ft. apart, as sometimes happens, this line takes no constant direction.
- (4.) The plants occur, roughly, in groups, but seldom close to one another and not often very near any other plants. Only in one small area were they found among tussocks (about a dozen altogether), and here the tussock formation is peculiarly scanty.
- (5.) The whole number of plants I counted was seventy. Allowing for possible errors and oversights, and portions not quite so minutely examined, it is safe to say, I think, that the area does not contain more than from one hundred and fifty to two hundred individuals, and I should think it probable that there are not more than one hundred.
- (6.) In one space which was most carefully examined, and in which the plants were as frequent as anywhere, the nearest neighbours of a particular plant of *Ranunculus paucifolius* were: *Poa acicularifolia*, *Lepidium sisymbrioides*, *Wahlenbergia albomarginata*, *Myosotis decora*, *Carmichaelia Monroi* var., and the introduced *Arenaria serpyllifolia* and *Cerastium glomeratum*. The plants in the vicinity were on an average about 6 in. from one another, and spaces about 12 in. square were frequently quite barren. This would be a typical "open formation."

In another case, not at all exceptional, at the other end of the area examined, a plant of *Ranunculus paucifolius* was seen to have no other plant nearer to it than 3 ft.; at this distance was a small patch of *Poa acicularifolia*; a little farther away was one plant of *Oreomyrrhis andicola* var. *rigida*, and at about the same distance one of *Lepidium sisymbrioides*; and 10 ft. away was one plant of *Notothlaspi rosulatum*. The rest of the 10 ft. circle was perfectly bare.

To complete the account of the surface of the hollow it may be added that areas of 12 yards by 6 yards were measured which supported no living plant of any kind. These completely barren spots form a fairly large part of the small available space.

Associations of the Area.

The small basin here described supports a limited community of calciphile

xerophytes, of which *Ranunculus paucifolius* is a typical member. It supports also a good number of mesophytes, representing the usual flora of the district, and a fairly large group of introduced plants.

(a.) On the barest portions of the area, where the debris is deepest, loosest, and, in dry seasons, presumably driest, the only plants are *Lepidium sisymbrioides*, *Oreomyrrhis andicola* var., *Oreomyrrhis andicola* var. *rigida*, the introduced *Arenaria serpyllifolia*, and occasionally *Myosotis decora*.

(b.) The usual open formation of the gentler slopes includes, besides the plant under consideration, all the above-named, and in addition *Pimelea prostrata* var., *Notothlaspi rosulatum*, *Poa acicularifolia*, *Anisotome Enysii*, *Cardamine heterophylla* var., *Carmichaelia Monroi* or *nana*, *Wahlenbergia albomarginata*, *Anisotome aromaticata*; and, more occasionally, *Ranunculus Monroi* var. *dentatus*, *Senecio Haastii*, *Crepis novae-zelandiae*, *Raoulia australis*, that variety of *Epilobium novae-zelandiae* which is distinguished by its generally reddish colouring and pink flower, and *Myosotis cinerascens* Petrie.

All these plants are perennial, and all are very low in stature.

These two—(a) and (b)—might be said to form a *Lepidium sisymbrioides* association. This association presents a most singular and characteristic facies. The general background is a glaring yellow, shading into pale brown in certain patches. Upon this ground the scattered plants of

Lepidium sisymbrioides make spots of very dull chocolate, which are confused in the general scheme with the paler browns, dull greenish-yellows, and greys, of *Oreomyrrhis andicola*, *Myosotis decora*, *Anisotome Enysii*, &c. The sparsely scattered plants of *Ranunculus paucifolius* become almost invisible in this environment, and play no leading part in determining the appearance of the whole unit. The whole effect is most peculiar; the calciphile flora gives the impression that it belongs elsewhere—to another age, another climate and country. Much the same effect is produced, in my experience, by the isolated

patches of ancient fen vegetation which survive at such spots as Wicken and Cottenham, set like savage aliens of some older and vanishing race in the midst of the green crops and pastures of modern Cambridgeshire.

(c.) As the formation becomes more nearly closed, on the borders of the grassy closed areas, *Plantago spathulata* appears in great quantities, and the closed formation of the immediate neighbourhood includes *Festuca novae-zelandiae*, two or three others of the usual grasses of the district, *Raoulia subsericea*, *Hydrocotyle novae-zelandiae* var. *montana*, *Vittadinia australis*, and a fair amount of moss. Here occasional plants of *Lepidium sisymbrioides* appear, but not far from the pure limestone patches.

(d.) The chief introduced plants which occur in the basin are *Arenaria serpyllifolia* (extremely abundant everywhere—more so than any native plant), *Cerastium glomeratum*, *Hypochaeris radicata*, the large ox-eye daisy (which completely covers the slopes on the eastern side of the rocks outside the basin), and *Verbascum Thapsus*. It is not without significance, as showing the very special and peculiar character of the locality, that *Hypochaeris radicata*, elsewhere so exceedingly abundant in New Zealand, is here comparatively rare.

It must be added that the rocks above the basin and the steepest slopes around them also harbour *Epilobium gracilipes* (which never occurs on the flat), *Senecio Haastii* (which is comparatively seldom seen below), *Senecio lautus* var. *montanus*, and a good number of such shrubs as *Coprosma propinqua*, *Discaria toumatou*, and *Aristotelia fruticosa*. Upon these shrubs the peculiar parasite *Korthalsella clavata* is found; this also grows upon shrubs in other limestone rocks (e.g., those at the junction of the Porter and Broken Rivers), but apparently is found only in the Castle Hill district.

A certain number of these plants are definitely calciphiles, and occur in no other situations; others seem to grow by preference on limestone, but are not confined strictly to it (in this district, at any rate); and the rest are of general distribution.

In the first class are *Ranunculus paucifolius*, *Poa acicularifolia*, *Korthalsella clavata*, *Epilobium gracilipes*, *Myosotis decora*, *Anisotome Enysii*. In the second are *Oreomyrrhis andicola* var. *rigida* and *Crepis novae-zelandiae*.

Several of them exhibit marked xerophytic characters, as described by Cockayne and Laing (Speight, Cockayne, and Laing, 1911, p. 358), and among these *Ranunculus paucifolius* is conspicuous. It has the pale ashenpurple colouring which distinguishes the shingle-slip plants generally, such as its relations *Ranunculus chordorhizos*, *R. crithmifolius*, and *R. Haastii*. *Lepidium sisymbrioides* has special adaptations, of which the disproportionately long root is most remarkable (Cheeseman, p. 42). *Anisotome Enysii* shows a colouring very similar to that of *Ranunculus paucifolius*. There is here a marked degree of epharmonic convergence.

These plants make up a community of intense interest, and the problem of their existence is bound up with that of *Ranunculus paucifolius*, whose limited distribution and feeble powers of reproduction help to put that problem in a clearer and more striking light.

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Ecological: Main Problems involved.

General.

These problems may be thus stated: How are we to account for the survival, in an exceedingly limited area, of a very special and peculiar formation, and in very limited numbers, of a plant which is obviously adapted to a climate very different from that of the present time, which reproduces itself only by seed, not vegetatively, and that only in a very sparing manner, and which apparently can exist only upon a kind of soil occurring only in limited areas separated from one another by great distances?

Apart from geological history several considerations may here be given as bearing upon the main problems.

Reproduction and Distribution of Seed.—The achene, on dropping off, no doubt falls into the soil and is moved by the wind, as the surface of the debris is quite unstable, most of the plants being actually buried in it above the rootstock. It is remarkable that none of the plants of this association is a "traveller." The seed of all is presumably distributed in the same way—by the action of the wind in shifting the soil; none of them is provided with a pappus or coma; no composite plant except *Raoulia australis* enters into the unit. *Epilobium gracilipes* and *Senecio Monroi* var. *dentatus*, which occur on the steep slopes and rocks above the basin and have seeds specially adapted for carriage to a distance by the wind, are absent altogether from the flatter portions of the area.

Instability of Soil.—The wind is always bringing fresh debris into the basin, and is

always stirring and shifting all that part of the surface which is entirely or nearly bare. As the rocks are now always rapidly crumbling, and no doubt have been in the same state for a very long period of time, it follows that they must formerly have been much larger than they are now; therefore they must formerly have set free annually a much larger amount of material, and therefore the superficial area of unstable debris must formerly have been much greater. But in recent times the area of bare debris could never have been really extensive, as the accumulation of it would hardly be possible under present conditions except within the enclosed space of the basin. However, in some much older age it may be imagined that a much greater area lying eastward of the small basin might during a period of steppe climate or drought become a semi-desert, mainly of this debris, supporting a calciphile and xerophytic flora, in open formation, of such individuals and in such disposition as we now see within the enclosed and protected area only.

Struggle for Life.—As Warming (1909, p. 256) observes of fell-field in general, the typical xerophytic plants are so thinly distributed that they do not interfere with one another nor compete with one another. It is so here, and it is so upon the steep shingle-slopes of the dry eastern mountains of the neighbourhood.

Ranunculus Haastii, for instance, is exactly like *R. paucifolius* in this respect. Only a certain small number of plants grow within a given space, when, so far as one can see, an infinitely greater number might grow there without in the least inconveniencing their neighbours.

Thus *Ranunculus paucifolius* has not been threatened with extinction in this manner. It seems, however, to have had to face two other dangers in recent times. On the one hand, if the surface upon which it grows were for any cause to become still more unstable, and the wind to act

more violently and continuously upon it, the plants might all be buried, as some of them no doubt have been. On the other hand, if the supply of material delivered into the basin should diminish and finally cease altogether, no doubt

the closed tussock formation which now covers the south-west portion of it would gradually invade the whole, and *Ranunculus paucifolius* would die out. This, it would seem, must ultimately happen.

The area has for many years been open to stock and rabbits, but they evidently do not care for the plant, otherwise it would have perished long ago. There are plenty of rabbits now in and about the basin. The openness of the formation has no doubt protected the plant from destruction by fire, a great and very real danger in New Zealand.

Influence of Slopes.—The fact that it is confined to the easier slopes—almost to level ground—is also of very great significance. Among its associates, for instance, *Lepidium sisymbrioides* and *Myosotis decora* easily maintain themselves upon very steep slopes, and consequently these plants are quite widely distributed, occurring, in the immediate neighbourhood, upon the limestone slopes at and near the junction of the Porter and Broken Rivers, and upon those of the Whitewater River and of the Upper Porter or Coleridge Creek, whereas *Ranunculus paucifolius*, by reason of its apparent inability to grow except upon easy gradients, is debarred from these areas, where every condition which it requires is to be had except this one, and can maintain itself only within the very limited basin where it is presumably doomed ultimately to perish.

Limestone Soil.—When it is said that the plant can exist only in limestone soil, it is not denied that it might live, if transplanted or sown, in some other soil; but the assumption is that in any other soil, if it can live at all, it cannot compete with the ordinary vegetation of that soil: it could live, that is, only under artificial conditions and when protected.

Relation to Geological Problems.

We may now consider what conditions are indicated as most probable in the remote past of this community in general and of *R. paucifolius* in particular.

It seems inconceivable that the plant should have “originated,” established itself, and subsequently maintained itself for countless ages, all within the narrow limits of its present distribution, and the first condition requisite for its establishment would be the existence of a very much larger area of continuous Tertiary limestone strata than is now to be found anywhere in New Zealand.

This area need not have been—and, indeed, could not have been—one continuous sheet of limestone beds covering the whole of the district within which the isolated fragmentary remnants now exist. But the inference here drawn from the existence of this whole calciphile unit, and of *Ranunculus paucifolius* in particular, is that these beds must once have been more extensive and more nearly continuous than they are now. The ancestral *Ranunculus* may well have existed upon soils of pre-Tertiary origin and developed there its xerophytic

characters, while one form of it established itself especially upon the limestone, developed characters accordingly, and ultimately become virtually incapable of maintaining itself elsewhere. This is, at any rate, one hypothesis which seems to fit the facts. But the exact sequence of events can here, in the nature of things, be only a matter of conjecture.

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This comparatively wide area must have had, at some remote period, a steppe or semi-desert climate, under whose influences a xerophytic and partly calciphile flora developed and flourished, and it is likely that what we now have represents only a portion of this flora, many species having probably died out altogether.

This area must have been partly a peneplain (upon which alone *R. paucifolius*, it would seem, could "originate" and flourish), and would probably be conterminous with a range or ranges of hills with limestone rocks exposed and weathering into dust exactly as they now do on the small area here under observation. But such peneplain need not have consisted entirely of Tertiary limestone beds.

The area would be in the nature of a strip or belt, of no very great width and probably much interrupted, corresponding roughly to the shoreline or lines of the hypothetic Tertiary sea or seas. It would be conterminous with and more or less alternated with an area or areas of pre-Tertiary formation, probably lying to the north and east, as posited, e.g., by Cockayne (1911, pp. 343–44), by way of which probably the mesophytic flora would return when a more humid climate should prevail in this area. Upon this pre-Tertiary area the related species, *R. chordorhizos*, &c., would have originated and flourished, or that single species or form from which they and *R. paucifolius* trace their common descent.

The greater part of these limestone beds was destroyed by erosion of various kinds in subsequent ages, leaving only the present small isolated remnants, of which the Trellissick Basin is one of the largest.

It is impossible that by the elevation of the land 3,000 ft. or 4,000 ft. (Haast,

Hutton, Park), and the consequent refrigeration and glaciation, the whole flora of the district (as has been thought) was driven to another tract, now non-existent, and returned with the subsidence of the land and consequent change of climate. "Return" of a calciphile flora over areas upon which the Tertiary beds had been destroyed would be impossible, especially since, as we have seen, this flora as a unit is not a "traveller"; and we cannot escape the conclusion that this plant community has been represented within the area of the small basin, since it first established itself or "originated" in that neighbourhood.

Glaciation bears upon the question in two ways:—

(1.) Hutton (1900, p. 176), followed by Cockayne, correlated the supposed drought epoch, of which our flora shows signs, with the glacial epoch, which he placed in the older Pliocene period. This view was adopted by Cockayne (1901, pp. 280 *et seq.*); but that authority believed that at the height of the glaciation the eastern mountains (within which this area is included) might still support a xerophyte flora like that of the shingle-slips of the present day (Cockayne, 1911, pp. 348 *et seq.*).

The view of Speight (1911) and others is that the last glacial epoch is much more recent, that the drought period was correlated with it (Cockayne, 1911, p. 344), that the Tertiary deposits were continuous over a much larger area than is the case now (Speight, 1915, p. 54), that the Castle Hill area probably escaped glaciation altogether (Speight, 1917, pp. 323 *et seq.*), and that the Treliwick Basin at the height of glaciation was "probably a snowfield" (Speight, 1917, p. 323).

It would seem certain that a steppe climate or period of drought must have obtained here over a large area at least once (probably more than once) since Tertiary times, but to the present writer it seems quite uncertain whether this was coeval with and resultant from the glacial epoch or not

and the analogy of other lands would seem to show that such a climate may have existed in New Zealand independently of any glacial epoch, whether that epoch

be (with Hutton) older Pliocene or (with Speight and others) Pleistocene. The question whether the "drought" be Pliocene or Pleistocene is here dwelt upon because, whatever conditions obtained and whatever balance was established at the end of the "drought," if that "drought" were Pliocene that balance must in all probability have been disturbed and a new set of condition reached when the later Pleistocene glacial period came. The problem is then, to discover what were the conditions during and after some more recent period, rather than during and after the exceedingly remote period of any possible Pliocene glaciation and concomitant steppe climate.

(2.) Glaciation also has been supposed to have been the chief, though not the sole, eroding agency by which the great area of Tertiary beds was destroyed (Hutton, 1885, p. 92; Speight, 1915, p. 337). The question of the agency by which, and the probable period during which, these beds have been destroyed is, however, one of secondary import in this connection. It is enough, for the botanical problem, if it is decided that they once existed, have been in one way or another largely destroyed (being now represented by the small isolated fragmentary areas which remain to us), and that the Trelissick Basin (including the small area here studied) escaped glaciation and any great degree of refrigeration during any glacial epoch. We may then imagine the ancient birthplace and habitat of *Ranunculus paucifolius* and its associates to have been a semi-desert area of flat or flattish plains diversified with ridges and islets of higher ground, and neighboured closely by a range of limestone hills or even mountains. The whole landscape would have a yellow hue; upon the surface large areas of unstable shifting debris would possibly alternate with ridges of more grassy and closed formation. Strong winds would be frequent and dust-storms violent. The vegetation would be sparse and harsh, including the species here described, and no doubt many others which have perished; a pale-purple, greyish, and brown colour scheme would predominate. The land would be occupied by no animals save lizards and birds, its whole appearance being monotonous, parched, and glaring; while the dreariness of the scene would be enhanced by the setting of pallid limestone rocks of grotesque and fantastic form—chessmen, collar-studs, sea-lions, and gorilla torsos. The general appearance of the limestone desert might be much like parts of the Sahara—e.g., as figured in plate 345 of Schimper's *Plant-geography*, p. 614.

If Speight's (1911) hypothesis of a pluvial climate in post-glacial times be accepted—and certainly the evidence collected by him seems to be conclusive—this community and others like it must have passed through and survived such a period, unless the districts in which they exist have been specially favoured. There is little or no reason to suppose that this was so, for, although Cockayne (1900) mentions that the Trelissick Basin is now very dry climatically, old residents do not support this view; and, in any case, the fact, if established, that it is now dry does not prove that it was always so in the remote past.

Origin of the Group to which it belonged.

With regard to the historical development of this group of *Ranunculi*, if the neo-Lamarckian view of the origin of species be adopted—the theory

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of direct adaptation or self-adaptation, as understood by Warming (1909) —it would seem probable that a single ancestral form of *Ranunculus* developed under conditions of extreme drought into a typical xerophyte, and that, after the conditions to which it had adapted itself had been modified or completely changed, this plant maintained itself against the competition of a mesophyte flora in certain localities—*i.e.*, shingle-slips—in which it had an advantage, and in course of a long period of time, existing only in isolated areas completely separated from one another (one of which is the limestone area here described), it developed those comparatively trivial distinctive characters (especially in the cutting of the leaf) which now distinguish the “species” from one another.

According to De Vries (1912), however, such speculations and conjectures as to the conditions under which a species originated are idle, and can achieve no result. Speaking of “beautiful adaptations” to local conditions, he says: “In no case is it possible to tell whether the species have acquired these during their migration or during their stay in the new environment, or perhaps previous to their being subjected to the influence in question” (p. 592). Again: “Adaptations to new conditions [which are conceded] depend upon characters which were inherent in the species before it arrived in the new environment. The characters themselves are not the effect of the external influences considered” (p. 579). Such characters, it is contended, cannot be good specific marks; they fall within the range of “fluctuations” (as distinguished from mutations) and “cannot lead to constant races” (p. 540). The species thus modified or adapted remains essentially the same, and will, if replaced in the favourable conditions, resume its older form (as in the classic experiments of Cockayne upon seedling forms, and those of Bonnier upon alpine plants). The sole condition required in the plant is therefore “high plasticity.” We must not say that a species originated under the stimulus of its environment, or that it acquired new characters in response to changed conditions: that would be confusing cause and effect. “Fitness for present life-

conditions... can hardly be considered as a result of adaptation, and we have to recur to previous hypothetical environments to explain the much-admired adjustments. All speculations of this kind are merely reduced to more or less plausible and more or less poetical^{*} considerations" (p. 574). It is concluded that "geological changes of climate may have been accompanied by the production of new forms, but there is no evidence that this has occurred in such a way as to provoke directly useful changes"; that "the characters of local and endemic types do not betray any definite relation to their special environment"; and, finally, that "the facts which are at present available plead against the hypothesis of a direct adjusting influence of environment upon plants, and comply with the proposition of changes brought about by other causes and afterward subjected to natural selection" (p. 595). The author then restates his personal belief "that the species-making changes occur by leaps and bounds, however small."

If these conclusions be accepted, the case of *Ranunculus paucifolius* and its associates may be thus considered in their light. It is generally accepted that a period of more or less severe drought or "steppe climate" has been passed through by a great part at least of the flora of New

[Footnote] * The writer explains in a footnote that this epithet is not intended to convey any reproach.

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Zealand. The particular community here studied shows this with especial clearness, consisting as it does of a small association of plants all of which show very definite xerophytic adaptations, while some of them can exist only under certain very special and peculiar edaphic conditions such as may have obtained more widely in the past. The conditions governing plant-life before and during this period of drought may be supposed to have been much the same as those of the Sahara at the present time, thus described by De Vries (after Battandier): "Originally this region must have had an ordinary degree of rainfall and moisture.... Then... the rainfall must have slowly diminished, taking centuries... to reach the conditions which now prevail. The consequent changes in this flora

must have been correspondingly slow, and must have consisted mainly in the disappearing of the larger part of the species; first of those which were dependent on the higher degree of moisture; then of others; until at the present time only the most drought-resisting forms are spared" (pp. 589–90). He proceeds to show that no specific changes, probably, were brought about by this process; that a large number of the species of this arid region are monotypic genera, each genus consisting of a single species; whereas, "if there had been any degree of adaptation during this whole period of increasing dryness, new species would have been produced —from those forms which by their own inherent capacities would be the very last to be threatened with extermination. These genera would therefore have produced quite a number of smaller or even of larger species, adapting themselves more and more to the changing conditions and stocking the desert, in the same way as other deserts have been stocked, from adjoining countries!" As this has not happened, it is concluded "that the single species... have not undergone any change in the direction of drought-resistance, but have simply been those which happened to be the best fitted for the life in the desert. A thick epidermis, a small display of leaves, long and deep roots, were the main qualifications for this choice" (p. 590).

Then, in our case, we assume that the moister climate re-established itself; the mesophyte flora which had been destroyed here, but had maintained itself in some adjoining land where the conditions remained favourable, returned and gradually repeopled the desert or semi-desert, while the xerophytes retreated before it to those places, such as shingle-slips and areas like the small hollow at Castle Hill, where they had an advantage and have subsequently maintained themselves. But, in contradistinction to what has been said above, we must accept the following propositions as to this community of plants:—

(1.) The species here studied—*e.g.*, *Ranunculus paucifolius*, *Lepidium sisymbrioides*, *Oreomyrrhis andicola* var. *rigida*, and *Poa acicularifolia*—all existed and held their own among the pre-drought mesophyte flora, but not perhaps exactly in their present form, since "adaptations" are not denied except as differential marks of new species. The only alternative is that they have originated, some or all of them, since the period of "drought."

(2.) All these species must have had a high degree of plasticity, and thus they are able gradually to accommodate themselves to the increasingly severe drought; but all must have had already, at the beginning of the period, a definitely drought-resisting structure, and this was not at any time acquired by any of them in response to any external stress, and it would be at first quite useless to them.

(3.) Each of these species originated by a mutation or sudden change involving the introduction of at least one quite new unit-character,^{*} and this must have happened at some period anterior to that of the drought, not as a result of any such condition. Like other differential characters in general, those induced by this mutation would be at first perfectly useless (De Vries, 1912, p. 534), and the changed form would get its advantage only by the chance of the occurrence of the drought. The new character or characters then became useful; but we must resist the temptation to regard the useful character (e.g., the excessively thick and coriaceous leaf or long thick roots of the xerophytic *Ranunculi*) as an adaptation to the needs of the new external condition.

(4.) As "adaptations" can in this case not be denied, it follows that all the changes which are truly "adaptations" in these species are of the nature of "fluctuations," and if any of them be cultivated under more favourable conditions the "adaptations" will disappear; the plant will then retain only so much of its xerophytic character as it had at the beginning of the drought, which gave it its initial advantage over others, and which was the result of some previous mutation. Until each plant of the community, therefore, has been so transplanted and tested it is impossible for us to tell which of its characters ought, and which ought not, to be regarded as differential specific characters; and it follows that the status of each is doubtful except where the plant has no near relatives at all among existing plants.

(5.) It is very improbable that the species of this community were all produced in the early stages of the drought by mutation. It is assumed "that the origin of new forms is not due to a hard struggle, but is promoted by a luxuriant environment and by easy conditions of development" (De Vries, 1912, p. 520). It is shown that a species (or genus) which is in a "state of mutability" may produce whole groups of new forms, even "swarms" (as in the case of *Draba* or *Viola* in Europe), though sometimes apparently such changes are only sporadic (p. 549). In this case it must be supposed that at some more or less remote period before the drought each of the genera *Ranunculus*, *Lepidium*, *Oreomyrrhis*, *Myosotis*, and *Poa* passed through a "mutation period" and threw off numbers of new species, some of which would immediately perish, while others would maintain themselves for shorter or longer periods under the stress of natural selection, and finally the

species here perpetuated would alone survive under the fierce stress of the drought until rejoined by their relatives under the new climatic conditions.

(6.) Narrowing down the proposition to the particular genus and species here studied, we must believe that there existed at the beginning of the period of drought a species (or possibly more than one) of *Ranunculus* which had originated by mutation at some period (as to which it is useless to speculate) having peculiarly thick leaves, long roots, and other characters which gave it an advantage when the drought began to be severe. These characters, however, had been acquired by it owing to causes which are completely dark to us, not in response to any external stimulus or stress of environment. Fortunate in possessing these characters, it continued to live when other less-favoured *Ranunculi* perished, and it may or may not have changed under the new conditions, adapting itself thereto. But if it did so change it acquired no new unit-character; and all its modification remained mere "fluctuations," and under more favourable conditions

[Footnote] * One is enough (De Vries, 1912, p. 562, in re *Oenothera gigas*).

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would disappear and leave it as it had been when the drought began. The five species here treated as a collective group would represent varying degrees of "adaptation" of this kind, and none of them is a true species, or even a microspecies, unless it already possessed its distinguishing specific characters at the beginning of the period. In this respect *Ranunculus paucifolius* is like any of the others of the group, and it is impossible for us to tell whether it originated from the same ancestral form with them or was already a true species when the stress of drought came upon it. Its "adaptation" to a limestone soil is thus most probably not a specific character, but an adaptation of the unstable kind which may disappear as soon as the need for it is withdrawn. The test of cultivation can alone decide this point.

It would be beyond the scope of this paper to discuss all the difficulties which

stand in the way of a full acceptance of these propositions. But it may be said that the words "however small" ("Species-making changes occur by leaps and bounds, however small") seem to imply a very great concession. Changes of the nature of "adaptations" to new conditions are not denied (De Vries, 1912, p. 579). "It is clear that we may call all these changes adaptations to new conditions. But then we must concede that these adaptations depend upon characters which were inherent in the species before it arrived in the new environment." And, as very small changes may be due to true mutations, there seems to be no very great difference between the opposing views. It is admitted that under new conditions a species may change very greatly and appear to become quite a different species, and it is admitted that under new (as under any other) conditions a species may acquire very small new characters by mutation and so become a new species. Is it not possible that the "state of mutability," whose causes have hitherto remained obscure, may be induced by the impact of new conditions and the demands of a new stress? No very great adjustment seems necessary to reconcile this view with that of De Vries. He says that plants may change and adapt themselves gradually to new conditions, but no new species can originate in that way; changes so induced are not "mutations." It may be suggested, on the other hand, that possibly new characters, due to "mutations," may be acquired by the plant as a direct response to Nature's ultimatum, "Change or die!"

Conclusions.

1. The original description of the species by Kirk is not quite accurate. The number of the leaves is not abnormally small, being frequently 5 and may be as many as 9. The style, when the achene is ripe, is curved, not straight. The flowering-period is late October and November, not December. The petals number 5 to 8.
2. It is one member of a xerophytic plant community, or association, of very ancient origin, and is specially adapted, like some others of that community, to live upon a limestone soil, or, rather, debris formation.
3. Though its habitat is now, so far as is known, extremely restricted, it must formerly, with its associates, have been distributed over a far more extensive area of Tertiary limestone beds. This conclusion supports that reached by Speight (1915, p. 345) upon quite different evidence.
4. It is the product of a period of drought or steppe climate, which directly caused the development of its xerophytic characters; and in this it resembles the other members of the community to which it belongs, one which was formerly, in all probability, far richer in species, and perhaps even in genera, than it is now.

5. It is adapted only for life under very special and peculiar conditions—*e.g.*, its confinement to gentle gradients and to a limestone soil—which conditions have been provided and preserved for it, by a series of fortunate chances, in one small locality only (so far as is known at present).

6. Its life-history may be thus summed up conjecturally: Originating in the very remote past during a period of drought (which was probably very long) somewhere within or not far from an extensive area of Tertiary limestone, this plant acquired marked xerophytic characters and flourished, maintaining itself with ease, and as the area upon which it grew was slowly and gradually eroded (or perhaps, in parts, more rapidly by glaciation) it was restricted to areas continually diminishing in size and farther and farther separated from one another, until it remained in only one very limited area peculiarly situated and adapted to its needs. Here, as in its original state, it had little or no severe competition to meet and overcome, and for countless ages it has continued to exist there, surviving at least one great period of glaciation, which its habitat escaped; at least one pluvial epoch, which could not be favourable to it; and finally the various dangers resultant upon human occupation—depredations of stock and of hares and rabbits, pests and blights, and agricultural necessities and accidents, such as the plough and the wax match. Thus within its own narrow nook, secure from the competition of rivals, this strange plant, relic of an earlier day and clime, is passing slowly and, it may be permitted to fancy, unreluctantly away before our eyes in an age-long euthanasia.

I desire to express my great obligation of Mr. R. Speight, who with infinite trouble and pains took photographs of the plant *in situ* and of the locality; to Dr. W. P. Evans, who also photographed and sketched the locality and took the necessary observations of heights and levels and the measurements of the area; to Mr. A. E. Flower, who, with Dr. Evans, assisted me in the task of counting the plants; and to Dr. L. Cockayne, who has most kindly read over the whole of the paper and given me the benefit of his invaluable suggestions and criticisms.

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Postscript.

This paper has been submitted to Professor Hugo de Vries, and he has sent me this comment:—

"It is, of course, interesting for me to read a statement of my views from a neo-Lamarckian standpoint, and the concession that the facts described by you do not contain any argument for a decision between the two contrasting theories.

"For me your article shows that *R. paucifolius*, *R. chordorhizos*, *R. crithmifolius*, and *R. Haastii* must have had a common ancestor, which was already a xerophyte, and that they must have inherited this character from it. This ancestor may have had the same geographical distribution which is now shown by the aggregate of its descendants. Perhaps one of them is identical with it; perhaps it has wholly disappeared. Under what conditions it lived we can, of course, not know, nor where and when it acquired its xerophytic properties. To conclude that it must have acquired them in a period of drought would be a *circulus vitiosus*, since it would simply be applying the theory to a special case and then considering the case as a proof of the theory.

"You say that possibly new characters may be acquired by a plant as a direct response to Nature's ultimatum, 'Change or die.' This is the old view, but not mine. The article you quote from was just intended to show that, as far as we know, the response has, as a matter of fact, always been, 'I cannot change at your will and so I must die.'

"You assume that your plants have passed through periods of moisture, but have retained their xerophytic character nevertheless. It seems to me that this is conceding that external conditions do not, as a rule, provoke corresponding useful changes. They may do so, or seem to do so, or they may not. My view, that mutations, although, of course, caused by external conditions, are not necessarily responses to the 'demands of a new stress,' seems quite adequate to interpret your facts. I gladly concede that the causes of mutations are still dark to us, but then I say that responses such as Warming and other neo-Lamarckians suppose are far darker. Especially if you take into consideration what is now known concerning the structure of chromosomes and the distribution of the hereditary characters in them, it seems impossible to imagine the nature of such a supposed response. On the other hand, if we do not know the causes of mutation, the fact of their occurrence has been proved in so numerous individual cases that it can no longer be doubted, even by those who want to exclude the Oenotheras from the discussion.

"I shall be very glad to learn the results of your garden cultures. I should not wonder if your plants would behave just like the creosotbush of Tucson, and prefer better conditions to those which they enjoy (?) just-now. To me it seems that plants are found in those localities where they can better endure the

circumstances than their competitors. But whether they really enjoy them, or would prefer more moisture and more fertile soils, and so on, is another question."

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Art. XVI.—*Helichrysum dimorphum Cockayne—a Hybrid?*

By A. Wall, M.A., Professor of English, Canterbury College.

[Read before the Canterbury Philosophical Institute, 1st October, 1919; received by Editor, 3rd October, 1919; issued separately, 10th June, 1920.]

Helichrysum dimorphum was discovered by Cockayne near the confluence of the Poulter and Waimakariri Rivers and described by him in 1915. Another plant was found by the same authority at Puffer's Creek, which runs into the Broken River not far from its junction with the Waimakariri. The two localities are about ten miles apart. The species has not been found again.

I visited the Puffer's Creek locality in February, 1919, and took specimens. The object of this paper is to suggest that *Helichrysum dimorphum* is a hybrid between *H. filicaule* and *H. depressum*, just as *H. Purdiei* seems to be certainly a cross between *H. glomeratum* and *H. bellidoides*.

Helichrysum dimorphum is a strong climber. The plant has a lusty, thriving appearance, and the branches grow in very great profusion and are most thickly massed together. Climbing upon a plant of *Coprosma propinqua* it shows leafless branches in the open, and leafy branches wherever it is at all shaded. The flowers, which are not fully open in my specimens, are borne upon the leafless branches. *H. depressum* occurs close to it in the bed of the creek, and *H. filicaule* is, as usual in such localities, abundant all round it. The plant grows about 8 ft. or 10 ft. above the bed of the creek.

Helichrysum filicaule shows a distinctly scandent or semi-scandent habit whenever it grows among tall plants, such as *Discaria* or *Leptospermum*. I have

collected specimens over 2 ft. in length at Akaroa and elsewhere, one of these being found in the immediate neighbourhood of the Puffer's Creek plant when I was unsuccessfully searching for it in 1917. *H. depressum*, on the other hand, has been observed growing in actual contact with plants of *Discaria* without showing any tendency to climb.

My suggestion is that *H. dimorphum* is a cross between the two, deriving its scendent habit from *H. filicaule*, and its strength and solidity of form, which enable it to become a true climber, from *H. depressum*. As regards the inflorescence, *H. dimorphum* appears to be more closely related to *H. depressum* than to *H. filicaule*. The flowers in my specimens are just sufficiently advanced to make this quite clear. The resemblance to the flower and involucre of *H. depressum* is very close indeed. The flower is sessile at the tips of the branches, as in *H. depressum*, not terminal on a long filiform peduncle, as in *H. filicaule*; and the involucral bracts in their number and arrangement are exactly like those of *H. depressum*, the involucre being rather cylindrical than hemispherical.

In support of the theory I should adduce the following considerations:—

(1.) In both its localities both *H. filicaule* and *H. depressum* are present at no great distance. In the Poulter locality the plant grows on the top of a high terrace (perhaps 60 ft. to 80 ft.) above the river, in whose bed *H. depressum* is abundant, while *H. filicaule* is present everywhere about it.

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(2.) The leafy parts strongly resemble *H. filicaule*, and the leafless parts *H. depressum*.

(3.) The plant is of extreme rarity, and this would be accounted for, in part, if *H. dimorphum* were a hybrid between the two plants named.

Postscript.

Since the above was written I have observed the plant in great quantities on the Lower Poulter, on the Esk River near its confluence with the Waimakariri, and along the Waimakariri itself between the confluence of the Poulter and that of the Esk with that river. The Esk mouth is not much more than five miles from the Puffer's Creek locality.

Art. XVII.—*On the Occurrence of Striated Boulders in a Palaeozoic Breccia near Taieri Mouth, Otago, New Zealand.*

By Professor James Park, 'F.G.S.

[Read before the Otago Institute, 9th December, 1919; received by Editor, 31st December, 1919; issued separately, 10th, June 1920.]

In a small cove close to Rocky Point, which is the first headland on the south side of Taieri Mouth, and about a mile and a half from the Taieri jetty, there is a conspicuous bed of coarse red and green breccia. It is underlain by bluish-grey micaceous phyllites, and overlain by altered flaggy greywacke. The strike of the breccia and associated rocks is about N.N.E.-S.S.W., and the dip S.S.E. at angles ranging from 5° to 30°. Generally the inclination of the lowermost beds is flatter than that of the uppermost beds. At Taieri Mouth the dip of the grey micaceous slaty rocks ranges from 5° to 15°, and that of the greywacke south of Rocky Point from 15° to 30°.

The breccia is well exposed in the sea-cliffs near Rocky Point, and can be traced northward along the line of strike one-third of the distance to Taieri Island as a line of submerged reef that is in places awash at low water. It is not present on Taieri Island.

To the southward of Rocky Point the breccia ought to crop out on the ridge between that place and Akatore Inlet, but I failed to find it there. It is a rock not easily overlooked, and I am inclined to believe that it peters out before it reaches the crest of the ridge. It is probably a lensshaped mass with a maximum thickness of some 120 ft.

At Rocky Point the breccia resembles a consolidated rock-rubble, being mainly composed of a confused pile of angular and subangular fragments and blocks of red and green siliceous slaty shale. It also contains numerous masses of an excessively hard jasperoid and aphanitic breccia that appear to have been torn from some pre-existing breccia. The constituent fragments range in size from small grains to masses many feet in diameter.

The largest block in the breccia occurs in place, at the foot of the sea-cliff in the first sandy cove south of Rocky Point. It is an included breccia-boulder, partially rounded at the corners and sides, compact, and intensely hard. It measures some 7.5 ft. by 5.3 ft. by 4.5 ft. Its upper surface is fairly flat, and covered with distinct striae that, as a rule, run parallel with the longer axis of the block. The area of the striated surface is about 10 square feet. Several of the smaller included blocks on the south side of the cove are similarly striated.

This remarkable rock resembles the typical Te Anau breccia of Sir James Hector. It is underlain, apparently conformably, by the semi-metamorphic Kakanui rocks of Hector, which everywhere in Otago overlie the mica-schists of Central Otago. There is no internal evidence to fix the age of the Kakanui rocks. All that can be said is that they underlie the Mount St. Mary series, which is Triassic, and overlie the mica-schists of the interior. The Te Anau series of Hector, as identified by him in Nelson, conformably underlies the Maitai series, which is now known to be Upper Carboniferous or Permo-Carboniferous. I have always found it difficult to separate the Te Anau rocks from the Maitai, and in 1910 grouped them as belonging to the same formation. Hector ascribed the Te Anau series to the Devonian period, the only evidence in favour of this being its inferior and conformable relationship to the Maitai, which he placed in the Carboniferous.

In Nelson and Marlborough, the rocks identified by Hector and McKay as belonging to the Te Anau series are underlain by semi-metamorphic rocks of supposed Kakanui age.

The Taieri Mouth breccia and overlying greywackes may very well belong to the Te Anau series of Hector, and the underlying grey silky micaceous phyllites to the Kakanui. If this position can be established, the Taieri Mouth breccia may be placed in the Upper Carboniferous or Permo-Carboniferous.

This is the first discovery of striated boulders in the Palaeozoic formations of New Zealand, and the origin of the striae is certain to give rise to some diversity of opinion.

The striation may be glacial or dynamical. If the striated boulders occurred along the fracture of a shear-plane I should ascribe the striation to shearing. Though

crushed and broken, the breccia shows no evidence of shearing along defined planes, and for this reason I am inclined to favour the glacial hypothesis.

If the glacial view be sustained we are at once confronted with the question—(a.) What relationship, if any, does the Taieri Mouth breccia bear to the glacial deposits reported in the Upper Palaeozoic formations of India,^{*} Australia,[†] South Africa,[‡] and Brazil[§]? (b.) Was the glaciation alpine or secular? (c.) Did the ancient Gondwana continent extend southward to the New Zealand area?

[Footnote] * H. B. Medlicott and W. T. Blanford, *Manual of the Geology of India*, pt. i, p. 110, 1879; and R. D. Oldham, *Quart. Jour. Geol. Soc.*, p. 469, 1894.

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[Footnote] § David White, Permo-Carboniferous Climatic Changes in South America, *Am. Jour. Geol.*, vol. 15, p. 618, 1907.

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Art. XVIII.—*The Tawhiti Series, East Cape District.*

By P. Marshall, M.A., D.Sc., F.G.S., F.N.Z.Inst., Hector and Hutton Medallist.

[Read before the Wanganui Philosophical Society, 3rd December, 1919; received by Editor, 31st December, 1919; issued separately, 10th June, 1920.]

The true geological position of the strata that are exposed on the coastline between Tokomaru Bay and the East Cape has never been definitely ascertained, for we have had to rely on rather incomplete statements of McKay. Fossils of a true Cretaceous nature were reported as occurring in some abundance near

Awanui. I visited the district in January, 1919, in company with Mr. J. A. Bartrum, with the primary object of making collections of fossils from the localities that were mentioned by McKay, in the hope that study of them would be of assistance in unravelling some of the debated points in regard to the relationship of the Cretaceous rocks to those of Tertiary age in New Zealand.

We spent two days on the coast near Awanui, but failed to find any of the ammonites and other fossils that were mentioned by McKay.^{*} The only fossil remains that we found were some fragments of *Inoceramus* near the wharf at Awanui and a number of small worm-tubes a little to the north of that place. *Inoceramus* was very abundant in the concretionary boulders on the north side of Tuparoa Bay, and there were also fossils in the marls on the south side of the bay. These, however, were badly preserved, and seemed to be of a distinctly Tertiary nature. The stratigraphy is extremely involved, and the strata have slipped so much, while the sections are so discontinuous, that in the limited time at our disposal we were quite unable to come to any detailed conclusions on the question of the relationship of the strata.

At Tawhiti Point, on the north side of Tokomaru Bay, fossils are quite numerous, and they are also abundant in the shell conglomerate which occurs on Tawhiti itself at an elevation of 500 ft. or more. From the former of these localities over a distance of about a mile along the coast from Kotunui Point a representative collection of fossils was made. McKay collected from these beds in 1872, and he made a further reference to them in 1886, when he classed them of Upper Miocene age.[†]

Hutton,[‡] in his paper on the geology of New Zealand, places the Tawhiti beds in the Pareora system, which is regarded by him as the equivalent of the Miocene of Europe.

No list of fossils that were found in these rocks has yet been published. The rocks are described by McKay as soft brown sandstones. We found that in their unweathered state they are of a grey colour and fine-grained. They are formed partly of small grains of quartz, with a good deal of partly-weathered feldspar, and black grains which seem to be volcanic glass. It is almost certain that the sand is of volcanic origin. The strata are considerably inclined, and strike 41° and dip 37° north-west. The thickness of the strata of which Tawhiti is composed is very considerable. Tawhiti itself rises to a height of 1,670 ft., and if the strike and

[Footnote] * A. McKay, *Rep. Geol. Explor. dur. 1873–74*, 1877, p. 124; *1886–87*, 1887, p. 214.

[Footnote] † A. McKay, *Rep. Geol. Explor. dur. 1873–74*, 1877, p. 147; *1886–87*, 1887, p. 210.

[Footnote] ‡ F. W. Hutton, *Quart. Journ. Geol. Soc.*, 1885, p. 209.

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dip remain the same throughout as at Kotunui Point there cannot be less than 3,000 ft. of rocks. Our collections were made from practically the lowest rocks that are exposed near Tawhiti. The rocks vary a good deal in coarseness and are concretionary in many of the strata, but the fossils did not appear to vary much, and we have made no attempt to distinguish between the faunas of any of the different strata. Actually the thickness of the strata from which we collected was quite small.

The following is a list of the fossils that were collected by Mr. Bartrum and myself. In identifying the species I have had the invaluable aid of Mr. R. Murdoch.

- *Anomia huttoni* (Sut.)
- *Astrea heliotropium* (Mart.)
- **Atrina* sp.
- **Calliostoma* sp.
- *Calyptaea* sp.
- **Conus* sp.
- **Corbula canaliculata* (Hutt.)
- *Corbula macilenta* (Hutt.)
- **Cucullaea worthingtoni* (Hutt.)
- **Cyllichnella enysi* (Hutt.)
- **Dentalium mantelli* (Zittel)
- *Dentalium nanum* (Hutt.)

- **Dentalium solidum* (Hutt.)
- **Diplodonta ampla* (Hutt.)
- **Divaricella* sp.
- *Dosinia greyi* (Zittel)
- *Dosinia lambata* (Gould)
- **Drillia aff. novae-zelandiae* (Reeve)
- **Galeodea senex* (Hutt.)
- **Galeodea sulcata* (Hutt.)
- *Glycymeris laticostata* (Q. & Q.) (thick form)
- **Macrocallista assimilis* (Hutt.)
- *Macrocallista multistriata* (Sow.)
- *Mactra ordinaria* (Smith)
- *Mactra scalpellum* (Reeve)
- *Malletia australis* (Q. & G.)
- *Myodora subrostrata* (E. A. Smith)
- *Natica australis* (Hutt.)
- **Natica callosa* (Hutt.)
- **Natica ovata* (Hutt.)
- *Nucula nitidula* (A. Ad.)
- *Nuculana fastidiosa* (A. Ad.)
- **Olivella neozelanica* (Hutt.)
- *Ostrea angasi* (Sow.)
- *Ostrea corrugata* (Hutt.)
- **Panope worthingtoni* (Hutt.)
- *Pecten convexus* (Q. & G.)

- **Pecten sectus* (Hutt.)
- *Pecten zelandiae* (Gray)
- *Protocardia pulchella* (Gray)
- **Sinum carinatum* (Hutt.)
- **Siphonalia conoidea* (Zittel)
- **Siphonalia costata* (Hutt.)
- **Siphonalia excelsa* (Sut.)
- **Siphonalia nodosa actuicostata* (Sut.)
- **Struhiolaria cincta* (Hutt.)
- *Tellina eugonia* (Sut.)
- *Tellina liliana* (Iredale)
- *Turritella symmetrica* (Hutt.)
- *Venericardia corbis* (Phil.)
- *Venericardia purpurata* (Desh.)
- **Voluta corrugata* (Hutt.)

Extinct species are distinguished by an asterisk. Several of the species that are unnamed are certainly extinct, but are not in a sufficiently good condition of preservation to allow of a satisfactory description being written.

This list contains fifty-two species, of which twenty-six are extinct—a percentage of 50. If this percentage of extinct species of mollusca is taken as a criterion for the correlation of the strata, the Tawhiti series must be almost exactly midway between the Target Gully series, where there are 35 per cent. of Recent species, and the Waipipi series, in which the percentage is 63. This position of the strata is suggested also by the very nature of the fauna. On the one hand *Olivella neozelanica* still persists, as well as *Diplodonta ampla*; while on the other hand a large number of species of Miocene occurrence appear, such as *Cucullaea worthingtoni*, *Siphonalia conoidea*, *S. costata*, *Galeodea senex*, &c. It is noticeable that there is no species of *Limopsis* in this collection, and that this genus is absent from those that have been made on the coast-line near Wanganui.

Art. XIX.—*The Hampden Beds and the New Zealand Tertiary Limestones.*

By P. Marshall, M.A., D.Sc., F.G.S., F.N.Z.Inst., Hector and Hutton Medallist.

[Read before the Wanganui Philosophical Society, 3rd December, 1919; received by Editor, 31st December, 1919; issued separately, 10th June, 1920.]

The facts that have recently come to light in regard to the palaeontology of the Hampden beds may be of some use in determining the relative ages of the Amuri and Oamaru limestones. The number of fossils that have been found actually in the Amuri limestone up to the present time is small but such as have been recorded suggest a Tertiary rather than a Cretaceous age. Within recent years, however, Thomson (1916, p. 51) and Speight (1917, p. 344) have found a fauna in tuff-beds interstratified with the upper portion of the Amuri limestone in the Treliwick Basin, in Canterbury.

The mollusca of this tuff-bed, so far as they have been collected up to the present time, number thirty-seven species, of which 19 per cent. are Recent. This is clearly a much later fauna than that of Hampden, for there the Recent species are no more than 10 per cent. of the total of eighty. If attention is focused more on the nature of the fauna than on the percentage the same conclusion will be reached, for the genera *Dicroloma*, *Trigonia*, *Gilbertia*, and even *Exilia*, of the Hampden fauna, have no representatives, or even counterpart, in the collections that have been made in the tuff-bed of the Treliwick Basin, the horizon of which is 10 ft. below the upper surface of the Amuri limestone as developed in that locality. It follows, if the palaeontological evidence is to be relied on, that the Hampden beds are considerably older than the upper portion of the Amuri limestone. If Thomson's statement is correct, that the Amuri limestone is Cretaceous at the base and Tertiary in its upper portion (*loc. cit.*, p. 51), the Hampden beds must represent some horizon in the middle or upper part of the Amuri limestone. Thomson's statement, however, is based rather on surmise than on actual fact, for up to the present time no fauna has been found in the deposits immediately at the base of the Amuri limestone, though at Amuri Bluff itself it is true that only

some 200 ft. of strata separate the beds with Cretaceous saurian remains from the base of the Amuri limestone.

Irrespective altogether of the accuracy of Thomson's statement, there is reason to believe that the Hampden beds are equivalent to some horizon of the Amuri limestone, or possibly to an horizon actually below the Amuri limestone. At Hampden itself there is no limestone, for on the fossil-bearing beds, which are mainly formed of greensand, there is a great thickness of submarine tuff, scoria, and other volcanic matter. The eruption of this apparently affected the sea-floor so much, and for such a long time, that all deposition of limestone was prevented. As a matter of fact, the first occurrence of limestone in this neighbourhood is at All Day Bay, fifteen miles farther north; and even there the limestone stratum is thin, and rests directly on submarine volcanic scoria. Since the regular succession of the Oamaru system in its upper members cannot be found at Hampden, some other neighbouring locality must be found where it is more complete, and where there are strata recognizable by their fossil contents as being of somewhat similar age to those of Hampden.

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Such a succession can be found near the Waihao Forks. Here the green-sand strata that are exposed on the right bank of the river, between the Forks and McCulloch's bridge, are similar lithologically to the Hampden beds, and there is a clear stratigraphical succession to the local representative of the Oamaru limestone above, as has been clearly shown by McKay, Park, Marshall, and all others except Hutton, who gave a most surprising account of the stratigraphy. Not only are the Waihao greensands similar lithologically to the Hampden beds, but there is also a close palaeontological similarity, for the following fossils which have not yet been found in any higher or, indeed, any other strata occur in both of them—*Polinices waihaoensis*, *Exilia waihaoensis*, *Turris regius*, *Turris complicatus*, *Surcula serotina*, *Fusinus solidus*, and *Euthriofusus spinosus*—though up to the present time only very small collections have been made in the Waihao beds. The Hampden beds may therefore be considered as of much the same age as, though perhaps a little older than, those at Waihao. In this locality, however,

the stratigraphy is not complicated by the occurrence of any strata of volcanic origin, and the greensands pass up without any break, and within a thickness of 100 ft. of strata, into a limestone which is thought by all observers except Park to be the local representative of the Oamaru limestone. No collection of fossils has yet been made from the limestone at the Waihao, but at Otiake, twenty miles distant, on the south side of the Waitaki River, there is a similar limestone, which is considered by all geologists who have examined this area to be of the same age, and in effect a continuation of the limestone stratum of the Waihao. At Otiake a collection of fossils was made by Marshall and others, who found sixty-one species, of which 24 per cent. were determined as Recent species.

The facts so far mentioned may be summarized as follows: At Coleridge Creek, in the Trelissick Basin, there is a fossiliferous horizon containing 19 per cent. of Recent species. This horizon is below the limestone (Speight, 1917, pp. 328 and 344), or 10 ft. below the upper surface of the Amuri limestone (Thomson, 1916, p. 51). In the greensands at Hampden there are 10 per cent. of Recent species. Lithologically and palaeonto-logically the Hampden beds are closely similar to those at the Waihao Forks, which pass up conformably into the arenaceous limestone. This limestone is always correlated with that at Otiake, which in its upper portion of 2 ft. or 3 ft. contains 24 per cent. of Recent species.

Such palaeontological evidence as we have at present therefore clearly points to the probability that the age of the Amuri limestone as developed in the Trelissick Basin is practically the same as the age of the Otiake limestone, which is admitted by all geologists except Park to be the same horizon as that of the Oamaru or Ototara limestone.

This consideration also shows that too much importance should not be attached to the absence of the Amuri limestone in Otago. This material is a *Globigerina ooze*, which was probably deposited on the floor of a deep, clear-water, oceanic area. The Oamaru or Ototara limestone was deposited in far shallower water, where Polyzoa abounded, but still outside the area to which sediment was carried. The Waihao and Otiake limestones, however, were deposited nearer to the shore, in an area to which terrigenous sediment was carried, and where tidal scour disturbed the sea-floor.

It seems unnecessary to call in the aid of local diastrophes to explain the differences between the Canterbury and Otago succession of Tertiary rocks, for, as I have often maintained, the differences that exist can easily be explained on general considerations. The Canterbury area was evidently

more deeply depressed during this middle Tertiary period than Otago, a fact that is clearly evidenced by the very nature of the Amuri limestone, which is often wholly composed of *Globigerina*, but in some cases of other pelagic organisms as well. In Otago, on the other hand, the limestones, whilst still free from all terrestrial sediment, consist mainly of organisms that live on the floor of moderately deep water only. While this is the case, however, it must still be remembered that at Oamaru the limestone rests on a deposit that is composed of diatoms, Radiolaria, and sponge-spicules. Park (1918, p. 50) has lately maintained that this is really a shallow-water deposit, an opinion that is based partly on the general geology of the district and partly on the nature of the mollusca and brachiopods that are found in the deposit. The fossil species to which he refers are not named. In a collection made by me in June, 1915, the following mollusca were obtained: *Amusium zitteli* (Hutton), *Nuculana (Leda)* sp., *Lima* sp. (small), and *Terebratulina suessi* (Zittel). These are all genera that have a wide occurrence in deep water, and until a list is published which contains the names of other mollusca, that have a shallow-water habitat there is no reason to suppose that the molluscan remains in these diatomaceous deposits are incompatible with the accumulation of the material on a deep oceanic floor. There is no reason to suppose that the water was of the same depth over all that portion of New Zealand that was then covered by the ocean. In Canterbury the area in which the Amuri limestone occurs was covered by deeper water than that portion of Otago where the Oamaru or Ototara limestone is found. It may therefore fairly be said that all the palaeontological evidence that is known at the present time supports the belief that the Oamaru limestone represents an horizon of the Amuri limestone, and that there are no stratigraphical or structural facts known that oppose this conclusion.

In the north of Auckland the so-called hydraulic limestone covers a large area. This limestone is also composed mainly of *Globigerina* ooze, and, like the Amuri limestone, it is often highly siliceous, and in places the siliceous organisms are calcified, though at others diatoms, Radiolaria, and sponge-spicules are in a perfectly fresh condition and can be obtained in large numbers. This limestone has generally been correlated with the Amuri limestone of Canterbury, and Thomson's objection to this has already been refuted (Marshall, 1919, p. 248, footnote). In addition, however, to the general stratigraphical position of this

limestone, there is palaeontological evidence of considerable importance. At Pahi, on the Arapaoa arm of the Kaipara Harbour, there is on the foreshore a little to the west of Pahi Township a bed of greensand lying between two beds of the hydraulic limestone. This greensand contains a considerable number of fossils, as first noted by Park. The fossils, however, are in a bad state of preservation, and only a few of them can be identified specifically. The following were collected in 1916:—

- *Atrina* sp.
- *Calliostoma* sp.
- *Cassidea* n. sp.
- *Corbula canaliculata* (Hutt.)
- *Cucullaea alta* (Sow.)
- *Cytherea* sp.
- *Dentalium solidum* (Hutt.)
- *Divaricella aff. cumingi* (Ad. & Ang.)
- *Limopsis zitteli* (Iher.)
- *Nucula* sp.
- *Nuculana aff. bellula* (A. Ad.)
- *Ostrea aff. corrugata* (Hutt.)
- *Panope worthingtoni* (Hutt.)
- *Polinices gibbosus* (Hutt.)
- *Psammobia* sp.
- *Struthiolaria* sp.
- *Surcula* n. sp.
- *Tellina* sp.
- *Turritella ambulacrum* (Sow.)
- *Venericardia aff. australis* (Lamk.)

Although this list is short and many species are not identified, it can be asserted that not more than two are Recent species, and even these are doubtful. The new species of *Surcula* is of considerable interest, for it belongs to the group that contains *S. hamiltoni*, *S. gradata*, and *S. torticostata*, all of which are restricted to the strata that lie beneath the limestone near Oamaru. The horizon is probably a little higher than the Hampden series, but also lower than the lower fossiliferous bed in the Treliwick Basin, to which reference has previously been made.

The hydraulic limestone of the Kaipara Harbour is thus, from a consideration of such palaeontological evidence as is available, seen to be of approximately the same age as the Amuri limestone of the Treliwick Basin.

The following changes and additions must be made to the list of the Hampden molluscan fauna given in *Trans. N.Z. Inst.*, vol. 51, p. 235, 1919:—

Siphonalia nodosa Martyn to be *Siphonalia nodosa acuticostata* (Suter).

Volutoderma zelandica Marshall to be *Borsonia zelandica* (Marshall).

The list of additions that is given below includes the species mentioned in the footnote on the page cited above:—

- *Admete anomala* (Marshall and Murdoch)
- *Epitonium aff. gracillimum* (Sut.)
- *Epitonium parvicostatum* (Marshall)
- *Euthriofusus spinosus* (Sut.)
- *Fusinus* sp. (fragments only)
- *Fusinus aff. morgani* (Sut.)
- *Leptoconus armoricus pseudoarmoricus* (Marshall and Murdoch)

- *Limopsis aurita* (Brocchi)
- *Limopsis catenata* (Sut.)
- *Nucula* n. sp.
- *Nuculana semiteres* (Hutt.)
- *Pecten aff. fischeri* (Zittel)
- *Phos* sp. (fragments only)
- *Protocardia pulchella* (Gray)
- *Rissoina obliquecostata* (Marshall and Murdoch)
- *Seila attenuissima* (Marshall and Murdoch)
- *Sinum carinatum* (Hutt.)
- *Siphonalia senilis* (Marshall and Murdoch)
- *Soletellina* n. sp.
- *Surcula hampdenensis* (Marshall and Murdoch)
- *Trifora aoteaensis* (Marshall and Murdoch)
- *Turris curialis* (Marshall and Murdoch)

This list raises the total to ninety-three species, of which some thirty-nine have not been found elsewhere. *Siphonalia nodosa* is now taken out of the list, and *Protocardia pulchella* and *Limopsis aurita* are added to the number of Recent species, which now number eight, a percentage of only 8.7. Cossman has pointed out that the identification of *Limopsis aurita* in New Zealand is an error, and that the species should be called *L. zelandica* Hutton. It is placed here under *L. aurita* because in other lists of Oamaru strata this identification has been made.

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Art. XX.—*The Tertiary Rocks near Wanganui.*

By P. Marshall, M.A., D.Sc., F.G.S., F.N.Z.Inst., Hector and Hutton Medallist, and R. Murdoch.

[*Read before the Wanganui Philosophical Society, 3rd December, 1919; received by Editor, 31st December, 1919; issued separately, 10th June, 1920.*]

The marine strata that occur in the neighbourhood of Wanganui have long been the subject of geological inquiry and research. As developed along the coast-line they are richly fossiliferous almost throughout their extent, and the fossils that they contain are so closely related to the Recent molluscan fauna that the rocks have always been referred to the higher divisions of the Tertiary era. A *résumé* of the earlier work that had been published on these sediments was given by Hutton (1886, p. 338), and it is in general unnecessary to refer to it here. In that paper also Hutton gave for the first time a fairly complete list of the mollusca that had been collected from the Wanganui system up to that date. The list, however, contains also a number of species that had been found in the strata at Matapiro and Petane, in Hawke's Bay, which were considered by Hutton to be of equivalent geological age.

In his Wanganui system Hutton included the blue clays at Castlecliff and the blue clays at Patea, but he makes no reference to the rocks that outcrop on the coast between those places—the mouth of the Wanganui River and that of the Patea River.

A fuller list, but based upon the same principles and containing descriptions of a number of additional species, was published by Hutton subsequently (1893, p. 35 *et seq.*).

In these papers Hutton rarely makes any statement as to the actual Wanganui locality at which the various species were found. For that reason none of his lists can be utilized in any statement of the species that occur in the beds at Castlecliff and elsewhere along the coast. This is the more regrettable because many of the new species that were described in the *Macleay Memorial Volume* were found by Drew in the marine cliffs somewhere to the north of Castlecliff.

Hutton (1886, p. 337) took this course deliberately, for he says, "In order to save space I have not thought it necessary to give separate lists of the fossils from each locality, but have contented myself with one list of all the species that have been found in the Wanganui system," but the work that has been done "will enable local geologists to fill in the details." This additional work has not been done up to the present time, and the details that have to be filled in are so numerous that much time must elapse before anything approaching a complete result is achieved.

Park (1887) examined all the Wanganui and west-coast district for the Geological Survey, and in his report there are lists of fossils that he collected from the various strata that crop out on the coast-line and on the banks of the Wanganui River, as well as a number of other adjacent localities. The lists that he gives are, however, far from complete, though they reveal the occurrence of a large number of extinct species, such as *Pecten triphooki*, *Pecten semiplicatus*, *Ostrea ingens*, *Cardium spatiostum*, and *Perna* sp., several of which were regarded by Hutton as characteristic of his Pareora system, of Upper Miocene age.

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In 1916 Thomson proposed to divide the rocks exposed on the Wanganui coast-line into the Castlecliffian and Waitotaran series. This proposal, however, was not based on any further work, but merely on a consideration of Park's work and of the lists of fossils that he had recorded.

Murdoch (1900, p. 216) described further species that had been collected by himself and others from the blue clays in the Castlecliff area.

All of the strata on the coast-line north of Wanganui, as far at least as Patea, were placed by Hutton (1885, p. 211) in the Pliocene system. Hector (1886, p. 48) placed the strata partly in the Upper Miocene. Park (1887, p. 57) placed the beds near Wanganui in the Upper Pliocene, those at Nukumaru in the Lower Pliocene, and those between Waitotara and Patea in the Upper Miocene.

The present work was undertaken partly to discover the thickness of the strata exposed on the coast-line, and partly to find out as accurately as possible the extent to which the fauna changed as the depth in the strata, and therefore the geological age, increased. At first the intention was to collect the fossils in every stratum in which they could be found, and to make a separate list of the fauna in every case. The great number of fossil-bearing strata soon showed that such a project was impracticable, and that for the present purpose it was also undesirable, for each single stratum contains a small fauna only. If the fauna of each stratum were taken separately there would result a very large number of lists, and the comparison of these would lead to much confusion. For these reasons four different collecting localities have been chosen, and in each instance a thickness of about 500 ft. of sediment has been searched carefully, and as complete a collection as possible has been made from it. The lists that have been made cannot in general be regarded as in any way exhaustive, but in nearly every instance several visits have been made by two collectors in company. The Castlecliff locality has probably been almost completely collected, for much time has been spent in the study of the strata there, because it is most accessible. The late S. H. Drew obtained a large number of fossils there, and one of us has collected in these strata for a number of years, and of late times it is only rarely that any additions have been made to previous lists.

The localities that have been chosen as suitable for the comparison of faunas are as follows:—

(1.) *Castlecliff*.—A thickness of about 500 ft. of strata, commencing at the southernmost end of the sea-cliffs and ending about a mile and a half from the mouth of the Wanganui River. Nearly every stratum in this thickness is fossil-bearing. Almost all of the strata consist of a fine but hard blue clay—the so-called "papa." The fineness and general nature of this material, as well as the mollusca that it contains, give the impression that the material was deposited on the floor of a sea that was not less than 50 fathoms in depth in this locality. As the strata are followed to the north and rise in the cliffs the material becomes a little coarser, and often changes to a micaceous sand before it works out at the top of the cliff. This apparently indicates that the water became shallower in the northern part of the district. This conclusion is supported by the nature of the fossil mollusca which have been found in the sandy facies of the strata.

(2.) *Kai Iwi*.—This locality is five miles to the north of the previous one. The rocks which extend about a mile to the south of the Kai Iwi Stream form the source of the collections classified under this name. The material is almost entirely blue

clay of a fine unctuous nature. The collection that has been made is less complete than those made in the other localities.

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(3.) *Nukumaru Beach*.—This locality is six miles to the north of Kai Iwi, and extends over a distance of one mile to the south of the boat-landing. The strata here are of a much coarser grain and are highly micaceous. In some of the strata there are pebbly bands. The pebbles are formed of extremely hard submetamorphic sandstones, or greywackes, often penetrated by quartz veins. Many of them are of a green tint. Much of the fossiliferous material in this locality is of a concretionary nature.

(4.) *Waipipi Beach*.—This is nine miles north of Nukumaru. The strata here consist of a stiff and fine blue clay, with occasional bands of fine micaceous sandy matter. It is mainly in these bands that the fossils are found. The best localities are directly north of the mouth of the Waipipi Stream and on a projecting headland three-quarters of a mile farther to the north. Sometimes as the sand drifts with changing winds and tides very fine fossils are exposed above low-tide level between these two localities.

It may be said definitely that lithologically the strata are of the same general nature throughout. A bluish-grey fine-grained sediment is the ordinary material. This in places becomes sandy, especially between Kai Iwi and Nukumaru, where there is much false bedding, due apparently to rough-weather and tidal scouring, for there does not appear to be any actual beach formation. Sometimes the fossiliferous bands have an extremely marked concretionary nature, and then the rock becomes a hard arenaceous limestone; but this is always a shoal-water rock, and it generally contains a number of small pebbles. This is the nature of the Nukumaru limestone, which is really a shell conglomerate. This hard rock fronts the coast for a distance of some three miles north of Nukumaru Beach.

The strata always strike to the east of north. The most northerly strike is N. 27° E., at the mouth of the Waipipi Stream, and the most easterly N. 85° E., near the

mouth of the Kai Iwi Stream. The average throughout the whole distance is considered to be N. 70° E. The dip is always to the south-east, and its amount is small throughout—never more than 6° and never less than 2½°. The average is considered to be a little over 4°.

No dislocations of any importance have been seen in the strata, though the sea-cliffs, which are continuous from Castlecliff to three miles north of Nukumaru, have been closely inspected throughout the whole distance. There are some small faults, but they always have a slight throw only. Nothing of the nature of an important unconformity can be seen. Three miles to the north of Kai Iwi an old land-surface can be seen distinctly in the stratification. The evidence of this is found in a stratum of beach-worn pebbles, a carbonaceous stratum with roots penetrating the blue clay beneath, and a number of molluscan bores penetrating it. There is, however, no discordance in the stratification, and no species of mollusca were found in the strata lying just above the old land-surface different from those that were found beneath it. It is, however, noticeable that *Crepidula gregaria* was far more abundant in the rocks below than in those above this old surface. The structure is certainly due to a purely temporary emergence of what was probably a small portion of the area of deposition.

There is another instance of interbedded carbonaceous matter and of penetrating roots near the south end of the Nukumaru Beach, a quarter of a mile to the south of the place where the fossil moa-bones were found. This is a far less marked instance than the former one. These

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two instances emphasize the shallow-water nature of the strata in the Nukumaru—Kai Iwi section, and they show also that there were temporary oscillations in the level of the land whilst the deposition of these rocks was in progress.

The continuity of the stratigraphical succession is, however, well shown by the nature of the fossil mollusca which are contained in the rocks, for they display a nearly uniform gradual change as one proceeds northward along the coast-line,

and therefore into lower strata. It has already been suggested that the small pebbles in some of the strata came from the northwest of Nelson, but no suggestion has yet been made as to the source of the great mass of the blue clay, which constitutes by far the greater part of these younger Tertiary sediments. One of the most notable features of the mineralogical composition of this blue clay is its highly micaceous nature. The mica is muscovite, and whenever a coarser stratum than usual occurs the mica flakes in particular are of such a large size that the only origin that can reasonably be assigned to them is a granitic rock. There is at the present time no such rock known to occur in the North Island, and unless some large pre-existing mass has been submerged, or covered up by sediments, we must look to the South Island for the rock-mass from which all this sediment was derived. There is no reason to think that any previously existing granite mass in the North Island is now concealed from view, and it is to the South Island that our attention is at once directed.

In the north-west of Nelson there is now a large area of country which is composed of a granite. It is suggested that it is from this rock that the younger Tertiary sediments of the Wanganui district were derived. It is true that so far as that granite is known there is not a great deal of muscovite in its composition; but up to the present time little petrographical work has been done on the rock, and it is quite possible that a portion of the granite, which crops out over an area of some 800 square miles, is more micaceous than the few specimens that have been closely examined. It is true also that on its seaward margin the granite has a superficial covering of Tertiary rocks of a greater age than the Wanganui series of sediments. The granite mountains rise, however, to a height of 6,000 ft., and no Tertiary sediments are exposed at a greater height than 2,000 ft. It is a fact also that no granite pebbles have been found in the coarser strata that often occur in the Wanganui sediments. This objection, however, is not a strong one, because the granite is notoriously friable, and no pebbles are found on the long beach of Farewell Spit, which is mainly composed of detritus from the granite.

At the present time there is no material on the beaches of the Wanganui coast that could have a granite origin assigned to it, and the depth of the north-west entrance of Cook Strait is too great to allow of the drift of any such material from the South Island, especially when the strong inflow and outflow of tides through the strait is considered. If the origin of the sediment is to be traced to the Karamea granite, as is here suggested, Cook Strait must at that time have been closed, and a continuous beach must have extended from Kahurangi Point to the Wanganui area.

The thickness of the sediments is a matter of great importance in the subject of this paper. The direction of the strike is, on the whole, so constant, and makes such a considerable angle with the coast-line, that it is at once evident that in a distance of twenty miles along the coast a great thickness of sediment must be passed through. Taking the average of the dip and strike mentioned above (strike 70° and dip $4\frac{1}{2}^{\circ}$), it is found that the thickness of rocks between Castlecliff and

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thickness between Kai Iwi and Nukumaru is 1,050 ft., and that between Nukumaru and Waipipi is 1,450 ft. If the rate at which these sediments were deposited can be approximately estimated, it should be possible to calculate the time at which various species of mollusca made their last appearance. It is generally estimated that the average rate of deposition of sediment amounts to about 1 ft. in 100 years (Sollas, 1905, p. 24). This estimate, of course, cannot have a precise application in all actual cases, if in any one, because in every case the true rate must depend upon the size of the country that is being denuded and is supplying the sediment, upon the hardness of the rock of which this country is mainly composed, and, of course, upon the distance from the coast-line of the area in which deposition is taking place.

In the present instance the area of land which was undergoing denudation was probably small, and therefore supplied sediment at a slow rate. Whether the land was composed of granite rock or was in part formed of sediments that had been derived from granite and raised above the sea-level a little while earlier and again submitted to denudation is by no means certain. On the one hand, the fact that from Karioi to Waiouru, sixty miles inland, rocks of this very young Tertiary age were being deposited points to the conclusion that there was at this time a wide extent of shallow sea in the Wanganui district. On the other hand, the interbedded land-surface near the mouth of the Okehu Stream supports the idea that a part at least of the huge Tertiary area to the north was above the sea-level for a portion at least of the period of deposition. If that was the case sediment would have been supplied at a relatively rapid rate. Until the country to the north has been more fully examined with the object of ascertaining how large an area is bare of a covering of these youngest Tertiary rocks it is not safe to offer any opinion on this matter. Much of the sediment was deposited at a considerable distance from the coast-line, and in water of considerable depth. This is proved both by the finegrained texture of the sediment and by the nature of the fossil mollusca embedded in it. The sediment is generally of an extremely fine grain and contains

a large proportion of small mica plates, two features which point to deposition in an area which was reached by the finest and lightest sediment only.

The fossil mollusca found over the first five miles north of Castlecliff are of a nature which indicates that the sea-floor was at a depth of between 50 and 100 fathoms. At Kai Iwi the depth of the water was probably nearer the former than the latter figure. If this were the case the rate of deposition must have been a very slow one. Thus the following considerations point to the probability of slow deposition: (1) The small size of the land area from which the sediment was derived; (2) the hard nature of the rocks that were undergoing denudation; (3) the distance of the area of deposition from the area of denudation; (4) the depth of water in which the deposition took place. On the other hand, it is possible that—(1) some of the material was derived from older Tertiary rocks only lately deposited (if that were the case the deposition area may have been quite close to that of denudation); (2) some of the strata were deposited under shallow-water conditions and close to the shore-line. A balancing of these considerations inclines us to the opinion that the material was possibly deposited at the rate of 1 ft. of sediment in 200 years. If this rate of accumulation is applied generally to the thicknesses of sediment that have been already mentioned, we find that the Waipipi beds are 690,000 years older, those at Nukumaru 400,000 years older, and those at Kai Iwi 190,000 years older than the Castlecliff beds.

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Fossils from Castlecliff.

The collections in this locality were made in the marine cliffs over a distance of two miles from the Castlecliff end. The rocks are everywhere blue clay, or "papa," which, however, has a tendency to become more sandy as the strata rise in the face of the cliff when they are followed to the northward. This probably indicates that the water became rather more shallow in this direction—a conclusion which is supported by the very nature of the mollusca that are found in them as they are followed northwards.

In the following lists extinct species are marked with an asterisk.

- *Acanthochites zelandicus* (Q. & G.)
- *Acmaea daedala* (Sut.)
- **Acteon sulcatus* (Hutt.)
- *Alcira inconstans* (Sut.)
- *Amphidesma gaymardi* (Desh.)
- *Amphidesma ventricosa* (Gray)
- *Ancilla australis* (Sow.)
- *Ancilla australis pyramidalis* (Reeve)
- *Ancilla depressa* (Sow.)
- *Ancilla mucronata* (Sow.)
- *Ancilla novae-zelandiae* (Sow.)
- *Arca novae-zelandiae* (E.A. Smith)
- [= *decussata* Sut., not Sow.]
- *Argobuccinum australasia* (Perry)
- *Astrea heliotropium* (Mart.)
- *Atrina zelandica* (Gray)
- *Barnea similis* (Gray)
- *Bathytoma albula* (Hutt.)
- *Bathytoma nodilirata* (Murd. & Sut.)
- *Bathytoma zealandica* (E. A. Smith)
- [= *cheesemani* (Hutt.)]
- **Bezanconia huttoni* (Coss.)
- *Caecum digitulum* (Hedley)
- **Calliostoma hodgei* (Hutt.)

- *Calliostoma pellucidum* (Val.)
- **Calliostoma ponderosum* (Hutt.)
- *Calliostoma punctulatum* (Mart.)
- *Calliostoma selectum* (Chemn.)
- *Calyptrea alta* (Hutt.)
- *Calyptrea novae - zelandiae* Lesson [= *maculata* (Q. & G.)]
- *Calyptrea tenuis* (Gray)
- *Cantharidus sanguineus* (Gray)
- *Cardita calyculata* (L.)
- *Chione mesodesma* (Q. & G.)
- *Chione spissa* (Desh.)
- *Chione stutchburyi* (Gray)
- *Chione yatei* (Gray)
- *Cominella lurida* (Phil.)
- *Cominella virgata* (A. Ad.)
- *Corbula macilenta* (Hutt.)
- *Corbula zelandica* (Q. & G.)
- **Couthouyia exilis* (Murdoch)
- *Crepidula costata* (Sow.)
- *Crepidula monoxyla* (Less.)
- *Cylichnella striata* (Hutt.)
- *Cymatium spengleri* (Chemn.)
- *Cytherea oblonga* (Hanley)
- *Daphnella cancellata* (Hutt.)
- *Daphnella lacunosa* (Hutt.)

- *Daphnella striata* (Hutt.)
- *Dentalium ecostatum* (T. W. Kirk)
- *Dentalium huttoni* (T. W. Kirk)
- *Dentalium zelandicum* (Sow.)
- *Diplodonta zelandica* (Gray)
- *Divaricella cumingi* (Ad. & Ang.)
- *Dosinia anus* (Phil.)
- *Dosinia greyi* (Zittel)
- *Dosinia subrosea* (Gray)
- **Drillia buchanani* (Hutt.)
- *Drillia laevis* (Hutt.)
- *Drillia novae-zelandiae* (Reeve)
- **Drillia wanganuiensis* (Hutt.)
- *Emarginula striatula* (Q. & G.)
- *Epitonium zelebori* (D [unclear:] ker)
- *Erycina parva* (Desh.)
- *Ethalia zelandica* (H. & J.)
- *Euthria linea* (Mart.)
- *Euthria linea traversi* (Hutt.)
- *Euthria littorinoides* (Reeve)
- *Euthria striata* (Hutt.)
- *Fissuridea monilifera* (Hutt.)
- *Fusinus spiralis* (A. Ad.)
- *Glycymeris laticostata* (Q. & G.)
- *Glycymeris modesta* (Angas)

- **Hipponix radiatus* (Hutt.)
- *Kellia suborbicularis* (Mont.)
- *Leptomya perconfusa* (Iredale)
- *Leptothyra fluctuata* (Hutt.)
- *Lima angulata* (Sow.)
- *Lima bullata* (Born)
- *Lima lima* (L.)
- *Liotia benhami* (Sut.)
- *Lissospira corulum* (Hutt.)
- *Lucinida concinna* (Hutt.)
- *Macoma edgari* (Iredale)

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- *Macrocallista multistriata* (Sow.)
- *Mactra discors* (Gray)
- *Mactra elongata* (Q. & G.)
- *Mactra ovata* (Gray)
- *Mactra scalpellum* (Reeve)
- *Malletia australis* (Q. & G.)
- *Mangilia amoena* (E. A. Smith)

- *Mangilia sinclairi* (E. A. Smith)
- *Mitrella choava* (Reeve)
- *Modiolus australis* (Gray)
- *Murex angasi* (Crosse)
- *Murex octogonus* (Q. & G.)
- *Murex octogonus umbilicatus* (T. -Woods)
- *Murex zelandicus* (Q. & G.)
- *Musculus impactus* (Herm.)
- *Myodora antipodum* (E. A. Smith)
- *Myodora striata* (Q. & G.)
- *Myodora subrostrata* (E. A. Smith)
- *Mytilus canaliculus* (Mart.)
- *Mytilus edulis* (L.)
- *Mytilus maorianus* (Iredale)
- *Natica australis* (Hutt.)
- *Natica zelandica* (Q. & G.)
- *Nucula hartvigiana* (Pfr.)
- *Nucula nitidula* (A. Ad.)
- *Nuculana bellula* (A. Ad.)
- *Nuculana fastidiosa* (A. Ad.)
- *Odostomia bembix* (Sut.)
- *Odostomia huttoni* (Sut.)
- *Odostomia rugata* (Hutt.)
- *Ostrea angasi* (Sow.)
- *Ostrea corrugata* (Hutt.)

- *Panope zelandica* (Q. & G.)
- *Paphia intermedia* (Q. & G.)
- *Pecten convexus* (Q. & G.)
- *Pecten medius* (Lamk.)
- *Pecten radiatus* (Hutt.)
- *Pecten zelandiae* (Gray)
- *Phalium achatinum pyrum* (Lamk.)
- **Philobrya trigonopsis* (Hutt.)
- *Protocardia pulchella* (Gray)
- *Psammobia lineolata* (Gray)
- *Psammobia stangeri* (Gray)
- *Psammobia zelandica* (Desh.)
- *Pupa affinis* (A. Ad.)
- *Pupa alba* (Hutt.)
- **Rissoa semisulcata* (Hutt.) [”*Lironoba*“]
- *Rissoina chathamensis* (Hutt.) [= *R. rugulosa* (Hutt.)]
- *Rissoina emarginata* (Hutt.) [”*Nozeba*“]
- *Rissoina olivacea* (Hutt.) [”*Dardanula*“]
- *Rochefortia reniformis* (Sut.)
- *Saxicava arctica* (L.)
- *Seila terebelloides* (Mts.)
- *Sinum undulatum* (Hutt.)
- *Siphonalia caudata* (Q. & G.)
- *Siphonalia dilatata* (Q. & G.)
- *Siphonalia mandarina* (Duclos)

- *Siphonalia nodosa* (Mart.)
- *Siphonalia valedicta* (Wats.)
- *Solariella egena* (Gould)
- *Soletellina nitida* (Gray)
- *Spisula equilateralis* (Desh.)
- *Spisula ordinaria* (E. A. Smith)
- *Struthiolaria papulosa* (Mart.)
- *Struthiolaria vermis* (Mart.)
- **Surcula castlecliffensis* (Marshall and Murdoch)
- *Tellina eugonia* (Sut.)
- *Tellina huttoni sterrha* (Sut.)
- *Tellina liliana* (Iredale)
- *Tellina spenceri* (Sut.)
- *Terebra tristis* (Desh.)
- **Thracia vegrandis* (Marshall and Murdoch)
- *Thracia vitrea* (Hutt.)
- *Tornatina pachys* (Wats.)
- *Trichotropis clathrata* (Sow.)
- **Trochus conicus* (Hutt.)
- *Trochus tiaratus* (Q. & G.)
- *Trochus viridis* (Gmel.)
- *Trophon ambiguus* (Phil.)
- *Trophon cheesemani* (Hutt.)
- *Trophon pumila* Sut. [= *T. bonneti* Cossm.]
- *Tugalia intermedia* (Reeve)

- *Turbo granosus* (Mart.)
- *Turbo smaragdus* (Mart.)
- *Turbanilla zealandica* (Hutt.)
- *Turritella carlottae* (Wats.)
- *Turritella rosea* (Q. & G.)
- *Turritella symmetrica* (Hutt.)
- *Venericardia lutea* (Hutt.)
- *Venericardia purpurata* (Desh.)
- *Venericardia unidentata* (Basterot)
- *Vexillum marginatum* (Hutt.)
- *Vexillum rubiginosum* (Hutt.)
- *Voluta arabica* (Mart.)
- *Voluta arabica elongata* (Swains.)
- *Voluta gracilis* (Swains.)
- *Xymene plebejus* (Hutt.)
- *Zenatia acinaces* (Q. & G.)

The total number of species is 181, of which 92.8 per cent. are Recent.

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In this locality collections were made for a distance of three-quarters of a mile south of the mouth of the Kai Iwi Stream. The collection was made by one of us (Marshall) in a single day's excursion, and it is probable that the list will have a large number of additions made to it in the future.

- *Acteon sulcatus* (Hutt.)
- *Alcira inconstans* (Sut.)
- *Ancilla australis* (Sow.)
- *Arca reticulata* (Gmel.)
- *Atrina zelandiae* (Gray)
- *Barnea similis* (Gray)
- **Bezanconia huttoni* (Cossm.)
- **Calliostoma hodgei* (Hutt.)
- *Calliostoma punctulatum* (Mart.)
- *Calliostoma selectum* (Chenn.)
- *Calyptrea novae-zelandiae* (Lesson)
- *Calyptrea tenuis* (Gray)
- *Cantharidus sanguineus* (Gray)
- *Cardita calyculata* (L.)
- *Chione mesodesma* (Q. & G.)
- *Cominella virgata* (A. Ad.)
- *Corbula macilenta* (Hutt.)
- *Cytherea oblonga* (Hanley)
- *Daphnella cancellata* (Hutt.)
- *Dentalium ecostatum* (T. W. Kirk)
- *Dentalium nanum* (Hutt.)
- *Divaricella cumingi* (Ad. & Ang.)

- **Drillia buchanani* (Hutt.)
- *Drillia novae-zelandiae* (Reeve)
- **Drillia wanganuiensis* (Hutt.)
- *Emarginula striatula* (Q. & G.)
- *Epitonium zelebori* (Dkr.)
- *Erycina parva* (Desh.)
- *Euthria littorinoides* (Reeve)
- *Glycymeris modesta* (Angas)
- *Leptomyia perconfusa* (Iredale)
- *Lucinida concinna* (Hutt.)
- *Macoma edgari* (Iredale)
- *Macrocallista multistriata* (Sow.)
- *Mactra scalpellum* (Reeve)
- *Malletia australis* (Q. & G.)
- *Mangilia amoena* (E. A. Smith)
- *Murex angasi* (Crosse)
- *Murex zelandicus* (Q. & G.)
- *Myodora antipodum* (E. A. Smith)
- *Natica australis* (Hutt.)
- *Natica zelandica* (Q. & G.)
- *Nucula nitidula* (A. Ad.)
- *Nuculana bellula* (A. Ad.)
- *Odostomia bembix* (Sut.)
- *Ostrea corrugata* (Hutt.)
- *Panope zelandica* (Q. & G.)

- *Pecten zelandiae* (Gray)
- **Philobrya trigonopsis* (Hutt.)
- *Poroleda lanceolata* (Hutt.)
- *Protocardia pulchella* (Gray)
- *Psammobia lineolata* (Gray)
- *Saxicava arctica* (L.)
- **Serpulorbis siphon* (Lamk.)
- *Sinum undulatum* (Hutt.)
- *Siphonalia caudata* (Q. & G.)
- *Siphonalia mandarina* (Duclos)
- *Siphonalia nodosa* (Mart.)
- *Spisula ordinaria* (E. A. Smith)
- *Struthiolaria papulosa* (Mart.)
- *Struthiolaria vermis* (Mart.)
- **Surcula castlecliffensis* (Marshall and Murdoch)
- *Tellina eugonia* (Sut.)
- *Terebra tristis* (Desh.)
- *Trichotropis clathrata* (Sow.)
- **Trochus conicus* (Hutt.)
- *Trochus tiaratus* (Q. & G.)
- *Trophon ambiguus* (Phil.)
- *Trophon cheesemani* (Hutt.)
- *Trophon corticatus* (Hutt.)
- *Trophon pumila* (Sut.)
- *Tugalia intermedia* (Reeve)

- *Turritella rosea* (Q. & G.)
- *Turritella symmetrica* (Hutt.)
- *Venericardia lutea* (Hutt.)
- *Venericardia purpurata* (Desh.)
- *Venericardia unidentata* (Bast.)
- *Vexillum planatum* (Hutt.)
- *Vexillum rubiginosum* (Hutt.)
- *Voluta gracilis* (Swains.)
- **Xymene expansus* (Hutt.)
- *Xymene plebejus* (Hutt.)

This list contains eighty-two species, of which eight are extinct. The percentage of Recent species is therefore 90.25.

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Fossils from Nukumaru.

Collections were made over a distance of one mile south from the Nukumaru boat-landing. One of us (Marshall) spent four days in collecting in this locality, and the other (Murdoch) spent two days. These are the *Rotella* beds of Park (1887, p. 63).

- *Acanthochites zelandicus* (Q. & G.)
- *Alcira inconstans* (Sut.)

- **Amphidesma crassiformis* n. sp.
- *Amphidesma gaymardi* (Desh.)
- **Anachis pisaniopsis* (Hutt.)
- *Ancilla australis* (Sow.)
- *Ancilla depressa* (Sow.)
- *Ancilla novae-zelandiae* (Sow.)
- *Anomia huttoni* (Sut.)
- **Ataxocerithium perplexum* (Marshall and Murdoch)
- *Barnea similis* (Gray)
- **Calliostoma hodgei* (Hutt.)
- *Calliostoma pellucidum* (Val.)
- *Calliostoma punctulatum* (Mart.)
- *Calyptera alta* (Hutt.)
- *Calyptera tenuis* (Gray)
- *Cantharidus sanguineus* (Gray)
- *Cardita calyculata* (L.)
- *Chione mesodesma* (Q. & G.)
- *Chione spissa* (Desh.)
- *Chione yatei* (Gray)
- *Cochlodesma angasi* (C. & F.)
- *Cominella lurida* (Phil.)
- *Cominella virgata* (A. Ad.)
- *Crepidula crepidula* (L.)
- **Crepidula gregaria* (Sow.)
- *Cylichnella striata* (Hutt.)

- *Cytherea oblonga* (Hanley)
- **Diplodonta ampla* (Hutt.)
- *Diplodonta zelandica* (Gray)
- *Dosinia anus* (Phil.)
- *Dosinia subrosea* (Gray)
- *Epitonium zelebori* (Dkr.)
- *Ethalia zelandica* (H. & J.)
- **Eulimella media* (Hutt.)
- *Euthria striata* (Hutt.)
- *Fissuridea monilifera* (Hutt.)
- *Glycymeris modesta* (Angas)
- *Leptomya perconfusa* (Iredale)
- **Lucinida levifoliata* (Marshall and Murdoch)
- **Lutraria solida* (Hutt.)
- *Macoma edgari* (Iredale)
- *Mactra ordinaria* (E. A. Smith)
- *Mactra rufa* (Hutt.)
- *Mactra scalpellum* (Reeve)
- *Mangilia amoena* (E. A. Smith)
- **Melina zealandica* (Sut.)
- *Myodora antipodium* (E. A. Smith)
- *Myodora subrostrata* (E. A. Smith)
- *Mytilus maorianus* (Iredale)
- **Neolepton* sp.
- *Nucula nitidula* (A. Ad.)

- *Odostomia huttoni* (Sut.)
- *Ostrea angasi* (Sow.)
- **Ostrea ingens* (Zittel).
- **Paphia curta* (Hutt.)
- *Paphia intermedia* (Q. & G.)
- *Pecten zelandiae* (Gray)
- **Philobrya trigonopsis* (Hutt.)
- *Rissoina olivacea* (Hutt.) [”*Dardanula*“].
- **Rissoa semisulcata* (Hutt.) [”*Lironoba*“]
- *Seila chathamensis* (Sut.)
- *Sinum undulatum* (Hutt.)
- *Siphonalia caudata* (Q. & G.)
- *Siphonalia dilatata* (Q. & G.)
- *Siphonalia mandarina* (Duclos)
- *Soletellina nitida* (Gray)
- **Struthiolaria frazeri* (Hutt.)
- *Struthiolaria vermis* (Mart.)
- *Terebra tristis* (Desh.)
- **Trochus conicus* (Hutt.)
- *Trochus tiaratus* (Q. & G.)
- *Trophon ambiguus* (Phil.)
- *Trophon cheesemani* (Hutt.)
- *Turbonilla zealandica* (Hutt.)
- *Turritella rosea* (Q. & G.)
- *Turritella symmetrica* (Hutt.)

- *Venericardia difficilis* (Desh.)
- *Venericardia lutea* (Hutt.)
- *Venericardia purpurata* (Desh.)
- **Voluta turrita* (Sut.)
- **Voluta turrita nukumaruensis* (Marshall and Murdoch)
- **Xymene expansus* (Hutt.)
- *Xymene plebejus* (Hutt.)

There are eighty-four species in this list, of which 76.2 per cent. are Recent.

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One of the main features of the fauna in this locality is the large size of many of the extinct species that are found. Not only this, but the large species are represented by a great number of individuals, and at the first glance it is apparent that the fauna is essentially different from that of Kai Iwi and of Castlecliff. In addition to this, several of the species that occur in the strata at Castlecliff and are also of Recent occurrence have unusual dimensions at Nukumaru. Of these, *Chione yatei*, *Cytherea oblonga*, and *Paphia intermedia* are noticeable. Of the extinct species, *Melina zealandica*, *Cytherea enysi*, *Lutraria solida*, *Lucinida levifoliata*, *Struthiolaria frazeri*, and *Amphidesma crassiformis* are all of large size. This large size of the shells in itself suggests that climatic conditions at the time that these strata were deposited were more genial than those that now prevail, and this suggestion, due to the mere size of the shells, is strengthened by the occurrence of such a genus as *Melina*, which is now, of course, extinct in New Zealand waters.

The bone of *Dinornis robusta* which was described in a previous paper came from the stratum that lies immediately below the bed in which the occurrence of the

large shells is first especially conspicuous. Another moa-bone has since been found, and it is identified by Professor Benham as part of the right tibia of *Mesopteryx casuarina* Owen. The medullary cavity of this bone is partly filled with pyrite, a sufficient proof that the bone has been preserved in strata that lie beneath the level to which oxidizing waters can percolate.

Fossils from Waipipi.

This locality is about five miles north of Nukumaru along the coastline. The collection was made from the outcrops of the cliffs over a distance of one mile to the north of the mouth of the Waipipi Stream and a quarter of a mile to the south of it. The rocks are for the main part tough blue papa, or blue clay, with a few distinctly sandy or micaceous strata. It is in the latter that the majority of the fossils were found.

- *Ancilla australis* (Sow.)
- *Ancilla novae-zelandiae* (Sow.)
- **Ancilla pseud-australis* (Tate)
- *Astraea heliotropium* (Mart.)
- *Atrina zelandica* (Gray)
- *Bathytoma albula* (Hutt.)
- *Bathytoma zealandica* (E. A. Smith)
- *Calliostoma pellucidum* (Val.)
- *Calyptrea alta* (Hutt.)
- *Calyptrea tenuis* (Gray)
- **Cardium spatiosum* (Hutt.)
- *Chione mesodesma* (Q. & G.)
- *Chione spissa* (Desh.)
- *Chione yatei* (Gray)
- *Corbula macilenta* (Hutt.)
- **Crassatellites obesus* (A. Ad.)
- *Crepidula crepidula* (L.)

- **Crepidula gregaria* (Sow.)
- **Cymbiola (Miomelon) corrugata* (Hutt.)
- **Cytherea enysi* (Hutt.)
- *Cytherea oblonga* (Hanley)
- **Dentalium solidum* (Hutt.)
- **Diplodonta ampla* (Hutt.)
- *Divaricella cumingi* (Ad. & Ang.)
- *Dosinia lambata* (Gould)
- **Dosinia magna* (Hutt.)
- *Dosinia subrosea* (Gray)
- **Erycina cf. bifurca* (Webster)
- *Glycymeris laticostata* (Q. & G.)
- **Glycymeris subglobosa* (Sut.)
- *Lima angulata* (Sow.)
- *Lima bullata* (Born.)
- **Lima waipipensis* (Marshall and Murdoch)
- **Lucinida levifoliata* (Marshall and Murdoch)
- **Lutraria solida* (Hutt.)
- *Macoma edgari* (Iredale)
- *Macrocallista multistriata* (Sow.)
- *Mactra scalpellum* (Reeve)
- *Marginella pygmaea* (Sow.) (?)

- **Melina zealandica* (Sut.)
- *Musculus impacta* (Herm.)
- *Mytilus maorianus* (Iredale)
- *Natica australis* (Hutt.)
- **Natica ovata* (Hutt.)
- **Natica sagena* (Sut.)
- *Natica zelandica* (Q. & G.)
- *Nuculana fastidiosa* (A. Ad.)
- *Odostomia aff. bembix* (Sut.)
- **Olivella neozelanica* (Hutt.)
- *Ostrea angasi* (Sow.)
- **Ostrea ingens* (Zittel)
- *Panope zelandica* (Q. & G.)
- **Paphia curta* (Hutt.)
- *Pecten convexus* (Q. & G.)
- **Pecten semiplicatus* (Hutt.)
- **Pecten triphooki* (Zittel)
- *Pecten zelandiae* (Gray)
- **Phalium fibratum* (Marshall and Murdoch)

- *Protocardia pulchella* (Gray)
- *Psammobia lineolata* (Gray)
- *Siphonalia mandarina* (Duclos)
- **Siphonalia subnodosa* (Hutt.)
- *Soletellina nitida* (Gray)
- **Struthiolaria canaliculata* (Zittel)
- **Struthiolaria zelandica* (Marshall and Murdoch)
- *Turritella rosea* (Q. & G.)
- *Turritella symmetrica* (Hutt.)
- *Venericardia difficilis* (Desh.)
- *Venericardia lutea* (Hutt.)
- **Voluta turrita* (Sut.)
- **Voluta morgani* (Marshall and Murdoch)
- *Zenatia acinaces* (Q. & G.)

This list contains seventy-two species, of which 61 per cent, are Recent.

The remarks that have been made about the occurrence of large shells in the strata at Nukumaru apply with even greater force to these beds, for there are these additional extinct species of large dimensions: *Cardium spatisum*, *Paphia curta*, *Ostrea ingens*, *Pecten triphooki*, *Dentalium solidum*, *Natica sagena*, *Natica ovata*, and *Crassatellites obesus*. The appearance of the large *Phalium fibratum* adds to the effect. It is hard to resist the opinion that either the climate of the country as a whole was more genial or that the region was a sea-floor that was washed by a warmer current when the sediment was deposited. The latter alternative, however, is an improbable explanation, because the nature of the sediment is essentially the same at Waipipi as it is in the highest of the Castlecliff beds. It thus becomes probable that there was a reduction in the temperature of the New Zealand area which extended over a considerable interval of time. This gradual cooling of the climate continued throughout the lapse of time between the deposition of the Waipipi beds and of the upper beds at Nukumaru. In an earlier portion of this paper this interval of time is stated as possibly as much as 300,000 years.

The general results of this examination of the fossils on the coast-line between

Castlecliff and Waipipi thus show clearly that as lower and lower strata are inspected the percentage of extinct species of mollusca becomes greater and greater. This increase of extinct species could be due mainly to three different conditions.

(1.) The mere increase in age as the lower beds are reached might in itself account for it, because as time proceeds various species become outclassed in the struggle for existence that is always in progress. The many slight changes in food-supply, ocean currents, and accompanying variations of temperature may be as potent in this direction as the mere lapse of time and the consequent change of vital energy of the different species.

(2.) The migration of additional species to the district or to the region would, of course, have a similar effect; but in our opinion our collections of the mollusca afford no evidence of this. On the contrary, as one of us (Marshall) has frequently pointed out before, the present molluscan fauna of New Zealand seems rather to be a remnant of a more extensive fauna

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of early or Middle Tertiary age. There is certainly a striking poverty of mollusca in the Wanganui beds when they are compared with that of the very small exposure of fossiliferous strata at Target Gully, near Oamaru, and elsewhere in the Middle Tertiary strata. This relative poverty in species is certainly not due to less careful collecting at Wanganui, for a greater amount of time has been spent in the latter locality and a much greater variety of strata has been scrutinized than at Oamaru. There are no additional genera of any importance in the Castlecliff strata, and there is no sudden inrush of new species, so far as our investigations go, at any horizon of the beds exposed on the coast-line between Wanganui and Waipipi.

(3.) A considerable and general change of climate must naturally have a great effect upon the molluscan life on the coast-line. It is, of course, well established that towards the close of Tertiary time in Europe and in America and elsewhere there was a great change in climate, especially during the Pliocene period. The

high percentage of Recent species of mollusca in all the strata with which this paper deals shows clearly enough that they are of Upper Tertiary age. Those at Waipipi perhaps correspond to the early Pliocene of Europe, or perhaps to the later Miocene, while the Castlecliff beds probably represent the highest Pliocene. The change in molluscan fauna may therefore be mainly due to the gradual reduction of temperature that was a feature of all climates during the Pliocene period. The faunal change in this district seems to have been much less rapid in the upper portion of the strata examined than in the lower ones. In the 960 ft. of strata between Castlecliff and Kai Iwi only 2.5 per cent. of extinct species appear, while in the 1,050 ft. between Kai Iwi and Nukumaru an additional 14 per cent. appear, and between Nukumaru and Waipipi, in a thickness of 1,450 ft. of sediment, 15 per cent. more of extinct species are found. In other words, between Waipipi and Nukumaru 1 per cent of the species becomes extinct in every 97 ft. of sediment. Between Nukumaru and Kai Iwi the rate is 1 per cent. of extinction for every 75 ft. of sediment, and between Kai Iwi and Castlecliff the rate is much slower and amounts to no more than 1 per cent. in a thickness of 384 ft. of sediment. The general average of extinction for a total thickness of 3,560 ft. is almost exactly 1 per cent. of the species in every 100 ft. If, as suggested before, this sediment has been deposited at an average rate of 1 ft. in 200 years, it follows that on the average during the greater part of the Pliocene period in New Zealand 1 per cent of the species of marine mollusca has become extinct in every 20,000 years. It is not intended to assert any accuracy for this result, though it is thought that it is of the same order of magnitude as the actual result would be if all the various factors could be ascertained with certainty.

It has been stated earlier that, as far as the stratigraphy can be seen in the marine cliffs, there is certainly no sign of any unconformity. The cliffs give an actually continuous section from Castlecliff to Nukumaru. To the north of Nukumaru the continuity is interrupted for a considerable distance, but the close resemblance of the fauna of the Waipipi beds to that of Nukumaru in itself points to the conclusion that deposition was continuous. This idea is strongly supported by the fauna which is found at Wilkie's Bluff, on the left bank of the Waitotara River, two miles and a half below the railway-bridge, a locality intermediate between Nukumaru and Waipipi. Here there is a great abundance of *Ostrea ingens*, with *Pecten triphooki* and some *Cardium spatiostum* and *Lutraria solida*. Palaeontologically as well as in geographical position the bluff

forms a connecting-link between Waipipi and Nukumaru. The large number of species that is found throughout this thick series of strata is in itself sufficient proof that the series is continuous, and it is interesting to find that so many well-known species of Miocene occurrence rise so high into the Wanganui Tertiaries. In this Wanganui area at least it is possible to determine the upper limits of their occurrence. So far as our collections have given us information the following are the levels at which the specified well-known Miocene species finally disappear. At present it is most convenient to define their position as so-many feet below the highest beds at Castlecliff.

- *Crepidula gregaria*, uncommon above 1,200 ft.
- *Lutraria solida*, 2,000 ft.
- *Cytherea enysi*, 2,100 ft.
- *Melina zelandica*, 2,100 ft.
- *Struthiolaria frazleri*, 2,100 ft.
- *Ostrea ingens*, 2,100 ft.
- *Cardium spatiostum*, 2,700 ft.
- *Pecten triphooki*, 2,700 ft.
- *Pecten semiplicatus*, 3,000 ft.
- *Dentalium solidum*, 3,500 ft.
- *Paphia curta*, 3,500 ft.
- *Natica ovata*, 3,500 ft.
- *Natica sagena*, 3,500 ft.
- *Crassatellites*, 3,500 ft.

- *Struthiolaria canaliculata*, 3,500 ft.
- *Olivella neozelanica*, 3,500 ft.
- *Dosinia magna*, 3,800 ft.

The highest beds at Castlecliff, the horizon to which these occurrences are referred, are covered unconformably by sands and gravels of volcanic material, which usually have a good deal of included timber, and are referred to the Pleistocene. Thomson has lately called this formation generally the Hawera series.

It is noticeable that many species which have a Recent occurrence and which are common at Castlecliff are quite absent from our collections at Nukumaru and at Waipipi, though from a lithological standpoint there is little change in the rock, and the conditions of deposition seem to have been substantially the same at Waipipi as at Castlecliff.

Struthiolaria papulosa was last found one mile north of Kai Iwi, about 1,200 ft. below the highest beds at Castlecliff. *Struthiolaria vermis* was last found at Nukamaru, 2,100 ft. down, and it is very scarce there.

Pecten medius has not been found below 500 ft., though a shell-fragment probably belonging to this species was found at the mouth of the Okehu Stream, 1,700 ft. down.

Murex zelandicus has not been found at Nukumaru or at Waipipi, though it has frequently been found in rocks of Miocene age in the Oamaru district, and at Pakaurangi Point in the Kaipara Harbour. *Murex angasi* and *Murex octogonus* also have not been found north of Kai Iwi, though they too occur in Middle Tertiary rocks in various parts of New Zealand.

It does not seem to be the case that any importance is to be attached to the absence of these species as an indication of climatic changes on the New Zealand coast-line. The absence of species of *Murex* and of the Recent species of *Struthiolaria* might at first suggest a colder climate for the Nukumaru and Waipipi beds, but this idea is at once offset by the fact that *Pecten medius* and *Struthiolaria papulosa* both occur at the present day in the most southern of New Zealand waters. As more extensive collections are made and additional localities of this district are examined it may well happen that such small peculiarities will be explained. It is also possible that by careful collecting the development of some of the species that have most recently appeared, such as *Pecten medius* and *Struthiolaria papulosa*, may be most definitely traced. On the other hand, it may possibly be found that a few of these species reached these shores from other faunal regions.

One point often crops up in the examination of various fossil localities in the Tertiary rocks of New Zealand. In some strata there is a great predominance of gasteropods, while in others the lamellibranchs are far more numerous. So far as observations have gone up to the present time, this striking difference does not appear to be due to the depth of the water or to any other of the ordinary conditions that control the deposition of sediment.

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Art. XXI.—*Some Tertiary Mollusca, with Descriptions of New Species.*

By P. Marshall, M.A., D.Sc., F.G.S., F.N.Z.Inst., Hector and Hutton Medallist, and R. Murdoch.

[*Read before the Wanganui Philosophical Society, 3rd December, 1919; received by Editor, 31st December, 1919; issued separately, 10th June, 1920.*]

Plates VI-X.

Additional collections made at Waipipi and Nukumaru have produced several new species, and have also brought to light others not previously recorded from

these horizons. These localities are not so accessible as the Castlecliff series, and have not been so carefully collected. Further, the Waipipi beds are not fossiliferous throughout, but fossils are restricted to short sections. One of the finest of these is rather below half-tide level and only available after certain weather conditions. During one visit it was sea-swept clean, and there was a most striking display of Pectens, Cardiums, Limas, and other large forms. Almost without exception the collections hitherto made have not been assigned to any definite locality, with the result that Shakespeare Cliff, which was regarded as the equivalent of all the sands and blue clays of the district, is credited with species which do not occur therein. The coastal cliff from Castlecliff to Kai Iwi and thence to Nukumaru and Waipipi presents a perfectly unbroken series of beds older than those of Shakespeare Cliff. The faunal changes, as might be expected, is very gradual, and it is only when horizons fairly distant are compared that a marked distinction is evidenced. Faunal lists from several horizons are recorded on pages 120–25 of this volume.

Hampden was visited by Dr. Marshall, who secured a number of undescribed species, several of which are too fragmentary to deal with, and it is abundantly evident that much collecting has yet to be done in that series of beds before a full knowledge of the fauna is obtained.

Rissoina obliquecostata n. sp. ([Plate VI, fig. 1.](#))

Shell small, ovato-elongate, deeply impressed sutures and oblique axial riblets. Whorls six (the protoconch missing), rounded and narrowly shouldered, the last slightly produced at the anterior end. Sculpture consists of about twenty-nine narrow axial riblets, in width about half that of the interspaces, on the sutural shelf they are rather less pronounced, form a

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Fig. 1.—*Rissoina obliquecostata* n. sp.

Fig. 2.—*Seila attenuissima* n. sp.

Fig. 3.—*Triphora aoteensis* n. sp.

Fig. 4.—*Siphonalia senilis* n. sp.
Figs. 5, 5a.—*Admete suteri* n. sp.
Fig. 6.—*Admete anomala* n. sp.
Fig. 7.—*Surcula hampdenensis* n. sp.
Fig. 8.—*Borsonia zelandica* Marshall
Fig. 9.—*Conus armoricus* Suter (protoconch).
Fig. 10.—*Conus armoricus* var. *pseudoarmoricus* n. var.

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Figs. 11, 11a.—*Struthiolaria zelandiae* n. sp.
Figs. 12, 12a, 12b.—*Fulguria morgani* n. sp
Fig. 13.—*Dicroloma zelandica* Marshall.
Fig. 14.—*Turris curialis* n. sp.

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row of small nodules on the angle, thence take a backward sweep, and vanish a little above the suture, on the anterior end of the last irregular and here and there in the form of strong growth-striae; spiral striae are preserved in places only and difficult to detect. There is a narrow, subperforation at the side of the columella, bounded by a small funicular ridge which curves around to the basal lip. Aperture

oval, narrow above, basal lip slightly produced and with a lightly impressed gutter at its junction with the columella, inner lip with a thin narrow callus, columella slightly curved and a little reflexed anteriorly.

Length, 6.25 mm.; width, 3.5 mm.; length of aperture, 2.5 mm.

Locality, Hampden. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

There is a single example only. It is very different from any other of our Recent or fossil Rissoids, and it is with hesitation we refer it to the genus. More material may be brought to light, possibly allied forms which would lead to a more confident classification.

Seila attenuissima n. sp. ([Plate VI, fig. 2.](#))

Shell partly embedded in the matrix, very small, gradually tapering, and exceedingly slender; whorls about seventeen, the protoconch of two and a half whorls, smooth, apex minute oblique to the axis, the two succeeding whorls well rounded and somewhat swollen, thence flattened and with three sharply-raised spiral cords, equal to or slightly narrower than the grooves, the lower cord perhaps slightly the stronger; the spacing of the sculpture, including the sutural groove, is exceedingly uniform; within the grooves and preserved in places only are microscopic sharply-raised growth-striae; the last whorl apparently with four or more spirals, the anterior end obscured by the matrix.

Length, 7 mm.; width, 0.9 mm.

Locality, Hampden. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

There is a single example only, characterized by its exceedingly attenuated form. The protoconch in some respects approaches *S. bulbosa* Suter.

Triphora aoteaensis n. sp. ([Plate VI, fig. 3.](#))

Shell small, slender, of twelve flattened whorls, excluding the apex, which is missing. Sculpture: There are three rows of gemmules on each whorl, a small undulating smooth threadlet at the suture above and occasionally a very minute thread on the margin below, both absent on the earlier whorls; on the last at the basal angle is a fourth smooth sharply-raised narrow riblet, below this a more slender cord, and between the latter and beak two or three ill-defined lines; of the gemmules there are about sixteen in a row, separated rather less than their own width and linked within the rows, axial buttresses low and broad, forming oblique

vertical rows but not always continuous; the lower row of gemmules is the most strongly developed, the second distinctly smaller, equal to their own width apart, the third separated by a narrow groove and much more feeble; the gemmules are somewhat oval in form, the anterior sides rounded, the posterior rising rather abruptly, giving to them a subtruncated and slightly ridged appearance. Base sloping, flattened; distinct growth-striae form small irregular riblets. Aperture small, subquadrate, outer lip imperfect, columella short, nearly straight, sharply bent and twisted at the anterior extremity.

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Length, 9.5 mm.; width, 3 mm.

Locality, Hampden. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

Described from a single specimen; the only other species of the genus recorded in our Tertiary fauna is *T. lutea* Sut. A casual examination of the Hampden shell might easily lead to its being referred to that species, and probably it is akin to it; the protoconch is missing, and not infrequently it possesses important specific characters.

Dicroloma zelandica Marshall. ([Plate VII, fig. 13.](#))

Trans. N.Z. Inst., vol. 51, pp. 228–29, pl. xv, fig. 16, 1919.

The example here described is partly embedded in the matrix, and the sculpture is much eroded, but the general form is well preserved. Shell small, fusiform, of six whorls, the last rounded, abruptly contracted at the base, with a narrow and moderately long anterior canal, which is slightly inclined or bent to the left; spire-whorls convex, the apex missing; sutures not impressed, the removal of the outer shelly layer gives to them a somewhat deep appearance. Sculpture: On the last whorl, a little below the periphery, is a strong spiral rib, a second below this margining the base, and beneath these two or three more slender cords, the first-

mentioned ribs about twice their own width apart. Aperture oblique, rather narrow, the outer lip expanded, thickened, and with two prominent lobes, while from each lobe proceeds a long stout digitation (the extremities broken off); the posterior digit is almost at right angles to the axis of the shell and proceeds from near to the sutural margin; above its junction is a fairly strong callus which spreads to the suture above; the median lobe and digit are somewhat larger than the above, and the space between and the angle formed are smaller than between the median and the anterior canal. Each digit has a pronounced smooth furrow; the groove of the anterior canal is little more marked than that of the digits.

Length, 23 mm.; width (excluding digit), 13 mm.

Locality, Hampden. Collected by Dr. Marshall.

Struthiolaria zelandiae n. sp. (Plate VII, figs. 11, 11a.)

Shell ovate, oblong, spire turreted, whorls spirally ribbed, rather flattened, shouldered at the sutures, which are deeply excavated, the last more or less angled at the base. Whorls six or more, apex lost. Sculpture: On the last whorl a broad usually strong spiral rib on the sutural shoulder, followed by six or seven narrow cords, thence two stronger cords, the first of which is the more prominent and forms the basal angle, anterior to this contracted and with five or six cords which are usually smaller and more widely spaced as they approach the anterior end; the grooves deep except immediately below the shoulder where they vary considerably, in some examples feeble ill-defined corrugations, in others narrow incised lines, or clean-cut, deep, and slightly narrower than the riblets. The first of the remaining spire-whorls with a few spiral threadlets, on the following whorls increasing to seven or eight, variable as on the last, usually distinct in the deeply excavated sutural area. A secondary sculpture of fine threadlets adorns both ribs and grooves. Aperture ovate, oblique; outer lip sinuous, strong, and reflexed; inner lip with a broad fairly heavy callus; columella curved, a distinct notch at the anterior end.

Length, 36 mm.; width, 27 mm. Another example: Length, 35 mm.; width, 24 mm.

Locality, Waipipi, near Waverley, in blue sandy clay.

Type to be presented to the Wanganui Museum.

The sculpture, together with the exceedingly deeply excavated sutures, readily distinguishes it from other Tertiary forms.

Phalium fibratum n. sp. (Plate VIII, figs. 16, 17.)

Shell large, ovato-globose, with prominent spiral sculpture. Whorls about seven; lightly angular; apex minute; spire short, less than one quarter the length of the aperture; the last very large; on the angle a rather prominent row of nodules, on the spire above the angle four or five spiral cords, and below the angle two or three, on the last about twenty-three flat spirals more than twice the width of the grooves, the latter becoming deeper on approaching the anterior end, in places there is a small groove on the rib and here and there a small threadlet in the groove; the axials consist of strong irregular growth-striae which have a fibrous subgranular appearance. Sutures lightly impressed, the marginal rib below rather pronounced. Aperture slightly oblique and narrow above, outer lip uniformly curved, thickened and reflexed; columella short, excavate and twisted, several small denticles above and two or three oblique plaits at the anterior end; body-whorl and columella with a wide, spreading callus produced anteriorly as a broad flat plait limited to the width of the columella.

Length, 75 mm.; width, 60 mm.

Locality, Waipipi.

Type to be presented to the Wanganui Museum.

Of this form there, is a single almost perfect specimen. It is allied to *P. labiatum* var. *pyrum* Lank., which is subject to considerable variation in size and sculpture. We have a good series of the latter for comparison, and in our opinion the Waipipi shell is sufficiently different to warrant specific distinction.

Siphonalia senilis n. sp. (Plate VI, fig. 4.)

Shell rather small; canal moderately long; body-whorl comparatively large. Whorls six or seven, rounded, lightly subangled above the middle; protoconch of about three and a half turns, smooth; thence spirally and axially sculptured; axials nineteen to twenty on the last, feebly raised, more pronounced on the spire; growth-striae rather strong; the spirals in the form of undulating cords, delicately beaded, usually one or two larger beads on the axials, in places an alternate larger and smaller cord, wider than the grooves except towards the anterior end; on the penultimate there are eleven to thirteen spirals, the cord at the suture rather pronounced and followed by two or three much smaller. Sutures not deeply impressed. Aperture imperfect. Columella curved, tapering, lightly twisted anteriorly, and thinly callused.

Length, approximately 17 mm.; width, 10 mm.

Locality, Hampden. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

There are three examples, somewhat distorted and in rather poor preservation. The species may readily be distinguished by the undulating finely beaded cords.

Admete (*Bonellitia*) ovalis Marshall.

Borsonia (Corderia) ovalis Marshall, *Trans. N.Z. Inst.*, vol. 50, p. 269, pl. 18, figs. 10–10a, 1918.

—A further examination of the type proves that it is a member of the Cancellariidae nearly allied to *Bonellita* as defined by M. Cossmann.

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Admete suteri n. sp. (Plate VI, figs. 5, 5a.)

Shell small, shortly fusiform; spire short turreted. Whorls five, the last

comparatively large, strongly angled; protoconch of two smooth rounded whorls, the apex obliquely disposed, thence rapidly increasing; axially and spirally cancellated, the latter more pronounced and forming small tubercles at the points of intersection; above the aperture and on the spire-whorls are two small spiral cords, on the last eight narrower than the interspaces, at the anterior extremity finer and closer; axials seventeen to twenty-one on the last, irregularly developed anteriorly, on the area between suture and angle sharply inclined forward, this area without spiral sculpture; sutural line undulating, not channelled. Aperture somewhat oblique, outer lip angled above, margin lightly crenulated, grooved within corresponding with the spiral sculpture; columella short, slightly curved, narrowed and twisted at the extremity, lightly callused, with two well-developed rounded plaits on the middle area and a third more slender on the anterior twist of the columella.

Length, 8 mm.; width, 5.25 mm.

Locality, Target Gully. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

Material consists of four examples in a good state of preservation. We name this pretty little shell in memory of our old friend Henry Suter.

Admete anomala n. sp. ([Plate VI, fig. 6.](#))

Shell small, elongate; spire exceeds the aperture in length. Whorls five or six, convex and lightly angled above the middle; apex blunt, and sculpture (if any) obscure, succeeding whorls spirally and axially ribbed, nodular at the crossings; axials broad, equal to the interspaces, nine or ten on a whorl, directed slightly forward, feeble above the angle and on approaching the lip; growth-striae in places well marked with here and there old lip-margins; spirals narrower than the interspaces, twelve on the last, five on the spire-whorls, one of which is above the angle; the first threadlet below the angle is much more slender than the others; a small area at the anterior end smooth. Sutures impressed, slightly undulating. Aperture oval, outer lip uniformly curved, sharp, within the margin a number of small elongated denticles; columella short, curved and obliquely truncated, the extremity slightly twisted to the left, thinly callused and with two small plaits; the anterior lip produced and on uniting with the columella forms a short wide canal.

Length, 8 mm.; width, 3.75 mm.

Locality, Hampden. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

The material consists of a single examples. The two denticles only on the columella and the peculiar wide shallow anterior canal are not quite in accord

with *Admete*; probably it may be allied to *Babylonella* of Cossmann.

Fulguraria (Alcithoe) turrita Suter.

F. (Alcithoe) arabica var. *turrita* Sut., N.Z. Geol. Surv. Pal. Bull. No. 5, p. 39, pl. 5, fig. 4, 1917.

Examples of this species, of which we have a fairly good series from Nukumaru and Waipipi, agree perfectly with Suter's description and figure. The produced spire and narrow form are constant characters, and some examples have the penultimate and last whorl adorned with small inconspicuous spiral lines. The general contour is, however, so different from *arabica* and its var. *elongata* as to warrant full specific distinction. It is

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not uncommon in the beds above mentioned, where we have failed to find examples of the Recent species.

Length, 125 mm.; width, 47 mm.

The series of specimens here noted to be lodged in the Wanganui Museum.

Fulguraria (Alcithoe) turrita var. *nukumaruensis* n. var. ([Plate IX, figs. 18, 19.](#))

Distinguished from the species by its more slender form, the absence of prominent nodules, the axial riblets being feeble and almost absent on the last, the body having the same flat slope as the whorls above.

Length, 102 mm.; width, 34 mm.; length of aperture, 57 mm.

Locality, Nukumaru.

Type to be presented to the Wanganui Museum.

There are several specimens, of which only one is perfect.

Fulgoraria morgani n. sp. ([Plate VII, figs. 12, 12a, 12b.](#))

Shell rather small, narrow, axially costate, spire turreted. Whorls six or seven, lightly shouldered above the middle, excavated or flattened above the shoulder, below slightly convex, the last whorl slightly tapering to the anterior end; the protoconch consists of about two and a half smooth whorls, somewhat rounded, apex blunt, the first half-turn somewhat laterally disposed by a comparatively wide and deep sutural excavation. Axial riblets sixteen to nineteen, rounded, rather narrower than the interspaces, usually less pronounced above the shoulders and on approaching the anterior end of the last whorl, on the latter towards the lip somewhat variable. Sutures undulating, not deep. Aperture slightly oblique, narrow, almost canaliculate above; outer lip with sharp margin, slightly curved to the anterior end, the latter rather broad and deeply notched; columella almost straight, lightly twisted at the anterior extremity, thinly callused and with four plaits, the lowermost occasionally feeble.

Length. 47 mm.; width, 17 mm.; length of aperture, 28 mm.

Locality, Waipipi, in blue sandy clay.

Type to be presented to the Wanganui Museum.

Originally an example of this species was submitted to Captain Hutton, who pronounced it *Voluta corrugata*, Miocene. It was said to occur in the Patea or Waverley district, but the exact locality was unknown. On comparing it with the description and figures given by Suter (*N.Z. Geol. Surv. Pal. Bull. No. 2*) it was apparently quite different from Hutton's species; we therefore submitted examples to Mr. P. G. Morgan, Director of the Geological Survey, for comparison with the types, and his report coincides with the opinion we had formed. Its nearest kin is perhaps *F. gracilis* Swains. We convey to Mr. Morgan the compliment of associating his name with the species.

Turris curialis n. sp. ([Plate VII, fig. 14.](#))

Shell narrowly fusiform; spire turreted; whorls with sloping flat shoulders bounded by a prominent nodular ridge; thence to the suture below excavated; the concavity below the ridge continues across the body-whorl immediately above the aperture and appears again on the lip strongly marked (shell partly embedded in the matrix), anterior to this slightly convex, thence gradually contracted to the canal. Whorls probably eight or more. Sculpture: Several small spiral threadlets between the suture and keel, and two somewhat stronger between the latter and

suture below, on the last numerous, exceeding twenty, and narrower than the grooves; axials consist of growth-striae only. Sutural line not deep, in places obscured by the spirals above and below. Aperture imperfect, rather narrow, the posterior sinus as indicated by the lines of growth situated at the nodular angle; columella almost straight, thinly callused, the anterior end missing.

Length, 26 mm.; width, 10 mm.

Locality, Hampden. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

The material consists of a single specimen of five whorls, including the last except its anterior extremity. The distinctive characters are the marked corrugation on the last whorl, which is a continuation of the peculiar excavate sutural area, the long sloping shoulder, and the prominent nodular angle.

***Surcula torticostata* Marshall. ([Plate VIII, fig. 15.](#))**

S. torticostata Marshall, *Trans. N.Z. Inst.*, vol. 51, p. 232, pl. 12, fig. 7, 1919.

This species was described from very imperfect material, consisting of upper spire-whorls only. An almost perfect specimen is now available, and we offer the following amended description.

Shell fairly large, narrowly fusiform, the aperture and canal apparently rather less than the spire in length (the anterior end of the canal missing). Sutures not deep, margined below by a flat rather prominent rib. Whorls nine or ten, flat or slightly concave below the sutural rib, thence lightly convex, the last gradually tapering to the canal. Axial sculpture varying as the shell progresses; apical whorls apparently smooth; then follow twisted, prominently backward-sloping narrow riblets, which arise a little below the sutural rib, and are suppressed a little above the lower suture, and on the later whorls, especially the penultimate and last, reduced to slight undulations and in places absent; growth-striae well marked, prominent on the last; the spirals consist of numerous fine feebly-raised threadlets wider than

the grooves and forming irregular minute granules on crossing the growth-striae. Aperture narrow, deeply channelled above; outer lip sharp, curving forward rather abruptly from the posterior sinus, which is situated immediately below the sutural rib; columella and body-wall thinly callused, the callus on the latter margined by a rather pronounced double groove.

Length, 59 mm.; width, 14 mm.; length from aperture to apex, 34 mm.

Locality, Hampden. Collected by Dr. Marshall.

This specimen to be lodged in the Wanganui Museum.

***Surcula hampdenensis* n. sp. ([Plate VI, fig. 7.](#))**

Shell narrowly fusiform; whorls obtusely angled; spirally lirate; short oblique axials at the shoulder and the sutures margined below. Whorls eight, the apex minute, thence gradually increasing, the last viewed dorsally exceeding the spire in length. Almost flat below the angle, then gradually sloping to the long anterior canal, the extremity of which is missing. On the spire-whorls the angle is slightly above the middle, the area above and below very slightly convex. Sculpture: Excluding the apex, the first four whorls with irregular ill-defined axials extending across the whorls; following these the angle well defined and on it developed fourteen or fifteen backward-sloping axials, narrower than the interspaces and not extending to the sutures below; growth-striae, especially on the last, strongly marked;

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spiral threadlets adorn the lower whorls throughout, that margining the suture comparatively large and with a sharply defined lower margin, a few minute threads on its flattened surface, on the last about fifty, those above the angle very slender, below with here and there an alternate larger and smaller threadlet, about equal to the grooves in width. Aperture: Outer lip imperfect; posterior sinus extending from the angle to the sutural cord; columella almost straight; callus thin, not obscuring the spiral sculpture.

Length, 22 mm.; width, 7 mm.

Locality, Hampden. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

Of this form there is only one example. Its nearest kin are perhaps *S. sertula*, *S. obliquecostata*, and *S. mordax*.

Borsonia (Corderia) zelandica Marshall. ([Plate VI, fig. 8.](#))

Volutoderma zelandica Marshall, *Trans. N.Z. Inst.*, vol. 51, p. 230, p. 17, figs. 4 and 5, 1919.

The material from which this species was described consists of two rather badly preserved specimens collected by Dr. Marshall at Hampden. The sculpture can be followed fairly well, and the position and form of the posterior sinus is clearly indicated by the well-marked growth-striae. The outer lip being broken away gives a somewhat marked prominence to the two small plaits on the columella, and this may in a measure have influenced the late Mr. Suter when he recommended its inclusion in *Volutoderma*. We offer a figure of the aperture restored as indicated by the lines of growth.

Conus (Leptoconus) armoricus Suter. ([Plate VI, fig. 9.](#))

N.Z. Geol. Surv. Pal. Bull. No. 5, p. 61, pl. 12, fig. 25, 1917.

As no description of the protoconch is recorded, we offer the following: The specimen has a total of nine and a half whorls, three and a half of which comprise the smooth protoconch, which is sharply conical and slightly oblique; whorls convex, with somewhat impressed sutures, the initial half-turn minute and somewhat laterally disposed, the third comparatively high, the last half narrowing and merging into the post-embryonic form.

Length, 21 mm.; width, 11 mm. (dimensions of specimen).

Locality, Pakaurangi Point, Kaipara Harbour. Collected by Dr. Marshall.

Conus (Leptoconus) armoricus var. *pseudoarmoricus* n. var. ([Plate VI, fig. 10.](#))

Shell small, spire low, gradated, the body elongated and sharply tapering. Whorls six, excluding the protoconch, which is missing; each whorl with a pronounced rim-like ridge, which overhangs and partly conceals the suture, giving to the volution a distinctly concave appearance; the last whorl immediately below the ridged shoulder slightly contracted. Sculpture: On the spire-whorls four or five

small spiral threadlets, on the anterior area of the last about twelve well marked and obliquely ascending; above these a few ill-defined lines which probably are continued to the crown; axial growth-striae irregular, on the spire distinctly curved, indicating a fairly deep sinus. Aperture narrow; the margins almost parallel; outer lip imperfect.

Length, 18 mm.; width, 10 mm.

Locality, Hampden. Collected by Dr. Marshall.

Type to be presented to the Wanganui Museum.

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Differs from *C. armoricus* by the spiral threadlets on the spire, the rim-like ridge which overhangs the sutures, and the accompanying concavity of the whorls. The material consists of a single example. *C. armoricus* is recorded from Komiti Point,^{*} Kaipara Harbour, and it is interesting to find a form so nearly akin in the Hampden beds.

Melina zealandica Suter. ([Plate X, fig. 20](#); [Plate IX, fig. 21](#).)

For all references see *N.Z. Geol. Surv. Pal. Bull. No. 5*.

A description derived from very fragmentary materials is given in the above-mentioned publication, pages 68, 69. Plate viii, fig. 4, is a part of the hinge; Plate xiii, fig. 1, is the large fragment from Shrimpton's, and not *Ostrea mackayi*, and fig. 2 is the latter species.

The species is not uncommon in the Nukumaru and Waipipi beds; numerous large fragments, including an almost complete hinge of a right valve, were obtained. Another example of hinge partly embedded in rock has both valves locked in natural position. Attached to a mass of rock a complete valve was noted, which was much eroded, but presented an approximate indication of the general outline. From this, aided by large fragments, we derive the figure of the restored

shell.

The shell is apparently subquadrate, somewhat swollen, the umbo near to the anterior end, the anterior ear small with the margin immediately below prominently inflexed. The ventral margin and posterior end may to some extent have been completely eroded, as the lamellar structure would lend itself to this, but it does not appear to have been prominently winged. The hinge is massive and wide, with four or five conspicuous resilifers. The length of the hinge exceeds 140 mm., and several measurements indicate that the united valves are not less than 90 mm. in diameter.

Amphidesma (Taria) crassiformis n. sp. ([Plate X, figs. 22, 23.](#))

Shell of medium size, massive, triangular; beaks almost at the posterior end which is abruptly truncated, strongly and acutely angled; the anterior dorsal margin long, downward sloping and almost straight, the anterior end narrow and rounded, ventral margin slightly curved; the posterior truncation is slightly concave as it approaches the lip-margin, and on the end there are two, usually three, feebly-raised curved ridges. The median area of the valves and towards the ventral margin sometimes has a slightly concave appearance. Sculpture is irregular shallow concentric corrugations with fine striae, the latter on the posterior end pronounced. Hinge conspicuously massive; right valve with deeply excavate sockets above the laterals, the posterior much the shorter; in the left valve the anterior lateral elongated and with a double tubercle on its crest, the right short high and triangular; cardinals in both lamellar and oblique. Adductorscars, pallial line, and sinus deeply impressed, the sinus short and with a broadly rounded apex. Lip-margins smooth.

Length, 80 mm.; height, 60 mm.

Locality, Nukumaru, in blue sandy clay.

Type to be presented to the Wanganui Museum.

Material consists of three valves, a right and left of which are almost perfect. Readily distinguished by its massiveness and the abrupt heavy truncation.

[Footnote] * *C. armoricus* occurs at Pakaurangi Point, not Komiti Point, which is some two miles distant.

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Fig. 15—*Surcula torticostata* Marshall.
Figs. 16, 17.—*Phalium fibratum* n. sp.


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Figs. 18, 19—*Fulguraria turrita* var *nukumaruensis* n var
Fig. 21—*Melina zealandica* Suter.


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Fig. 20.— *Melina zealandica* Suter.

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Art. XXII.—*Tertiary Geology of the Area between the Otiake River (Kurow District) and Duntroon, North Otago.*

By G. H. Uttley, M.A., M.Sc., F.G.S., Scots College, Wellington.

[Read before the Wellington Philosophical Society, 18th September, 1918; received by Editor, 31st December, 1919; issued separately, 15th June, 1920.]

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V. Structure of the Area.

VI. Conclusion.

I. Introduction.

As will be seen from the accompanying geological map ([fig. 1](#)), the area described in this paper extends from the Otiake River, the southern boundary of the Kurow Survey District, to near Duntroon, on the Otago side of the Waitaki River. The district north-west of the Otiake River is dealt with in a later paper in this volume, but to save unnecessary repetition a full historical summary of the work of previous observers in that area, as well as in the present area, is given below.

In the geological map no attempt has been made to map the various types of gravels, as the delimitation of their boundary-lines and their differential characteristics will demand a great deal of detailed work. The gravel lands are now covered with vegetation and soil, and this fact renders their distinction difficult. The Wharekuri-Otekaike fault, which bounds the Kurow tilted block, follows an almost straight line, but between the Otekaike basin and the Otiake basin, a spur of the undermass, dipping easterly at 6° beneath the Tertiary rocks, apparently breaks the continuity of the main fault-line. It would appear that in this locality the low-lying block had failed to break away, as the stripped surface of the spur is certainly continuous with that of the uplifted block for some distance to the west of the main line of faulting. No convincing evidence was obtained to show whether the boundary scarps of this protruding spur were fault-scarps or fold-scarps, except in the neighbourhood of Newsome's Creek, where the quartz-grits were found lying directly on the sloping surface of the undermass on the southern side of the spur, three-quarters of a mile east of Trig. Station D. The surface and overlying quartz-grits at this point dip southerly at 30° , indicating that, in this locality at least, the scarp is a fold-surface.

McKay was the only geologist who investigated the area in any detail, and the sequence of rocks as recorded by him was characteristically accurate. His classification of the sediments was based almost entirely upon lithological characters, but he made large collections of fossils from several parts of the Waitaki Valley, and these were determined by the late Mr. Henry Suter two or

three years ago, but the lists have not yet been published. McKay's account of the geology is rendered somewhat difficult

[Footnote] * Spelt also "Maerewhenua" and "Maraewhenua."

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Fig. 1.—Geological map of the Waitaki Valley between the Otiake River and Duntrroon. In the legend the order of superposition is indicated by the numbers.

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to follow owing to the necessity he was under of finding in the series an unconformity marking the line of division between the Cretaceo-Tertiary and Tertiary systems of the old Geological Survey under Sir James Hector.

The relationship of the various rocks present in the area is obscured by the thick deposit of post-Tertiary gravels, and exposures are revealed only when the streams of the area have entrenched themselves in the gravels and cut through the Tertiary rocks. The outcrops of Tertiary rocks along the fault-lines have been mapped only where they were observed. They are probably continuous beneath the gravels.

The writer wishes to thank Mr. P. G. Morgan for kindly allowing him to examine the lists of fossils determined by the late Mr. Henry Suter from the collections made by McKay forty years ago. To Dr. J. Allan Thomson the writer is much indebted for assistance in determining the brachiopods, and for permission to incorporate his list of molluscan fossils from the upper beds at Otiake in the lists detailed below. Mr. H. Suter named many forms from the same beds for the writer some years ago, and his determinations are included in these lists.

The paper furnishes geological evidence for the existence of two strong faults, which are shown to be intimately connected with the great fault-system of Central Otago, so ably described by Cotton (1917A, p. 272). The elongated relatively depressed area of the Waitaki Valley, between the mountains of South Canterbury and North Otago, occupied by Tertiary beds, is shown to be a tectonic depression which is partly a graben and partly a fault-angle depression. McKay's statement that the Hutchinson Quarry beds lie above the Otekaike limestone is shown to be supported by the evidence. It is further shown that McKay's "two-limestone theory" is radically different from Park's "two-limestone theory," and that the latter's statement (1918, p. 110) that Hutton, Hector, and McKay considered the limestone of the Waitaki Valley to be of Hutchinsonian age is not warranted. On the evidence of the brachiopod fauna this limestone is shown to be Ototaran.

II. General Description of the Area.

Between the Otiake and the Otekaike Rivers, flowing in a north-easterly direction to join the Waitaki River, the surface rock is a thick deposit of coarse water-worn boulders and silt. The initial gravel tableland has been rather deeply entrenched by the streams, and the Otiake and the Otekaike now flow in braided courses to join the trunk stream. Remnants of high-level terraces are to be seen near the school at Otekaike, indicating recent elevation. Before debouching from the mountains on to the gravel-covered plain these rivers flow in steep-sided gorges, and narrow terraces are noticeable on the sides of the streams. The mountainous country that flanks this part of the area on the south-west rises fairly rapidly to a height of over 6,000 ft. in the Kurow Mountains, or at least 5,000 ft. above the general level of the gravel tableland.

From Ben Lomond to Black Hill an even-topped gently sloping ridge extends almost to the main road, and the rise from the Otekaike basin to this ridge is abrupt. The quartz-grits that crop out in the basin of the Waikaura Creek have been deeply dissected and eroded, and in places the greywacke undermass crops to the surface, particularly in the higher country towards Ben Lomond. The country to the east is an elevated tableland, deeply dissected by the streams that traverse it. The surface rock is formed of heavy river-gravels and silts, and limestone is revealed

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in many of the creeks, and forms prominent escarpments on the banks of many of the larger streams. The Maruwenua River, a north-easterly-flowing tributary of the Waitaki, rising in the neighbourhood of Dansey's Pass, where a distant sag is noticeable in the main Kakanui-Kurow Range, is flanked by the rather steeply sloping back of a tilted block, the stripped surface of which dips beneath the Tertiaries exposed in the neighbourhood of the river.

The Waitaki River flows in an east-south-east direction near the base of the well-preserved fault-scarp of the South Canterbury block mountains.

The Tertiary rocks in the Waitaki Valley occur in an elongated depression between the mountain-ranges of North Otago and South Canterbury, and the origin of this depression has been referred to various causes. Haast had no difficulty in imagining that a glacier was the agent of erosion; Hutton and Park invoked the aid of a pie-Tertiary river, the valley of which, after general subsidence of the land, was drowned by the encroachment of the sea, and the sedimentary deposits laid down. Marshall detected signs of tectonic movement in the neighbourhood of Wharekuri, and Cotton later elaborated the idea in his work on the block mountains of Otago, and described the depression as a somewhat complex graben between the uplifted block mountains of North Otago and Canterbury.

The Tertiary rocks consist of quartz conglomerates and sands, and sometimes fireclays, with seams of inferior brown coal. These rocks rest on the eroded surface of the older greywacke rock, and are followed by greensands, often pebbly, sandy, and micaceous, and containing marine fossils 20 ft. above the coal. These greensands pass up into more calcareous greensands containing much less quartz and mica, but glauconitic casts of Foraminifera are abundant. The limestone which overlies these greensands sometimes has at its immediate base a band of calcareous greensand containing brachiopods in abundance; in other cases the transition from a calcareous glauconitic sand to a slightly glauconitic limestone is almost insensible. The glauconitic limestone passes up into a much harder limestone free from glauconite, and the latter rock is capped by very fossiliferous concretionary hardened bands, covered in turn by more sandy beds, which

appear to be unfossiliferous in their upper part. Overlying these rocks unconformably is a heavy deposit of river-gravel and silts.

III. Historical Summary.

That the historical summary of the views of previous workers may be more easily followed, the classification as finally adopted by McKay for the Waitaki Valley is tabulated.

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Age.	Formation.
Recent to Pleistocene	Alluvial and glacier deposits.
Lower Miocene	Pareora formation. (a.) Gravels and sands, with lignite-beds. (b.) Pareora clays.
Upper Eocene	(a.) Hutchinson Quarry beds. (b.) Otekaike limestone. (c.) <i>Kekenodon</i> beds (greensands).
Cretaceo-Tertiary	(a.) "Grey marls." (b.) Maruwenua limestone. (c.) Wharekuri greensands. (d.) Island sandstone. (e.) Coal-beds.

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Hector, in 1865, classified the Waitaki arenaceous rocks as Lower Miocene, and the Oamaru rocks as Upper Miocene. In 1870 he considered the Oamaru rocks to be Older Tertiary, and those of the Waitaki Valley Middle Tertiary. In 1877 he placed the coal-grits, sandstones, and overlying limestones at Maruwenua in his

Cretaceo-Tertiary system. In 1882 he considered the Otekaike limestone to be of Tertiary age, and at a higher horizon than the Maruwenua limestone (Cretaceo-Tertiary).

Hutton (1875, p. 46), after examining a collection of fossils from Otekaike, classed them as Upper Miocene (Pareoran or Awamoan); and (1875, p. 89) considered that the Tertiary rocks at Wharekuri occupied a depression "hollowed out by an Eocene glacier." The brown coal at Wharekuri was said to be Eocene. McKay (1877) reported on the geology of the Oamaru and Waitaki districts, and referred the Maruwenua lime-stone and the overlying fossiliferous horizon ("Phorus beds") to the Cretaceo-Tertiary system, and stated that the "equivalent beds of Hutchinson's Quarry, Oamaru, and even higher beds, assume the character of a calcareous sandstone at Otekaike, and at Big Gully (Wharekuri) of a tufaceous greensand." In the same report (1877, p. 58) he declared the impossibility of separating the Awamoan, either stratigraphically or otherwise, from the Hutchinsonian. In a later report (1882a) he described the Waitaki Valley more fully, and stated that the Tertiary rocks, comprising limestones and calcareous greensands of Upper Eocene age, rest indifferently on various members of the Cretaceo-Tertiary series. Certain sandstone gravels, often steeply tilted, were classed as Upper Pareoran (Awamoan), and the coal at Wharekuri was referred to this horizon. The Hutchinson Quarry beds at Wharekuri were said to rest conformably on the Otekaike limestone, which was classed as a Tertiary rock, quite distinct from the Maruwenua limestone of Cretaceo-Tertiary age. The "sandy beds with cement concretions" ("Phorus beds") above the limestone at Maruwenua were referred to the horizon of the "grey marls" of Cretaceo-Tertiary age, although the fossils "resemble those from Hutchinson's Quarry and the Otekaike limestone more than those of the 'grey marls.'" The Wharekuri greensands were said to be overlain unconformably by the "Kekenodon greensands" (a Tertiary rock), and to belong to the Cretaceo-Tertiary system. The fossiliferous beds that overlie, the coal-rocks at Black Point were said to be at the same horizon as the island sandstone. The heavy angular gravels, containing boulders with Triassic and Permian fossils, were considered to be of glacial origin, the glaciers having taken their rise in the surrounding mountains. McKay collected fossils from Station Peak, opposite Otekaike, and stated that in the section exposed there "the Hutchinson's Quarry beds do not present their usual characters, and must be considered as merged in the Otekaike limestone." Again, referring to the same section, he affirmed that "the oldest beds seen are limestones as pure as, though less fossiliferous than, the higher part." In this locality and at Otekaike McKay considered that the limestone rests directly on the subschistose rocks.

In a later report (1882b) McKay still maintained that the coal-beds were of Pareora age, but that quartz sands and fireclays of Eocene age, similar to the rocks usually associated with the coal-seams, lay beneath the "Kekenodon greensands," of Eocene age. The Maruwenua limestone was now considered to consist of three distinct rocks. The upper part (the "Phorus beds," of Upper Cretaceo-Tertiary age

of his former reports) was referred to the Hutchinson Quarry horizon, the middle part was

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correlated with the Otekaike limestone, both being referred to the Tertiary; while the basal part of the Maruwenua limestone was stated to be of the same age as the Ototara limestone (Cretaceo-Tertiary). McKay asserted that, although these three rocks are quite conformable at Maruwenua, unconformity was deemed to be present, as the Otekaike limestone rested directly on the subschistose rocks at Otekaike and Station Peak. He gave a section (1882b, p. 104) showing the relationship between the two limestones, and the Hutchinson Quarry beds were shown above the limestone at Otekaike.

Hutton (1885, p. 547) described a section on the Rakaia River, Canterbury, at a locality called "The Curiosity Shop." The aim of the paper was to show that the division of the rocks in this locality into a Cretaceo-Tertiary and a Tertiary series was quite unjustifiable on either stratigraphical or palaeontological grounds. In the course of the paper he discussed the rocks and fossils of the Waitaki Valley, criticized adversely McKay's arguments in favour of an unconformity anywhere in the series, and showed clearly that the sequence at Wharekuri from the Hutchinson Quarry beds down to the greensands forms a single series. In a later paper (1887, p. 429) he again contended that the Otekaike limestone and the Maruwenua limestone belonged to the same series.

Park (1887, p. 139) traced the Ototaran stone almost continuously from Oamaru to Ngapara, where it rests conformably on greensands, the upper part of the greensands being represented at Oamaru by the Waiarekan tuffs. The limestone (at Ngapara) was said to have lost all the characteristics of the fine Oamaru building-stone, yet "standing on the high hills surrounding Ngapara it is quite obvious that the Ototara stone at one time formed a continuous bed" (*loc. cit.*, p. 140). Park (1904a, p. 416) determined the succession of the younger Tertiaries in South Canterbury and Otago to be, in descending order, (a) Oamaru stone, (b) marly and sandy clays, (c) marly greensands, often with calcareous concretions,

(d) quartz-grits, fireclays, and coal; and he stated that "the sandy *Kekenodon* beds and underlying greensands, &c., form the base of the Tertiary beds in the old Waitaki Fiord, and, proceeding westward, they pass under a yellowish-brown limestone, which McKay calls the Otekaike limestone. I think there can be no doubt that this limestone is the horizontal equivalent of the Ngapara (Oamaru) limestone. But, without laying any stress upon the exact correlation of the limestones, we have in the Wharekuri basin a section of the Oamaru series exactly parallel with that at the Waihao River; and there is little to wonder at in this parallelism if these beds, as seems to me likely, were deposited on the floor of the same continuous sea. The position of the sandy beds [the greensands], containing, as we find, most, if not all, of the forms hitherto supposed to be typical of the Pareora [Awamoan] series, at once raises a question as to the relations of the Awamoa and other supposed Pareoras in North Otago to the Oamaru stone." In a note (1904, p. 418) Park stated that he had since obtained evidence in North Otago and South Canterbury which confirmed his conclusion that the Pareora beds (Awamoan) underlie the Oamaru (Waitaki) stone.

Hamilton (1904, p. 465) described some vertical faults striking north- north-west at Wharekuri, and his section showed the Wharekuri green-sands in contact with the quartz-grits along a line of faulting. Park (1905) elaborated his position in regard to the position of the Pareora (Awamoan) fauna beneath the Waitaki stone, and contended that there were really

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two limestone horizons in North Otago, separated by the Hutchinson Quarry and Awamoan beds. The lower limestone he called the Oamaru stone, and the upper limestone the Waitaki stone, as it was strongly developed in the Waitaki Valley. The Maruwenua limestone and the Otekaike limestone at Wharekuri were considered to be at the same horizon above the Awamoan, which, it may be remarked, is an altogether different view from that which McKay held in regard to the relationship of the Ototara (Maruwenua) limestone and the Otekaike limestone. McKay certainly considered the two limestones distinct rocks; but the requirements of the Cretaceo-Tertiary theory demanded this, as a break had to

occur somewhere in the series. Never did McKay dream of placing the Waitaki limestone above the Hutchinsonian and Awamoan horizons, for he always maintained the infra-position of the limestone in North Otago and South Canterbury (1882a, p. 65, and 1882b, p. 103). Park correlated the greensands at Wharekuri with the Hutchinson Quarry beds at Kakanui (1905, p. 523), but McKay had always maintained that the beds *above* the limestone in the Wharekuri area were undoubtedly the representatives of the Hutchinson Quarry beds at Oamaru. Park placed the coal-beds at Wharekuri at the base of the Tertiary series.

Marshall, Speight, and Cotton (1911, p. 405) stated that there was no evidence that the greensands lying beneath the Maruwenua limestone are the equivalent of the Hutchinson Quarry beds at Oamaru, but agreed with Park in his contention that the series is conformable.

Marshall (1915, p. 383) gave a list of fossils from the fossiliferous beds at Otiake, and referred them to the horizon of the Oamaru limestone (Ototaran).

Cotton (1917a, p. 285, and 1917b, p. 432) showed that the Waitaki River followed a complex graben along the northern boundary of the block-complex which forms the mountains of Otago, and he described several interesting examples of tectonic forms.

IV. Description of the Tertiary Beds.

(1.) *Trig. Station Z, Otiake River.*

The exposure of fossiliferous beds in this locality is seen on the face of a rather prominent cliff, near the Trig. Station Z, close to the Otiake River, and about a mile above the railway bridge. The beds dip 7° in a direction N. 20° W. The section exposed here is illustrated in [fig. 2](#).



Fig. 2.—Section at Trig. Station Z, Otiake River. (a) Otekaike limestone; (b) glauconitic calcareous bands; (c) less glauconitic calcareous sandstones with glauconitic bands passing up into (d); (d) softer calcareous mudstone.

The lowest bed (a) is a compact light-yellowish-brown limestone (Otekaike limestone) containing abundant tests of Foraminifera, a small quantity of clear subangular minute grains of quartz, and some glauconitic casts of Foraminifera. Microscopic fossils are scattered through the mass of the rock. *Pachymagas huttoni* Thomson, *Pecten huttoni* (Park), *Limopsis aurita* (Brocchi), *Dentalium solidum* Hutt., *Cucullaea* sp. were found in the limestone. The overlying bed (b) is distinctly marked out from the underlying

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limestone by its glauconitic nature and by the abundance of fossils it contains. Though occurring in (c) as well, the fossils are most abundant in the glauconitic bands. The bed (b) is hardened and concretionary, and is 3 ft. in thickness. Bed (c) is a calcareous, less glauconitic bed, showing a thickness of 20 ft., and containing occasional thin bands of glauconite with fossils. It appears to pass up into less fossiliferous, more sandy beds (d). The fossils collected from beds (b) and (c) are given below, and include the species collected by Dr. Thomson, Dr. Marshall, and the writer. The collector's name in each case is denoted by the initial letter of his name. For purposes of easy reference and comparison the list is arranged alphabetically. Recent species are marked with an asterisk.

<i>Ampullina suturalis</i> (Hutt.)	M, T, U.
<i>Ancilla hebera</i> (Hutt.)	M.
*— <i>mucronata</i> (Sow.)	M, U.
*— <i>novae-zelandiae</i> (Sow.)	M.
— <i>papillata</i> (Tate)	T, U.
<i>Anomia trigonopsis</i> Hutt.	T.
<i>Bathytoma sulcata excavata</i> Sut.	M, T, U.
<i>Borsonia rufis</i> (Hutt.)	M, U.
* <i>Calyptrea alta</i> (Hutt.)	T.
*— <i>maculata</i> (Q. & G.)	M, T, U.
<i>Cominella pulchra</i> Sut.	M.
<i>Corbula canaliculata</i> Hutt.	M, T, U.
— <i>humerosa</i> Hutt.	M, U.
— <i>kaiparaensis</i> Sut.	M, U.
* <i>Crassatellites obesus</i> (A. Ad.)	M, U.
<i>Crepidula gregaria</i> Sow.	M.
— <i>striata</i> (Hutt.)	M, U.
<i>Cucullaea attenuata</i> Hutt.	M, U.

<i>Cymatium minimum</i> (Hutt.)	U.
<i>Cymbiola corrugata</i> (Hutt.)	M, T, U.
<i>Cytherea chariessa</i> Sut.	U.
*— <i>oblongata</i> (Hanley)	M, T, U.
<i>Dentalium mantelli</i> Zitt.	M, U.
— <i>pareorense</i> P. & S.	T.
— <i>solidum</i> Hutt.	M, U.
* <i>Divaricella cumingi</i> (Ad. & Ang.)	M, T, U.
* <i>Dosinia greyi</i> Zitt.	M, T, U.
<i>Drillia callimorpha</i> Sut.	M.
<i>Epitonium lyratum</i> (Zitt.)	M, U.
<i>Exilia dalli</i> Sut.	M.
<i>Ficus parvus</i> Sut.	T.
* <i>Fulgoraria gracilis</i> (Swains.)	M, T.
<i>Leucosyrinx alta</i> (Harris)	M, U.
— <i>alta transenna</i> (Sut.)	M.
<i>Lima colorata</i> Hutt.	M, T.
* <i>Limopsis aurita</i> (Brocchi)	M, T, U.
— <i>catenata</i> Sut.	U.
* <i>Loripes concinna</i> Hutt.	U.
<i>Macrocallista assimilis</i> (Hutt.)	M, U.

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* <i>Macrocallista multistriata</i> (Sow.)	M, T, U.
<i>Mangilia blandiata</i> Sut.	U.
<i>Marginella harrisi</i> Cossm.	M, U.
<i>Mitra armorica</i> Sut.	T, U.
<i>Modiolaria elongata</i> (Hutt.)	U.
* <i>Modiolus australis</i> (Gray)	M.

* <i>Murex zelandicus</i> Q. & G.	M, T, U.
* <i>Natica zelandica</i> Q. & G.	M, T, U.
<i>Nucula sagittata</i> Sut.	U.
* <i>Ostrea tatei</i> Sut.	T.
<i>Pecten beethami</i> Hutt.	T.
— <i>chathamensis</i> Hutt.	T.
*— <i>zelandiae</i> Gray	M.
<i>Polinices gibbosus</i> (Hutt.)	M, T, U.
— <i>huttoni</i> Iher.	M, T, U.
* <i>Psammobia lineolata</i> Gray	T.
<i>Ptychatractus tenuiliratus</i> Sut.	U.
<i>Sinum cinctum</i> (Hutt.)	M.
<i>Siphonalia conoidea</i> (Zitt.)	M.
*— <i>nodosa</i> (Mart.)	M, T.
— <i>turrita</i> Sut.	T, U.
* <i>Struthiolaria vermis</i> (Mart.)	M.
* <i>Tellina glabrella</i> Desh.	T.
<i>Terebra orycta</i> Sut.	M.
<i>Teredo heaphyi</i> Zitt.	M, T, U.
* <i>Trichotropis clathrata</i> Sow.	M.
* <i>Turbanilla zealandica</i> (Hutt.)	T.
<i>Turris uttleyi</i> Sut.	M, T, U.
<i>Turritella ambulacrum</i> Sow.	T.
*— <i>carlottae</i> Wats.	M.
— <i>cavershamensis</i> Harris	M, T, U.
— <i>semiconcava</i> Sut.	M, T.
<i>Typhis maccoyi</i> T. Woods	M, U.
* <i>Venericardia difficilis</i> (Desh.)	M.
— <i>pseutes</i> Sut.	T, U.
— <i>purpurata</i> (Desh.)	T.
* <i>Zenatia acinaces</i> (Q. & G.)	M.

Out of this list of seventy-six species twenty-six are Recent, giving a percentage of 34.

In addition to the molluscs, *Pachymagas huttoni* Thomson is abundant in the glauconitic bands. Two new species of *Surcula* were found in the writer's collection, and Dr. Thomson obtained a new species of *Vexillum*.

Every one of the above species occurs in the Awamoan beds elsewhere, and thirty-nine species have never been found below the "*Pachymagas parki*" greensand band (the upper limit of the Hutchinsonian) in the Oamaru district. Corals also occur in these beds. (Note.—To avoid circumlocution the writer will refer to these upper fossiliferous beds as the "Otiake beds.")

Dr. Marshall has published a list of fossils from this locality, and they are stated to have come from the limestone (1915, p. 383). All fossils

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collected by the present writer have been gathered from the glauconitic band (*b*) and overlying, bed, and at least 50 ft. of limestone is exposed below this bed. This limestone is poorly fossiliferous. Corals occur in the glauconitic bands above the limestone, as well as *Pachymagas huttoni* Thomson (possibly Marshall's *Magellania* sp.), but the writer did not find *Isis dactyla*. Nor was he more successful in finding a glauconitic band of greensand *below* the limestone in which the corals and brachiopods were said to occur.

Park (1918, p. 83, footnote) says, "Mr. Uttley states (*fide* Dr. J. A. Thomson) that the beds from, which the collection was made lie above the Waitaki stone, and are undoubtedly Awamoan"; and on the next page of his report (1918, p. 84) he writes, "On the palaeontological evidence the so-called Waitaki. stone at Otiake should be referred to the Awamoan instead of the Upper Hutchinsonian."

These statements, together with Marshall's view that the fossils came from the limestone, need some comment. The fossils were collected from the top of the section, with a considerable thickness of limestone below them. The fossils are almost certainly Awamoan, but the writer considers the limestone to be of Ototaran age. In the Waitaki Valley there is a lack of brachiopods that characterize the Hutchinsonian greensands of the Oamaru coastal district, particularly the brachiopod *Pachymagas parki* (Hutt.), which, though not restricted to the Hutchinsonian, occurs abundantly in a well-marked indurated glauconitic band, and marks the upper limit of the Hutchinsonian. In the absence of a brachiopod

fauna it would scarcely be possible to differentiate this horizon, except perhaps lithologically, even in the Oamaru district, and the Hutchinsonian and Awamoan would, as far as the molluscan fauna is concerned, have to be considered as part and parcel of the same series. (See McKay, 1877, p. 58; Hutton, 1887, p. 416). The writer believes that this is the case in the Waitaki Valley, and that these fossiliferous beds at Otiake represent the Hutchinsonian and Awamoan horizons of the coastal district. McKay (1882a, p. 65) recognized the beds above the limestone at Wharekuri as Hutchinsonian, and these are at the same horizon as the Otiake beds. There is no evidence to show that the Otekaike limestone is other than Ototaran in age. The beds beneath the limestone are not seen, but on the right bank of the Otiake River, where the limestone again crops out, greyish-green foraminiferal sands, underlain by intensely dark greensands, crop out farther up the river, dipping in the same direction as the limestone; and a short distance from the outcrop of greensands the quartz-grits also dip in the same direction.

(2.) *Otekaike Special School.*

This is the locality (Geological Survey locality No. 481) where McKay collected fossils in 1881. His collection, he states, was made from the Otekaike limestone, which crops out on the left bank of the Otekaike River, two-miles and half from the main road. Where exposed it contains a few fossils, *Cucullaea worthingtoni* Hutt. (?) and *Pachymagas huttoni* Thomson being the forms collected by the writer. McKay records ten forms, eight of which occur in the upper beds at Otiake. Traill's collection (Geol. Surv. loc. 259) is also said to have come from the limestone. Seven species were determined, and six occur in the upper beds at Otiake.

These geologists evidently failed to find a highly fossiliferous horizon in this locality.; On the sloping right bank of the creek, immediately behind the school, the writer discovered, at the top of the limestone, two glauconitic beds crowded with fossils, which are undoubtedly at the same

horizon as the Otiake beds. Only 40 ft. of limestone remains, and its base is not seen. The fossils collected from the Otiake beds in this locality were—

- *Ampullina suturalis* (Hutt.)
- *Ancilla papillata* (Tate)
- *Anomia trigonopsis* Hutt.
- *Bathytoma, sulcata excavata* Sut.
- **Calyptaea alta* (Hutt.)
- *— *maculata* (Q. & G.)
- *Cominella pulchra* (?) Sut.
- *Corbula canaliculata* Hutt.
- — *humerosa* Hutt.
- — *kaiparaensis* Sut.
- **Crassatellites obesus* (A. Ad.)
- *Crepidula gregaria* Sow.
- *Cucullaea attenuata* Hutt.
- *Cymbiola corrugata* (Hutt.)
- *Cytherea chariessa* Sut.
- *Dentalium pareorense* P. & S.
- — *solidum* Hutt.
- **Divaricella cumingi* (Ad. & Ang.)
- *Epitonium lyratum* (Zitt.)
- *Leucosyrinx alta* (Harris)
- *Lima colorata* Hutt.
- **Limopsis aurita* (Brocchi)
- **Loripes concinna* Hutt.
- *Mangilia praecophinodes* (?) Sut.

- *Marginella harrisi* Cossm.
- **Natica zelandica* Q. & G.
- *Nucula sagittata* Sut.
- *Pecten chathamensis* Hutt.
- *— *zelandiae* Gray
- *Polinices gibbosus* (Hutt.)
- — *huttoni* Iher.
- *Siphonalia turrita* Sut.
- **Tellina glabrella* Desh.
- *Terebra orycta* Sut.
- *Teredo heaphyi* Zitt.
- **Turbonilla zelandica* (Hutt.)
- *Turritella ambulacrum* Sow.
- — *cavershamensis* Harris
- — *semiconcava* Sut.
- *Venericardia pseutes* Sut.
- *— *purpurata* (Desh.)

Out of this list of forty-one species, two were doubtfully identified. Eleven species are Recent, giving a percentage of 27. This collection was obtained after two or three hours' work, and there is not the slightest doubt that many additional forms may be obtained from this locality.

The brachiopod *Pachymagas huttoni* Thomson is again very abundant, and corals are also found similar to those found at Trig. Station Z. McKay (1882A, p. 66) states that in this locality the Otekaike limestone rests directly on the Palaeozoic rocks, and he gives a section (1882B, p. 104) illustrating his views. It is true that a short distance from the present locality the old rock crops out, but McKay observed no junction, as the country between is obscured by heavy gravel deposits. The writer followed up the various small creeks that have cut deeply into the gravels, and found the quartzgrits dipping towards the limestone a short distance away close up to the mountain-front, so that there is no doubt that the limestone does not

lie on the old rock at Otekaike. The section given by McKay (1882B, p. 104) was intended to illustrate his views of the relationship between the Otekaike limestone and the Maruwenua limestone, which he considered to belong to different systems. In his first report on the locality he gave a section (1882A, p. 75) showing the Otekaike limestone at a higher horizon than the Maruwenua limestone in its entirety; but in a later report during the same year he gave another section (1882B, p. 104), in which he modified his views considerably. He divided the Maruwenua limestone into three distinct rocks, and correlated the Otekaike limestone with the middle portion of the Maruwenua limestone, and the Hutchinson Quarry beds with the fossiliferous horizon ("Phorus beds") that lies at the top of the Maruwenua limestone. He had previously referred these fossiliferous beds to the top of the Cretaceo-Tertiary. His section shows clearly the Hutchinson Quarry beds lying above the Otekaike limestone at Otekaike (the present locality), although he makes no reference to them in his report. He frequently refers, however, to the Hutchinson Quarry beds

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lying above the Otekaike limestone at Wharekuri. The writer has no doubt that if McKay had discovered the glaucomitic fossiliferous beds above the limestone at Otekaike he would have referred them to the Hutchinson Quarry horizon, for his description of the latter beds at Wharekuri would apply equally well to the Otiake beds at Otiake and Otekaike. Although McKay made the break between the Cretaceo-Tertiary and Tertiary systems at the top of the lower third of the limestone at Maruwenua, yet he states that there is stratigraphical conformity throughout the section; but that unconformity is proved, as the Otekaike limestone rests on the old "subshistose" rocks at Otekaike. As there is no evidence forthcoming to show that this is so, and as the basal quartz-grits of the series are present, as shown above, unconformity has not been proved. McKay was perhaps justified on lithological grounds in dividing the limestone at Maruwenua into three portions. The "Phorus beds" at Maruwenua, as will be shown below, are similar to the Otiake beds, and therefore probably Hutchinsonian-Awamoan. The less glauconitic limestone below these at this locality has all the lithological characters, of the limestone at Otekaike, while the

more glauconitic basal portion of the limestone at Maruwenua represents the basal part of the Otekaike limestone, which is not visible in the present locality, as it is obscured by gravels.

The quartz-grits crop out again at the point where the Otekaike River leaves its gorge and debouches on to the gravel-covered plain. They lie near the foot of a steep escarpment of greywacke rock on the right bank of the stream, and mark the point of intersection of two strong faults, the one extending from Wharekuri to this point, and another trending in a north-easterly direction. The small exposure of the quartz-grits mentioned in the description of the beds at Otekaike lies on the line of the Wharekuri- Otekaike fault, and it will be shown in another paper in this volume that there are other outcrops of Tertiary rocks lying near the base of the mountain-front in the Kurow district. This fault has a north-westerly trend. The escarpment referred to above extends in a north-easterly direction towards the main road, and the crest of the evenly sloping ridge drops 500 ft. in a distance of three miles. Patches of quartz-grits and limestone crop out at various places at the foot of the scarp, and define the direction of this fault, which bounds the northeast portion of the great Kakanui tilted block (Cotton, 1917A, p. 279). The back slope of this portion of the block is stripped of its cover in the higher country towards Ben Lomond, but the covering strata (quartz-grits, greensands, limestone, &c.) are still preserved in the country extending north and south from Black Hill to Livingstone.

(3.) White Rocks and Duntroon Area.

In the Waikaura Creek, quartz-grits crop out to the east of Black Hill, and a prominent limestone mesa rises steeply from the bed of the creek. The slopes are buried in talus, and the intervening rocks are not exposed. The limestone resembles the Otekaike limestone in containing little glauconite. Its dip is westerly. From this point the Maruwenua tableland stretches to the southeast, covered by heavy gravels and silts, but the limestone is exposed in many places where the creeks have cut through the gravels.

At White Rocks, where the limestone crops out on the main road two miles above Duntroon, the highest rocks are the high-level river-gravels, overlying a limestone showing in places a thickness of 70 ft. The underlying rocks are not exposed, but the quartz-grits crop out about three-quarters of a miles up the valley, dipping in the same direction. The dip

of the limestone is easterly, at an angle of 6°. The lower part of the limestone is very glauconitic, and contains abundant Foraminifera and small echinoderms. Brachiopods also occur, being particularly abundant in one narrow band about 4 ft. wide. The limestone gradually gets less glauconitic and more indurated, and at the top it resembles the harder portions of the Otekaike limestone.

Pachymagas huttoni Thomson, *Epitonium lyratum* (Zitt.), *Graphularia* sp., and *Lima* sp. were found in this upper part.

The lower glauconitic limestone in its upper portion furnished the following fossils:—

- *Aetheia gaulteri* (Morris)
- *Liothyrella landonensis* Thomson
- *Neothyris tapirina* (Hutt.)
- *Rhizothyris rhizoida* (Hutt.)
- *Pachymagas huttoni* Thomson
- *Pachymagas ellipticus* Thomson
- *Terebratella totataensis* (?) Thomson
- *Terebratulina suessi* (Hutt.)
- *Epitonium lyratum* (Zitt.)
- *Pecten huttoni* (Park).

Foraminifera and echinoderms are plentiful in this bed.

In the neighbourhood of Dunroon, and in other places in the Maruwenua district, prominent salients in the shape of well-rounded hills and ridges are prominent above the surface of the tableland. They are capped with silts or

gravels, and their flanks are usually covered with soil and grass, but where cuttings have been made through them fossiliferous beds are exposed which correspond with the horizon above the limestone (the Otiake beds). McKay clearly recognized that the form and position of these salients were an index of their nature, for, after describing them as capped with gravels, which are underlain by brown or light-coloured sands, in the lower part of which lenticular masses and beds of hard sandstone, occur full of fossils, he says that "the fossiliferous beds underlying [the gravels] will probably be found in the isolated hills behind McMaster's Station" (1877, p. 57).

The Trig. Station A is situated on one of these prominent ridges, and on the road from Duntroon to the "Earthquake," which cuts through this ridge about one mile and a half from the railway-line, these upper fossiliferous beds crop out. In some places the fossils occurred in concretionary masses, but usually as casts. The looser portions of the rock are glauconitic and calcareous, but the fossils in these are very friable. From the hardened bed were obtained *Pachymagas huttoni* Thomson, and casts of *Turritella* sp., *Dentalium* sp., *Venericardia* sp. In the looser deposits lying immediately above, the following forms were obtained:—

- *Anomia trigonopsis* Hutt. (?)
- *Cardium* sp.
- *Corbula canaliculata* Hutt.
- **Crassatellites obesus* (A. Ad.)
- *Cytherea chariessa* Sut.
- **Limopsis aurita* (Brocchi)
- *Modiolus* sp.
- *Venericardia pseutes* Sut.

These beds are the "*Phorus* beds" of McKay, and this appears to be the locality from which he collected (Geol. Surv. loc. No. 178). These beds, as pointed out above, in his earlier reports he referred to the top of the Cretaceo-Tertiary, but subsequently he correlated them with the Hutchinson Quarry horizon, considering the underlying white limestone as the equivalent of the Otekaike limestone, while the basal portion of the limestone (usually very glauconitic) he referred to his Cretaceo-Tertiary system. The writer is in agreement with McKay in placing the "*Phorus* beds" in the Hutchinsonian, and believes they are the equivalent of the Otiake beds at Otekaike and Otiake.

At the "Earthquake" the limestone at the top of the cliffs is of the harder whitish variety, but lower down it gradually gets more glauconitic and in the lower 10 ft. it

contains an abundance of brachiopods.

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The fossils collected from the lower part of the limestone were—

- *Aetheia gaulteri* (Morris)
- *Liothyrella landonensis* (?) Thomson
- *Neothyris tapirina* (Hutt.)
- *Pachymagas ellipticus* Thomson
- *Pachymagas huttoni* Thomson
- *Rhizothyris rhizoida* (Hutt.)
- *Terebratulina suessi* (Hutt.)
- *Epitonium lyratum* (Zitt.)

Foraminifera are also abundant.

Below this fossiliferous portion 2 ft. or 3 ft. of greyish-green glauconitic marly sands are exposed, and in the basin of Waipati Creek the quartz-grits are exposed dipping towards the limestone.

(4.) *Maruwenua River.*

The quartz-grits and overlying greensands can be seen at many places between Duntroon and Livingstone. At the latter place the grits are worked for gold, and are immediately overlaid by a bed of fossiliferous greensand in which shark's teeth are abundant. This in turn is followed by concretionary greyish sands full of fossils (McKay, 1882B, p. 105). McKay, however, gave no list of fossils.

On the right bank of the Maruwenua River, at a point about a mile south-west of Trig. Station S (Maruwenua Survey District), a calcareous concretionary band full of fossils occurs in quartzose micaceous greensands, not far above, the basal quartz sands. Twenty feet above this band occurs a sill of basalt, followed by another sill higher in the section, the two sills being separated by 20 ft. of greensands. The beds dip easterly at 10°. The calcareous concretionary band is full of fossils, but, they are very difficult to extract. The late Mr. Henry Suter determined the following forms from a large quantity of material gathered by the writer. The work of identification was rendered difficult, as most of the fossils were casts.

- **Ancilla novae-zelandiae* (Sow.)
- **Capulus australis* (Lamk.)
- *Cardium waitakiense* Sut.
- *Cardium* n. sp.
- *Corbula humerosa* Hutt.
- *Cyllichnella enysi* (Hutt.)
- *Mangilia* n. sp.
- **Nucula stranger* A. Ad.
- **Polinices amphialus* (Wats.)
- *Sinum* n. sp.
- *Surcula* n. sp.
- **Turritella carlottae* Wats.
- **Venericardia difficilis* (Desh.)

Out of this small list four species are new. Mr. Suter has published the description of only one of these species—*Sinum fornicatum* Suter.

Some distance to the north-east a steep escarpment of the limestone occurs, the lower portion being glauconitic; the dip is easterly, at 7°. A few fossils were obtained from the lower part of the limestone:—

- *Aetheia gaulteri* (Morris)
- *Epitonium lyratum* (Zitt.)

- *Terebratulina suessi* (Hutt.)

At four places in the road-cuttings in Blocks 2 and 3, Maruvenua Survey District, the writer found a hardened calcareous concretionary band lying above the limestone. The fossils were in the form of casts, but the position of the beds above the limestone indicates that the Otiake beds are widely spread throughout this part of the district.

(5.) **Station Peak.**

Although this locality is beyond the scope of the present paper, a brief reference should be made to it. On the Canterbury side of the Waitaki, opposite the mouth of the Otekaike River, there is an outcrop of fossiliferous Tertiary rocks lying near the base of a well-marked fault-scarp. The beds dip 40° to the west. This scarp, which bounds the

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block mountains of South Canterbury, and close to the base of which the Waitaki River is now flowing, was diagnosed by Cotton on geomorphological evidence as a fault-scarp. The occurrence of these steeply dipping Tertiary beds at the base of the scarp confirms Cotton's view. This isolated patch of Tertiaries evidently rests on the toe of the splinter described by Cotton (1917B, p. 432). The surface of this splinter is a "fossil plain," and shows few signs of erosion. Although the Tertiary rocks that formerly covered it have been almost completely stripped, a small remnant has been preserved at Station Peak, close up to the fault-scarp at the back of the splinter. McKay collected fossils from these beds, and states that "in this section the Hutchinson's Quarry beds do not present their usual characters, and must be considered, as merged in the Otekaike limestone" (1882A, p. 65). He further adds that "the lowest beds seen are limestones as pure as, though less fossiliferous than, the higher part. Upwards these beds pass into clay-marls resembling the fossiliferous Pareora beds." There is no doubt that McKay collected his fossils from the upper, portions of the calcareous rocks at Station Peak, and that these fossiliferous rocks are underlain by a much less fossiliferous

limestone. As has been shown above, the limestone at Otiake and Otekaike is also capped by a development of very fossiliferous beds, and it has been pointed out that these beds are probably widely extended beneath the gravel deposits of the Maruwenua tableland. McKay's collection from the beds at Station Peak were determined by the late Mr. Henry Suter. Of the thirty-one species specifically determined, nineteen occur in the Otiake beds at Otiake (Trig. Station Z). Of the remainder, ten species are common Awamoan fossils, *Lima lima* (L.) is Recent, and *Ancilla subgradata* (Tate) is apparently not found elsewhere. Further, ten of the species have never been found below the Hutchinsonian-Awamoan horizon of North Otago. These fossiliferous beds are almost certainly at the horizon of the Otiake beds (Hutchinsonian-Awamoan), lying above the main body of limestone of the Waitaki Valley.

V. Structure of the Area

A fuller description of the structure will be given in a later paper after the area north-west of the Otiake River has been discussed. A fault (Wharekuri-Otekaike fault) is clearly defined by the outcrops of the basal quartz-grits, lying close to the base of the mountain-front, as shown on the map; whilst another fault, trending north-easterly, runs north-west of the conspicuous ridge extending from Black Hill as far as Ben Lomond. The geological evidence for the latter fault is clearly indicated by the outcrop of tilted quartz-grits and limestone at intervals at the foot of the scarp, and by the occurrence of the same beds on the back slope of the tilted block to the south-east. The majority of the streams draining this portion of the back slope flow in an easterly direction and are consequent on the deformation. These streams have stripped the Tertiary beds from the higher country in the vicinity of Ben Lomond, and the surface here exhibits the characteristic features of a tilted "fossil plain." Towards the Maruwenua River the plain disappears beneath the Tertiary basal grits and overlying beds in the basin of the stream. From Black Hill to Black' Point the structure of the Tertiary Rocks is synclinal, indicating that the great Kakanui tilted block (Cotton, 1917A, p. 279) has in this locality been warped or folded. The Wharekuri-Otekaike fault, forms the northeasterly boundary of the elevated block known as the Kurow Mountains. The southeasterly boundary of this block is a well-marked narrow

depression, which follows the line of the Black Hill-Ben Lomond fault as far as Dansey's Pass, near the watershed between the Kyeburn River and the Otiake and Maruwenua Rivers; but there are indications that this relatively depressed area beyond Ben Lomond is complex in structure, and not due to simple differential elevation along a single fault-line. Beyond the pass occurs the reentrant forming the northeast corner of the great Maniototo depression (*loc. cit.*, p. 278). The Kurow block is bounded on the southwest by a conspicuous fault-scarp, which rises abruptly from the fault-angle of the Hawkdun tilted block (*loc. cit.*, p. 278).

From the description given it will be seen that the tilted block is bounded on the northwest by a tectonic depression, which in the lower course of the Otekaike River is a graben, and towards Dansey's Pass appears to be a narrow somewhat complex fault-angle or synclinal depression. This depression connects the Waitaki Valley tectonic depression with the Central Otago chain of tectonic depressions (*loc. cit.*, p. 268). The Kurow mountain-chain is an uplifted elongated block, bounded by faults on the northeast and southwest, and separated from the Kakanui block by a narrow probably complex tectonic depression. To the northwest the crest of the range is remarkably even when viewed from the Waitaki Valley, and it slopes gently towards the northwest. The Waitaki Valley, northwest of the Otekaike River, is a graben; southeast of this line the river flows for some distance in a fault-angle depression, the depression being bounded on the Canterbury side by the splintered fault-scarp of the South Canterbury block mountains.

VI. Conclusion.

The brachiopods listed above from the limestone at White Rocks all occur in the glauconitic base of the limestone at Maruwenua (Park, 1918, p. 83), with the exception of *Terebratella totaraensis* Thomson, which is doubtfully identified. *Murravia catinuliformis* (Tate) occurs in the limestone at the "Earthquake," in addition to the brachiopods collected by Park (*loc. cit.*) at Maruwenua. These brachiopods, with the exception *Pachymagas huttoni* Thomson, have not been found in rocks below the limestone in North Otago. Eight brachiopods—

- *Aetheia gaulteri* (Morris)

- *Liothyrella landonensis* Thomson
- *Murravia catinuliformis* (Tate)
- *Neothyris tapirina* (Hutt.)
- *Pachymagas ellipticus* Thomson
- —— *huttoni* Thomson
- *Rhizothyris rhizoida* (Hutt.)
- *Terebratulina suessi* (Hutt.)

can now be recorded from the body of the limestone in the Waitaki Valley. None of these fossils occurs in Park's so-called Upper Hutchinsonian of the Oamaru coastal district. None of them except *Rhizothyris rhizoida* (Hutt.) occurs in the "Pachymagas parki" band (Uttley, 1916, p. 20) of the coastal district, which Park would call Lower Hutchinsonian. The writer has found *Pachymagas parki* (Hutt.), *Aetheia gaulteri* (Morris), *Terebratulina suessi* (Hutt.), and *Rhizothyris rhizoida* (Hutt.) in the greensands between the nodular top of the limestone and the "parki" band. *Pachymagas ellipticus* Thomson, *Neothyris tapirina* (Hutt.), *Liothyrella landonensis* Thomson, and *Murravia catinuliformis* (Tate) have not been found by the writer above the limestone in the Landon Creek area. Of these, *Neothyris tapirina* (Hutt.) and *Liothyrella landonensis* Thomson are undoubtedly Ototaran fossils, and never occur above the Ototaran in the typical Oamaru district. The Hutchinsonian of the Oamaru district has as its highest member a hard glauconitic band crowded with *Pachymagas parki* (Hutt.), and usually accompanied with *Rhizothyris rhizoida* (Hutt.), which Park calls

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Lower Hutchinsonian (1918, p. 109). He would, however, place the limestone in the present locality in the Upper Hutchinsonian; but the evidence is strongly against it, as the brachiopods mentioned above occur below the "parki" band in

the Oamaru district. The Otiake beds, which lie above the limestone, contain an Awamoan molluscan fauna, and in the absence of the typical brachiopod of the Hutchinsonian, *Pachymagas parki* (Hutt.), it is a difficult matter to differentiate the Hutchinsonian horizon in the Waitaki Valley. McKay and Hutton both considered the Awamoan beds to be part and parcel of the same series, and this may be true when the molluscan fauna alone is taken into account, although the Awamoan beds are far more fossiliferous than the Hutchinsonian. The Otiake beds at their base are lithologically similar to the Hutchinson Quarry beds, and all the evidence available tends to show that the Otiake beds are the equivalent of the Hutchinsonian-Awamoan horizon of the typical Oamaru district. The Otekaike limestone has been shown to be underlain by the basal rocks of the Tertiary series, and not by the "subschistose" rocks of McKay, and this fact invalidates the only evidence produced by McKay to prove an unconformity between the lower part of the Maruwenua limestone and the middle portion of that rock (his Otekaike limestone). It has been shown that McKay considered the Hutchinsonian ("Phorus beds") to lie above the limestone, and not below it as Park believes. The Waitaki Valley in the present locality is a tectonic depression, being partly a graben and partly a fault-angle depression. Extensive faulting has been proved by geological evidence.

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Art. XXIII.—Tertiary Geology of the Area between Wharekuri and the Oiake River, North Otago.

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I. Introduction

The area described in this paper covers a narrow strip of country on the right bank of the Waitaki River, extending from Wharekuri Creek to the Otiake River. The adjacent strip of country south of the Otiake River has already been described in another paper in this volume. Although the exposures of Tertiary rocks are few and widely distant, being obscured over the greater part of the area by heavy gravel deposits, the general sequence of the beds is clear. McKay has dealt with the country in some detail, but various modifications of his interpretation of the succession are necessary. The writer's thanks are due to Mr. P. G. Morgan, Director of the New Zealand Geological Survey, for permission to examine the lists of fossils collected by McKay, and determined by the late Mr. Henry Suter. An examination of these lists serves to emphasize the truth of the writer's contention (refer to Thomson, 1915, p. 123) that the molluscan fauna below the limestone is similar to that above the limestone. The upper beds, however, contain a much greater number of species.

A full historical account of previous geological work in the Waitaki Valley has already been given in another paper in this volume (pp. [140–143](#)), and only a brief critical summary of the views of other writers is necessary here.

McKay's opinion that there is an unconformity in the Tertiary rocks at Wharekuri, and that the coal occurs at the top of the sequence, is untenable. McKay was right in his view that an horizon of fossiliferous beds occurs *above* the limestone at Wharekuri, and that they are at the Hutchinson Quarry horizon. These beds are the equivalent of the writer's Otiake beds (Hutchinsonian-Awamoan) at Otiake, Otekaike, and Duntroon. As the base of the limestone is not exposed at Wharekuri, Otiake, or Otekaike, McKay was right in not correlating the limestone exposed in these places with the basal part of the Maruwenua limestone, but with a higher part of that rock. The "Pareoran" characteristics of the fauna below the limestone at Wharekuri caused Park (1905, p. 527) to correlate

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the greensands *below* the limestone in that locality with the Hutchinsonian-Awamoan horizon at Oamaru, instead of correlating the fossiliferous beds *above* the limestone at Wharekuri with that horizon, as McKay had done (1882B, p. 103). A similar error was made by Hutton in correlating the greensands below the limestone at Waihoa with the Pareora (Awamoan) horizon. Park's correlation lent support to his view that the Ototara limestone and the Waitaki Valley limestone were at different horizons. The latter in a later work (1918, p. 110) still maintained that the Wharekuri greensands are Hutchinsonian in age, but the writer is in agreement with Marshall (1915, p. 386) that the greensands are pre-Ototaran.

The geological evidence clearly shows that the Waitaki Valley is a tectonic depression of post-Awamoan age, as affirmed by Cotton on geomorphological evidence, in opposition to the view of Park (1905, p. 523) that the depression was in existence before the deposition of the Tertiary sediments.

II. General Description of the Area

From the vicinity of the Wharekuri-Otekaike fault, which bounds the present area on the southwest to within half a mile of the Waitaki River, prominent ridges and hills, possibly composed almost entirely of heavy gravels and silts, form prominent features of the landscape between the lower middle course of the Awahokomo Creek and the Kurow River. These gravel uplands are in many places 800 ft. above the Waitaki valley-plain. From the Kurow River to the Otiake River a gravel-covered tableland sloping gently towards the Waitaki River forms a rather strong contrast to the pyramidal hills and ridges just mentioned. Several prominent salients stand above the general surface of this evenly sloping plain, and, where their flanks have been cut into, fossiliferous beds are exposed.

The southwestern portion of the area is bounded by the steeply rising foothills of the Kurow Mountains. Within a short distance of the fault-line the country rises

rapidly to a height of 3,000 ft., or over 2,000 ft. above the valley-plain of the Waitaki River. To the northeast the area is flanked by the block mountains of South Canterbury, reaching to heights of 3,000 ft. not far from the Waitaki River, which now flows close to the almost undissected front of these mountains.

The average height of the Waitaki valley-plain is 650 ft. above sea-level. Kurow Hill (1,947 ft.), composed of Maitai sediments (greywacke), rises abruptly from the general level of the plain, and farther to the northwest the hill on which Trig. Station G is situated reaches a height of nearly 1,300 ft., these two prominences being separated by the depression known as the Little Awakino Valley.

The district is thus a relatively depressed area lying between the block mountains of North Otago and South Canterbury, drained by the Waitaki River, which is fed, from the Otago side, by a number of small streams, flowing in a northeasterly direction from the Kurow Mountains.

III. Geology of the Area.

(1.) *Wharekuri Basin.*

On both banks of the Waitaki River, a mile below the point where the Wharekuri Creek joins the main stream, there is an exposure of glauconitic greensands extending for two miles down the river. A list of fossils collected on the Canterbury side of the river has been published

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by Marshall (1915, p. 382). The following forms were collected by the writer and determined by Mr. Suter. Recent species are indicated by an asterisk.

- *Ampullina suturalis* (Hutt.)
- *Ancilla papillata* (Tate)

- **Anomia trigonopsis* Hutt.
- *Bathytoma sulcata excavata* Sut.
- *Borsonia rufis* (Hutt.)
- **Calyptrea maculata* (Q. & G.)
- *Chione meridionalis* (Sow.)
- *Corbula humerosa* Hutt.
- **Crassatellites obesus* (A. Ad.)
- *Cucullaea attenuata* Hutt.
- *Dentalium mantelli* Zitt.
- —— *solidum* Hutt.
- **Dosinia greyi* Zitt.
- *Epitonium lyratum* (Zitt.)
- *Glycymeris cordata* (?) Hutt.
- **Limopsis aurita* (Brocchi)
- *Limopsis zitteli* Iher.
- **Macrocallista multistriata* (Sow.)
- **Malletia australis* (Q. & G.)
- *Miomelon corrugata* (Hutt.)
- **Ostrea tatei* Sut.
- *Polinices gibbosus* (Hutt.)
- —— *huttoni* Iher.
- **Psammobia lineolata* Gray
- *Sinum cinctum* (Hutt.)
- *Teredo heaphyi* Zitt.
- *Turritella ambulacrum* Sow.

- *— *carlottae* Wats.
- — *concava* Hutt.
- *— *symmetrica* Hutt.
- *Venericardia pseutes* Sut.

In addition to the above, five new species have been described from the same locality by Mr. Suter. These are—

- *Borsonia mitromorphoides* Sut.
- *Epitonium gracillimum* Sut.
- *Euthria callimorpha* Sut.
- *Niso neozelanica* Sut.
- *Vexillum ligatum* Sut.

The greensands from which these fossils were collected, are greyish-green in colour and very glauconitic, the glauconite occurring as foraminiferal casts. There is also a considerable quantity of microscopic, subangular, clear quartz. On the Canterbury side of the river these beds form a flat syncline, both limbs showing a dip of 3°, the axis of folding running north by east. Quartz-grits crop out on the bank of the river dipping below the greensands, and farther to the north coal occurs associated with the quartz-grits in a shallow depression on the Canterbury side of the river, this depression being hemmed in by the steep fronts of elevated blocks. On the Otago side of the river the greensands again prove fossiliferous. The following species were collected on the right bank of the river, near Trig. Station H:—

- *Ampullina suturalis* (Hutt.)
- **Ancilla australis* (Sow.)
- — *papillata* (Tate.)
- **Anomia trigonopsis* Hutt.
- *Bathytoma sulcata excavata* Sut.
- *Chione meridionalis* (Sow.)
- *Cominella exsculpta* Sut.
- — *pulchra* Sut.

- **Crassatellites obesus* (A. Ad.)
- *Cucullaea attenuata* Hutt.
- —— *australis* (Hutt.)
- **Cytherea oblonga* (Hanley)
- *Dentalium mantelli* Zitt.
- —— *solidum* Hutt.
- *Epitonium gracillimum* Sut.
- —— *lyratum* (Zitt.)
- **Limopsis aurita* (Brocchi)
- —— *zitteli* Iher.
- **Macrocallista multistriata* (Sow.)
- **Malletia australis* (Q. & G.)
- *Miomelon corrugata* (Hutt.)
- *Nucula* sp.
- *Panope orbita* Hutt.
- *Pecten chathamensis* Hutt.
- —— *huttoni* (Park).
- —— *yahliensis* T. Woods
- *Polinices gibbosus* (Hutt.)
- —— *huttoni* Iher.
- **Psammobia lineolata* Gray
- *Sinum elegans* Sut.
- **Siphonalia nodosa* (Mart.)
- *Teredo heaphyi* Zitt.
- *Turbo approximatus* Sut.

- *Turritella ambulacrum* Sow.
- *— *carlottae* Wats.
- — *cavershamensis* Harris
- — *concava* Hutt.

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Out of the thirty-seven species of Mollusca enumerated above, ten are Recent, giving a percentage of 27.

McKay's collections from the "Kekenodon beds" (Geol.' Surv. loc. No. 476) and from the Wharekuri greensands (Geol. Surv. loc. No. 486) contain in all thirty-one definitely determined species. If McKay's collections and the list given above are combined the percentage is still 27.

Corals are abundant in the greensands at this locality. The genera represented are *Flabellum*, and *Trochocyathus*. *Aturia ziczac* var. *australis* Hamilton and *Kekenodon onomata* Hector were also obtained here, by McKay and Hamilton. *Pachymagas huttoni* Thomson also occurred. These greensands, which are similar to the greensands on the opposite side of the the river, contain in their lower portions small quartz pebbles, well rounded; and occasional pieces of wood up to 18 in. in length, and completely carbonized, also occur. The lower part of the beds is very concretionary, and the fossils are difficult to remove. The oxide of iron which forms the concretionary masses has been derived from the decomposition of the glauconite.

At the Wharekuri Bridge greensands again crop out, but the fossils are not abundant. The following forms were recognized:—

- *Corbula canaliculata* Hutt.
- **Crassatellites obesus* (A. Ad.)

- *Cucullaea attenuata* Hutt.
- *Dentalium mantelli* Zitt.
- *Dentalium solidum* Hutt.
- **Limopsis aurita* (Brocchi)
- *Pecten huttoni* (Park)
- *Polinices huttoni* Iher.

Similar corals to those so abundant in the greensands on the banks of the Waitaki River also occur here.

McKay (1882A, p. 73) always considered that the greensands (Cretaceo-Tertiary) near the Wharekuri bridge lay unconformably below the “*Kekenodon* greensands” on the banks of the Waitaki River, but he saw no unconformable junction between these two beds. Hutton (1885, pp. 563–64) and Park (1905, p. 523) have shown clearly that McKay's unconformity had no justification, and was merely a deduction in the light of a preconceived theory (Cretaceo-Tertiary theory). The writer is satisfied that the greensands form one series of rocks lying immediately on the quartzose rocks of the coal series. As shown above, the greensands contain pebbles of quartz in their lower portions.

The coal-rocks crop out at Wharekuri a short distance above the bridge, where they are lying in close contact with the greensands. The line of junction is vertical, and is undoubtedly a faulted one, as Hamilton (1904, p. 465) has shown. This vertical fault strikes N. 20° W. The coal-rocks dip 26° to the west—that is, towards the mountains—which a short distance away rise abruptly from the bed of the creek. McKay considered that the quartzgrits and sandstones associated with the coal in this locality were of Pareora (Awamoan) age, but in other places in the area, as shown above, they dip beneath the greensands, and are, undoubtedly at the base of the series. Beyond the coal-mine on the right bank of the creek the following section is exposed:—



Fig. 2.—Section, right bank of Wharekuri Creek. (a), (c), (e), gravels and sands; (d), fine micaceous sandy bed; (b) and (f), greenish-grey clay.

The beds dip 70° in a direction N. 10° E. Beds (*a*), (*c*), and (*e*) are gravel deposits, composed of pebbles up to the size of a cricket-ball, intermingled with fine sands. The pebbles consists of greywacke, sandstone, and quartz, all well water-worn. Bed (*c*) contained a piece of lignitized wood. Beds (*b*) and (*f*) are light-coloured greenish-grey unctuous clays. Bed (*d*) is a fine micaceous sandy bed. On the opposite side of Wharekuri Creek, not 20 yards away, a steep face of the Maitai rocks rises abruptly from the bed of the creek. Slickensided surfaces were noted, and much crush-breccia; and extensive faulting is everywhere indicated. The steeply dipping beds just described show no contact with the other Tertiary rocks in the area.

McKay's section (1882B, p. 101) certainly indicates the order in which the various rocks crop out, as the Wharekuri Creek is followed from its junction with the Waitaki River to the point past the coal-mine, where the tilted beds occur, except that the limestone does not occur in the section exposed in the creek. The tilted beds just described were said by McKay to be of Upper Pareora (Awamoan) age, and to contain, the coal deposits that are worked at Wharekuri. He observed no junction of these tilted beds, and the quartz, sandstone, and clays in which the coal-seam occurs are separated from them by slope deposits and heavy river-gravels. The composition of the beds is also quite different from the beds associated with the coal at Wharekuri Coal-mine. Park (1905, p. 524) stated that there was no evidence to show that the coal-rocks lie at the top of the sequence. The tilted beds, however, may lie conformably at the top of the Tertiary series, although this cannot be definitely affirmed, as no junction was observed. They have certainly been involved along with the Tertiaries in the tectonic movements of the district, the evidence for which is seen at many points in the Waitaki Valley. These tilted gravels appear to be widespread in the Upper Waitaki Valley and in the Waihao district, for McKay described another section in the former locality as follows: "In this section [Quail Burn] the lowest beds seen are soft sandstones, divided into thick bands by beds of greenish greasy clay. These beds dip northwest at an angle of 45°.... At two or three places along the southeast slopes of these hills pieces of lignite have been found and ... having, as I consider, proved that the Wharekuri coal-seam farther down the Waitaki occurs in beds of this age, there is more than a possibility of coal being found near the mouth of the Quail Burn." No other geologist would, agree with McKay in the inference drawn in the

last part of this quotation, but the description of these gravel-beds indicates that they are similar to the tilted beds at Wharekuri.

In the Waihao district the gravels are also often tilted, and Hector refers to these in the following words: "With the Waitaki Valley as it now is these beds have no direct connection, since they abundantly show that movements of the lands involving a considerable alteration of its surface configuration have taken place since their deposition; the beds being frequently tilted at high angles, especially in districts distant from the coastline" (1882, p. xxv), These tilted gravels in the Wharekuri locality are overlain unconformably by the high-level terrace - gravels (McKay 1882B, p. 102).

(2.) *Awahokomo Basin*

McKay (1882A, p. 66) states that the Otekaike limestone at Wharekuri "is traceable as a continuous line for three miles." The exposure, however, has nothing like the extent ascribed to it by McKay; it crops out

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on the foothills flanking the Awahokomo Creek on its northern bank. In its upper portion, which is almost inaccessible, as the cliffs are precipitous, two shell-bands were noticed, and, judging by talus strewing the slopes at the base of the cliff, they are glauconitic. The writer examined the limestone, and its main body appeared to be poorly fossiliferous. McKay (1882A, p. 67) states that in the limestone "fossil shells are most abundant... covering the whole ground with shells in a more or less perfect state of preservation." As he comments on the fact that the limestone forms vertical, cliffs not less than 50 ft. in height, it is possible that the fossils were collected from the slopes and had come from the shell-bands higher in the section.

Suter determined seven forms said by McKay to have come from the Otekaike limestone, and five of these occur in the Otiake beds at Otiake, which lie above the main body of limestone, while the two remaining fossils are found in the

Awamoan. McKay recognized the Hutchinson Quarry beds at Wharekuri, and he described them as "loose dirty greensands full of shells, followed by grey sands, and they follow the Otekaike limestone conformably." In the list of fossils determined by Suter from these beds, ten occur in the Otiake beds at Otake, three occur in the Awamoan at Oamaru, and one has not been reported elsewhere. The following note was appended to the manuscript list of fossils, evidently written by one of the staff of the Geological Survey: "According to McKay's MS., the beds collected from form the higher part of the ridge south of the coal-mine at Wharekuri." This means that the collection came from beds lying immediately above the limestone, and these beds are undoubtedly at the same horizon as the fossiliferous beds that occur at the top of the section at Otiake, at Otekaike, and in bands at the top of the limestone near the Awahokomo Creek. Although only fourteen species were determined by Suter, Hector stated that "altogether, about a hundred species were collected from this horizon in the Wharekuri section" (1882, p. xxvii).

McKay himself reported the following forms (*nom. mut.*):-

- *Cucullaea alta* (?) Sow.
- *Dentalium solidum* Hutt.
- *Limopsis zitteli* Iher.
- *Pecten hochstetteri* Zitt.
- *Polinices huttoni* Iher.
- **Venericardia difficilis* (Desh.)
- *Waldheimia triangulare* Hutt.

The brachiopod is evidently, *Pachymagas huttoni* Thomson, and is said by McKay to be very abundant, as it always is at the horizon of the Otiake beds. At one locality on the ridge extending from Wharekuri to the Awahokomo the writer found an outcrop of ferruginous micaceous quartz sands at a higher elevation than the limestone. McKay writes that "in this locality the Otekaike limestone passes upwards into the Hutchinson Quarry greensands, which are here overlain by rusty quartzose gravels ... not unlike the rocks met with at the base of the Cretaceo-Tertiary series ... these quartzose gravels are followed by sandstones." The beds observed by the writer appear to be conformable to the limestone, as the dip was the same, but no junction was seen. It is in these beds that McKay thought the Wharekuri coal occurred, and he correlates them with the tilted beds there. The limestone of the ridge on the left bank of the Awahokomo dips 10° in a direction N. 30° W. towards the Kurow Mountains.

The quartzgrits and sandstones at the base of the series crop out on both banks of

the Awahokomo south of the limestone exposure, and farther up the stream the greensands are seen dipping 30° westerly towards

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the Maitai rocks, which, at this point rise very steeply. From the green sands the following forms were obtained:—

- *Corbula canaliculata* Hutt.
- *Cucullaea* sp.
- **Limopsis aurita* (Brocchi)
- *Panope orbita* Hutt.
- *Polinices gibbosus* (Hutt.)
- *Ostrea* sp.
- *Turritella cavershamensis* Harris

Corals similar to the genera collected on the south, bank of the Waitaki River also occur here

Marshall (1915, p. 381) obtained several species from these greensands at an horizon lying 20.ft. above the quartzgrits. This writer recognized the fault in this locality, and traced the fault-breccia towards Wharekuri, and there can be no doubt that this fault is a continuation of that described above at Wharekuri.

(3.) *Awakino Basin.*

Traces of the quartzgrits are seen in many places in the basins of the Awahokomo and Little Awakino Streams. In the basin of the latter, about a mile and a half from the main road, these rocks are exposed on the right and left banks, and to the

southwest the eroded surface of the Maitai rocks rises from beneath them, and slopes gently upwards towards the crest of Kurow Hill. The quartzgrits evidently formerly covered the whole of this "fossil plain," which has now been partially stripped of its former cover. The plain forms the back slope of the tilted block figured by Cotton (1917B, p. 432). This block will be referred to later as the Awakino tilted block. Quartzgrits and greensands occur as mapped in several places in a southwesterly direction towards the Big Awakino River, and in many places close to the line of the Wharekuri-Otekaike fault, where the Maitai rocks rise very abruptly. A mile west of the trigonometrical station on Kurow Hill there is a small coal-mine, which supplies an inferior type of coal. It is being worked at present close up to the face of a steeply rising greywacke scarp. The coal-rocks dip away from the scarp at 45° in a direction S. 28° W. The scarp, which is almost undissected in this locality, extends in a northwesterly direction, gradually diminishing in height, and reaching the road-level about half a mile northwest of the point where the west branch of the Little Awakino crosses the road on the southwest side of Kurow Hill. The scarp is evidently a fault-scarp, determined by a fault of diminishing throw, which trends N. 60° W. to meet the main Wharekuri-Otekaike fault. The fault bounds the Awakino tilted block on the southwest. In the angle defined by these two faults the gravel deposits are of great thickness, but the basal quartzgrits and overlying greensands (McKay, 1882B, p. 102) crop out occasionally. The Tertiary rocks have evidently been extensively eroded, and their remnants are buried by the gravel deposits, which now form hills 2,000 ft. in height (*loc. cit.*, p. 99). Cuttings show that the gravels are of at least two types—heavy greywacke and sandstone boulder deposits, and deposits composed of well-rounded sandstone pebbles and sands. At one place on the road between the basin of the Little Awakino and the Big-Awakino the soft unctuous bluish clay similar to that described at Wharekuri was observed in a cutting. McKay states that the latter (the so-called "Pareora gravels") are highly tilted in the present locality, and he refers the coal deposits of the neighbourhood to the horizon of these rocks (1882B, p. 102). The gravels extend to the Kurow River, forming even-topped elongated ridges and pyramidal hills, which have been blocked out by the action of the numerous intermittent streams that drain the area. Across

this gravel-mass the Big Awakino flows, entrenched below the general surface of its former valley-plain, which in this portion of its course, over the area lying between the two faults referred to above, is about a quarter of a mile wide. At the coal-mine the stream enters a narrow gorge, which it has cut through the Awakino tilted block on its way to join the Waitaki River. The Big Awakino pursues a remarkably straight course from its source, near the crest-line of the Kurow Mountains, to its mouth, and this course is evidently consequent on the initial deformation; but, as the movements were probably not simultaneous over the whole of northern Otago, the uplift of the Awakino block may have commenced later. The course of the Big Awakino across the Awakino block in a narrow gorge-like channel must be considered as antecedent to the uplift of this block. Its lower course is therefore what Cotton (1917A, p. 253) has termed "anteconsequent."

(4.) *Kurow River to Otiake River.*

On the left bank of the Kurow River, four miles above its junction with the Waitaki River, an outcrop of fossiliferous Tertiary rocks occurs. There is only a small exposure, extending along the bank for about 30 yards. The rocks dip at an angle of 46° towards the south-west, and the Maitai rocks rise steeply a short distance from these beds. The junction is again obscured by the gravel deposits, but it is undoubtedly a faulted one. The Tertiary exposure here consists of a hardened calcareous greensand containing Foraminifera, mainly in the form of glauconitic casts. Minute subangular grains of quartz also occur. The larger fossils are poorly preserved, and specific identifications could not be made. The following genera were found: *Cucullaea*, *Malletia*, *Panope*, *Pecten*. This outcrop is on the line of the Wharekuri-Otekaike fault.

The outcrops of Tertiary rocks are few and scattered between the Kurow River and the Otiake River. About three-quarters of a mile to the south-east of the last locality quartz-grits occur in places, and farther on there is a small exposure of a glauconitic calcareous rock. The only forms obtained were *Dentalium solidum* Hutt. and *Limopsis aurita* (Brocchi). Near the source of the most southerly tributary of Malcolm's Creek the quartz-grits again crop out, flanked to the south-west by the steeply rising foothills of the ranges. Traces of greyish-green glauconitic sandstones were found near Trig. Station N. In a cutting on the road that leads from Malcolm's Creek to the basin of the Otiake River there is a small outcrop of calcareous rock, from which the following fossils were obtained:—

- *Corbula canaliculata* Hutt.
- *Cytherea chariessa* Sut.
- *Dentalium solidum* Hutt.
- **Limopsis aurita* (Brocchi)

- **Malletia australis* (Q. & G.)
- *Nucula sagittata* Sut.
- *Panope* sp.
- *Pecten huttoni* (Park)

Traces of brachiopods were also found.

A mile from the railway-line the following section ([fig. 3](#)) is exposed on the right bank of the Otiake River:—



Fig. 3.—Section, right bank of Otiake River. (a), Limestone (Otekaike limestone); (b), glauconitic calcareous shell-bed; (c), calcareous sandy mudstone; (d), hardened calcareous glauconitic bed; (e), calcareous sandy mudstone.

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The limestone (a) becomes glauconitic in its upper 8 ft., and is then capped by (b), a glauconitic calcareous shell-bed 18 in. in thickness and crowded with fossils. The band is concretionary in places, and similar to the beds at the top of the Otiake beds at Trig. Station Z, which is only a short distance from this exposure. From this band the following species were obtained:—

- *Ancilla papillata* (Tate)
- *Bathytoma sulcata excavata* Sut.
- *Corbula canaliculata* Hutt.
- — *Kaiparaensis* Sut.
- **Crassatellites obesus* (A. Ad.)

- *Cucullaea australis* (Hutt.)
- *Cytherea chariessa* Sut.
- *Dentalium mantelli* Zitt.
- —— *solidum* Hutt.
- **Divaricella cumingi* (Ad. & Ang.)
- *Lima colorata* Hutt.
- *Nucula saggitata* Sut.
- *Pecten beethami* Hutt.
- —— *chathamensis* Hutt.
- —— *huttoni* (Park)
- *Placunanomia incisura* Hutt.
- *Polinices huttoni* Iher.
- *Siphonalia turrita* Sut.
- **Tellina glabrella* Desh.
- *Teredo heaphyi* Zitt.
- *Turritella ambulacrum* Sow.
- —— *cavershamensis* Harris
- —— *semiconcava* Sut.
- *Venericardia pseutes* Sut.

The coral *Balanophyllia hectori* T. Woods and *Pachymagas huttoni* Thomson were also identified. The overlying bed (*c*) is less glauconitic, but is capped by another glauconitic hardened bed (*d*), and above this the rock passes up into a poorly fossiliferous calcareous mudstone (*e*). From bed (*c*) were obtained many of the forms detailed above from bed (*b*). The following additional species occurred:—

- *Corbula humerosa* Hutt.
- *Cucullaea attenuata* Hutt.
- *Leucosyrinx alta* (Harris)

- **Limopsis aurita* (Brocchi).

River-gravels and silts lie unconformably at the top of the section.

These fossiliferous beds lie above a limestone, of which about 40 ft. is exposed, and are certainly the equivalent of the Otiake beds at Trig Station Z and at Otekaike School. The beds dip 8° in a direction N. 30° W. Greensands crop out on the right bank of the stream about 12 chains farther up the river, dipping in such a way that they would pass beneath the limestone. They are similar to the greensands described, at Wharekuri, containing in places ferruginous nodules. Traces of lamellibranchs were seen, but, none could be identified. The rock is calcareous, and the glauconite in it occurs as foraminiferal casts. Still farther up the stream, at the point where the road crosses the river, intensely dark greensands crop out. These greensands are threaded with ferruginous veins. Farther up the stream the quartzgrits occur dipping towards the higher beds.

IV. General Succession and Palaeontological Notes.

The Tertiary rocks in the Waitaki Valley form a conformable sequence. The general succession is similar to that in the Waihao district of South Canterbury. Quartzgrits, often containing coal, are followed by micaceous quartzose, greensands with interbedded concretionary bands, usually fossiliferous; these are followed by calcareous glauconitic greensands (containing a little microscopic quartz and mica), which are often fossiliferous. In the basin of the Maruwenua River and at Black Point a few fossils have been determined, and these undoubtedly represent an horizon near the base of the greensands—Park's Bortonian. The looser glauconitic greensands lying above the Bortonian have not proved fossiliferous in the

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Duntroon or Kurow districts, except at Wharekuri, where the fossils are abundant. No junction has been observed between the greensands and the underlying Ngaparan coal-rocks except at Black Point. There appears to be a very gradual

transition from the quartz conglomerates and fine micaceous quartz sands into the overlying greensands, the glauconite of the latter becoming very abundant, and the quartz and mica gradually diminishing. In the Maruwenua cliffs near Duntroon the limestone overlying the greensands is very glauconitic, and at White Rocks and the "Earthquake" this glauconitic lower portion of the limestone increases greatly in thickness. In the Landon Creek area also this glauconitic portion of the limestone shows a thickness of 50 ft. below the Hutchinsonian horizon (refer to Park, 1918, p. 46). It is noticeable that where the limestone is very glauconitic the brachiopods are abundant. From the glauconitic portion of the limestone near Duntroon, as well as from a higher horizon in the limestone at White Rocks and the "Earthquake" in the Waitaki Valley, a brachiopod fauna similar to that occurring in the glauconitic portions of the limestone at Landon Creek, in the Oamaru district, has been found; and the evidence available strongly favours the view that both rocks are Ototaran. There is no evidence to show that the limestone of the Waitaki Valley is Hutchinsonian. The base of the Otekaike limestone at Wharekuri, Otiake, and Otekaike is not seen in any of the sections exposed. It is probable that if the base of the limestone were not hidden by the gravel deposits we should find the same brachiopod fauna that characterizes the base of the limestone at Maruwenua. The fossiliferous beds overlying the limestone at Wharekuri, at Otiake, at Otekaike, at Duntroon, and at Station Peak are at the same horizon, and represent the Hutchinsonian-Awamoan horizon of the Oamaru district. These rocks pass up into poorly fossiliferous calcareous mudstones.

In the Oamaru district the Ngaparan rocks are overlain by fossiliferous glauconitic calcareous greensands, which in turn are overlain by the Waiarekan tuffs, followed by interbedded tachylite tuffs and diatomaceous deposits, which are overlain by the Ototaran limestone, followed by the Hutchinsonian and Awamoan beds. In the Papakaio district the succession is similar, although the Awamoan beds have been denuded, except at Pukeuri, where all observers agree that they follow the Hutchinsonian. In the Waitaki Valley the succession is not complicated by the presence of volcanic rocks, nor are there diatomaceous beds; but all the evidence available goes to prove that the greensands below the limestone are of Waiarekan age, and that the limestone is Ototaran. The beds above the limestone contain a distinctly Awamoan fauna, and, as both Hutton and McKay believed that the Hutchinsonian and Awamoan were part and parcel of the same series (and the evidence of the molluscan fauna in the Oamaru district supports this view), these fossiliferous beds (Otiake beds) have been classed as Hutchinsonian-Awamoan. In the Oamaru district, however, the occurrence of a brachiopod fauna fully justifies the separation of the post-Ototaran rocks into two stages.

The greensands between the Ngaparan coal-rocks and the limestone in North Otago and South Canterbury will probably admit of subdivision in the future. The fossils have hitherto been "lumped," but, judging from McKay's report on the Waihao district, several lithological divisions can be recognized; and, as the rocks are very fossiliferous, careful collecting and accurate determinations of fossils

from each horizon would probably enable a subdivision of the Waiarekan to be made, as has been

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done by Park in his latest work (1918, p. 26). Many of the species contained in these lower greensands occur also in the Awamoan, but the latter horizon contains a much greater variety of species, and a large number of these appear to be restricted to this horizon. In the Oamaru district the brachiopods have proved serviceable in differentiating several horizons, but some of these brachiopods are apparently restricted to this area, and detailed correlation with beds in the Waitaki Valley is not yet possible. This brachiopod fauna has been discussed in another paper in this volume (pp. [152–53](#)). Corals, Echinoderms, and Foraminifera occur abundantly in the Oamaruan of North Otago, but our knowledge of them is very incomplete, and useless for detailed stratigraphical work. A revision of all these groups is urgently needed.

Of the ninety-four species of Mollusca determined from the beds above the limestone in the Waitaki Valley (Otiake beds), seventy-three species occur in the typical Awamoan at Oamaru, four occur in the Hutchinsonian (of Thomson), twelve forms have apparently not been recorded elsewhere in North Otago, whilst only five species have not been previously recorded from post-Ototaran beds. Five of these not recorded elsewhere are new species, seventy-nine species have now been listed from the greensands below the limestone in the Waitaki Valley, and fifty-six of these occur in the Awamoan beds at Oamaru. Nearly three hundred species have been recorded from the Awamoan beds at Oamaru; but in the case of the beds of the Waitaki Valley the collections are few, and previously unrecorded species are continually turning up. The figures quoted above, in the absence of fairly exhaustive collections, do not give much ground for definite conclusions, but they do show that the Otiake beds contain a molluscan fauna of which 78 per cent. occurs in the typical Awamoan, beds of Oamaru. The fauna of the greensands below the limestone contains 70 per cent. of the fossils recorded from the Awamoan at Oamaru, showing that in the Waitaki Valley the fauna above and below the limestone has a strong resemblance to the typical Awamoan fauna

V. Physiography of the Area.

(1.). *Kurow Block.*

From what has already been said it will be evident that Cotton's statement (1917A, p. 285) that the Waitaki River "follows a complex graben along the northern block-complex ... which forms the northern highland of Otago" is amply justified by the geological evidence. This graben, is bounded on the southwest by the elevated block called the Kurow-Mount Mary Range (Kurow-block); on the northeast it is flanked by the block mountains of South Canterbury; on the southeast by a portion of the Kakanui block (*loc. cit.*, p. 272). Towards the northwest the fault on the Canterbury side of the river and the Wharekuri-Otekaike fault approach each other, and probably coalesce farther up the Waitaki Valley; but this area lies beyond the scope of the present paper.

The Kurow-Mount Mary Range is an elevated, tilted block of probably complex structure; it is elongated in a northwesterly direction. It is bounded towards the west by a conspicuous fault-scarp (*loc. cit.*, p. 278), and its rather steeply dipping back slope descends towards the Waitaki River, and is then intersected by the Wharekuri-Otekaike fault. A line of dislocation runs from the Otekaike River to Dansey's Pass to meet the great reentrant occupied by part of the Maniototo depression (*loc. cit.*,

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p. 278). It has been shown in a former paper that a well-marked fault occurs on the right bank of the Otekaike River, and it probably extends in a south-westerly direction for some distance. The district maps show a marked depression beyond Ben Lomond, and it is probable that sharp folding or faulting has taken place on the same line. The back slope of the Kurow block is not simple, and signs of warping are not wanting, the general slope, however, is north-westerly, and the majority of the streams are consequent. As already pointed out, the Big Awakino

in the lower part of its course is anteconsequent.

(2.) *Awakino and Trig. G Blocks.*

Kurow Hill is a tilted block, as shown by Cotton (1917b, p. 432), and, as the Big Awakino and the Little Awakino flow across it, it has been called the Awakino block. The geological evidence for the boundary faults has been already presented. It has been shown that the coal-rocks crop out on the south-west side of the block, near the base of a steep fault-scarp almost entirely undissected, and traceable for a distance of four miles. This north-westerly-trending fault meets the main Wharekuri-Otekaike fault in the basin of the Little Awakino Creek, where the scarp dies out and the stripped surface of the Awakino block is seen to dip below the Tertiary rocks. In the basin of the Little Awakino, about a mile from the main road, quartz-grits are exposed on both sides of the creek, "concealing the erosion-surface of the Awakino block, which has been stripped of its covering strata towards the south-east in the higher parts of Kurow Hill. These grits on the left bank of the creek crop out near the base of a prominent scarp which rises 200 ft. or 300 ft. above the quartz-grits, the attitude of the rocks clearly indicating faulting. From the top of the scarp the surface slopes towards the north, and the quartz-grits crop out in several places, but the surface has been almost completely stripped. The back slope of this small tilted block, on which the Trig. Station G is situated, descends towards the Waitaki River, where the Tertiary rocks are exposed on both banks. The fault-scarp of this block diminishes in height as the Little Awakino Creek is ascended, and the fault dies out towards the west, the erosion-surfaces of the Awakino block and this small one evidently coalescing, and dipping beneath the Tertiary rocks in the Awahokomo basin. These two blocks are flanked on the east by the Waitaki River, which in this part of its course flows close to the steep scarp of the more elevated Canterbury mountains. The valley-plain of the Waitaki River from near Trig. Station G to Kurow is narrow and rock-bound, and the stream is now flowing close to the main fault-line on the southern side of these mountains.

VI. The Gravels (excluding Recent Deposits).

The terraces and gravels of the Waitaki Valley are well worthy of a detailed study, but good topographical maps are a prime necessity. Some remarks, however, should be made on the gravel deposits. McKay clearly recognized that the gravels were not all of the same origin. His descriptions are somewhat difficult to follow. He distinguishes three types of these deposits—(1) angular gravels, (2) well-rounded coarse gravels, (3) gravels and sands with lignite deposits. He notes that (1) and (2) contain fossiliferous Triassic and Permian boulders, and that (3) are often highly tilted. These three types can undoubtedly be recognized, but it will be

a difficult matter to trace their boundaries, and this has not been attempted in the present paper. The angular gravels are ascribed by McKay to the action of glaciers—that is, they are glacier-deposits that owe their origin to former glaciers from the neighbouring Kurow and Hakataramea Mountains. Not having discovered these Triassic and Permian fossiliferous rocks in the Kurow Mountains, McKay concluded that glaciers brought them from the Canterbury mountains which were known to contain these older fossiliferous rocks. There is, however, a total absence of the characteristics of glacial deposits, glacial striations being quite lacking. It is true that large masses of rock and fine silts and clays are mixed confusedly together in the deposits near Wharekuri. Marshall explained these angular deposits differently, and (1915, p. 381) stated that the Maitai rocks in the neighbourhood of the fault (Wharekuri-Otekaike fault) have been much shattered; that weathering has developed their shattered nature, and they break down into "a clayey material which still contains angular fragments of rock." Park (1904, p. 448) traced the fossiliferous boulders to their source near the summit of Mount Mary. The rocks were found *in situ* at a height of 5,160 ft., at a point distant about three miles and a half from the Wharekuri-Otekaike fault-line. These deposits which occur close to this line were probably derived from the dissection of the fault-scarp as it rose, for deep aggradation would take place as the deformation proceeded. The sloping surface of the tilted block, to the west of the fault-line, would also undergo degradation by the numerous consequent streams, and the waste would be spread out on the floor of the depression, forming an alluvial gravel-plain. This plain appears to have been built up after the reduction of the valley lowland to somewhat low relief. The extensive aggradation would therefore imply a great increase in the supply of waste due to the increasing differential elevation. As the streams that deposited these gravels are now well entrenched, regional uplift has probably been the most recent movement. McKay believed that the tilted sandstone gravels at Wharekuri lay conformably above the higher fossiliferous beds. They may do so, but the writer was unable to satisfy himself on that point. There is no doubt, however, that they have been involved in the differential movements, and may possibly represent the period of emergence of the land.

VII. Summary and Conclusion.

- (1.) The Maruwenua limestone is overlain directly by the Otiake beds (Hutchinsonian-Awamoan).
- (2.) McKay's unconformity between the lower and upper parts of the limestone is non-existent, and all other observers agree that the rock is a unit.
- (3.) McKay correlated the base of the limestone with the Ototaran limestone; the upper part (his Otekaike limestone) must, therefore be Upper Ototaran, -and the overlying beds (McKay's Hutchinson's Quarry beds) are the equivalent of the Hutchinsonian-Awamoan of the coastal district.
- (4.) The upper part of the limestone at Landon Creek contains a number of brachiopods that are similar to the brachiopods from the lower portions of the Maruwenua limestone (so-called Waitaki stone). Some of these brachiopods do not rise above the Ototaran of the typical Oamaru district. The evidence points to the limestone of the Waitaki Valley being Ototaran.

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- (5.) The greensands at Wharekuri probably represent a slightly higher horizon than the Bortonian of Park, and from the evidence at present available they are probably the equivalents of the Waiarekan tuffs, yet the latter are practically unfossiliferous.
- (6.) Volcanic rocks, as shown in a previous paper (*Trans. N.Z. Inst.*, vol. 50, pp. 106-17, 1918), occur in the Maruwenua district: they may be either lava-flows or sills—the evidence in the small exposure observed was neutral. These volcanic rocks, however, extend towards Tokarahi, and are interbedded with the greensands. If they are Waiarekan it would fix the age of the greensands overlying Park's Bortonian.
- (7.) The Tertiary rocks of the Waitaki Valley above Duntroon occupy a tectonic depression. McKay has recorded Tertiary rocks from the Hakataramea Valley,

which is also undoubtedly a tectonic depression. As post-Awamoan gravels have been involved in the differential movements in many localities in the Waitaki and Waihao Valleys, these "fiord-like depressions" manifestly did not exist in Tertiary or pre-Tertiary times, and the evidence to be gathered in north-east Otago points to the conclusion that the Tertiary rocks once formed a continuous cover on the denuded surface of the pre-Notocene oldermass. The mountain-building period of central and north-east Otago was post-Awamoan.

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Art. XXIV.—*Remarks on Bulletin No. 20 (New Series) of the New Zealand Geological Survey.*

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VI. Summary and Conclusion.

I. Introduction.

In Bulletin No. 20 (New Series) of the Geological Survey Branch of the Mines Department Professor Park has described the geology of the Oamaru district of North Otago. The present writer has examined this area in some detail, and his observations have been recorded in several papers read before this society. In several important matters he finds himself at variance with Professor Park, and some notes on the latter's recent work are given in the following pages. The paper deals with the "two-limestone" theory of Professor Park, with his classification of the fossiliferous tufaceous beds, and with his subdivision and correlation of the beds of north-eastern Otago. The evidence on which the present writer's conclusions are based has been detailed in former papers.

Park first formulated his "two-limestone" theory in an attempt to reconcile the differences of opinion that had long existed between Captain Hutton and other geologists as to the position of the so-called "Pareora fauna". The present writer (1916, p. 25) showed that the "two-limestone" theory was not tenable in the Oamaru coastal district, and that the Awamoan (Pareora) beds lie above the limestone and Hutchinson Quarry beds. In Bulletin No. 20 Park has accepted this interpretation in part, for he places the Awamoan (Pareora) beds at the top of the series; but the so-called Waitaki stone is now placed in the Upper Hutchinsonian,

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immediately below the Awamoan beds. The classifications adopted by Park (1905, p. 492) and later in Bulletin No. 20 indicate the change in his views.

1905.

Waitaki stone

Awamoan	Awamoan beds	Awamoan beds.
Hutchinsonian	Hutchinson Quarry beds	(a.) Upper Hutchinsonian = Waitaki stone. (b.) Lower Hutchinsonian.
Ototaran	Ototara limestone	Ototara limestone.

1918.

It will be seen that the Hutchinson Quarry beds (Hutchinsonian) have been subdivided, the Lower Hutchinsonian being the well-known Hutchinson Quarry greensands, which are said to lie beneath the so-called Waitaki stone (Upper Hutchinsonian).

That Park's latest view has not gained general acceptance is clearly indicated by the following quotation from the letter of transmittal to the Minister of Mines which prefaces Bulletin No. 20. Mr. P. G. Morgan, Director of the Geological Survey, writes: "Although quite agreeing with most of the conclusions reached, I cannot follow Professor Park in all respects, more particularly in his views regarding the relative ages of the Oamaru and Waitaki stones." The present writer, has also found considerable difficulty in following Professor Park in his arguments for the differentiation of two-limestone horizons. In discussing the "two-limestone" theory, as formulated in Bulletin No. 20, it will be contended (1) that Park's Upper Hutchinsonian in the area between Kakanui and Target Gully, Oamaru, is really the base of the Awamoan; (2) that his Upper Hutchinsonian of the Landon Creek area is the equivalent of his Lower Hutchinsonian in the district between Kakanui and Target Gully; (3) that no evidence is brought forward to show that the Upper Hutchinsonian is present in the Flume Creek area; (4) that the correlation of the rocks called "Upper Hutchinsonian" in the Oamaru and Papakaio districts with the limestone of the Waitaki Valley (Waitaki stone) is not justified by the evidence brought forward in Bulletin No. 20. The discussion on the Bortonian and Upper Waiarekan of Park aims at showing that lists of fossils ascribed to these stages must be considerably reduced, as the horizons are very doubtful. References to Bulletin No. 20 will be made by quoting merely the pages of that publication.

II. The "Two-Limestone" Theory.

Park's "two-limestone" theory, as stated above, was an attempt to solve the problem of the "Pareora fauna." This problem first presented itself to the New Zealand geologists when Haast submitted four collections of fossils from different localities to Hutton (1887, p. 430) for identification. The latter referred all the shells to the Pareora (Awamoan) horizon above the limestone. Haast himself was convinced that one of the collections had been obtained from beds which lay below the limestone. Other collections of fossils examined by Hutton were determined by him as "Pareora," and in all cases he referred the beds to an

horizon above the limestone. Haast and the officers of the old Geological Survey agreed with Hutton that some of his "Pareora" faunas came from above the limestone, but the field evidence convinced them that other collections of fossils determined by Hutton as "Pareora" came from below the limestone. Park (1905, p. 491) clearly recognized the difficulties, and attempted

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a solution by his theory that there were two limestone horizons, separated by the Hutchinson Quarry and Awamoan beds (Pareora); or, in other words, that there was but one "Pareora fauna," lying between two limestones, the lower being called the Ototaran stone and the upper the Waitaki stone.

The present writer (refer to Thomson, 1915, p. 123), after an excursion to the Waihao district of South Canterbury, was convinced that, where the full series was developed, there was but one limestone present. An examination of the fauna beneath the limestone showed that it bore a remarkable resemblance to the fauna above the limestone in the Waihao district, where the beds occur in the same section. This view was supported by Thomson (1915, p. 123), who subsequently visited the Waihao district. Park, however (1905, p. 510), had given a section at Kakanui in which his two limestones were shown separated by the fossiliferous beds. The present writer (1916, pp. 22-25) sought to prove that this section had been misinterpreted, and that only one limestone was present, with the fossiliferous beds lying above it. Park in his latest work has evidently accepted this interpretation of the section, for the Awamoan beds are now placed at the top of the sequence in the Oamaru and Kakanui districts. As pointed out above, however, he still maintains that the limestone of the Waitaki Valley is distinct from the limestone of the Oamaru district.

III. Description of the Hutchinsonian and Awamoan Stages as Interpreted by Park.

Before discussing the sections described in Bulletin No. 20 it will be necessary to form a clear conception of Park's various subdivisions of the beds above the

Ototaran. Correlation of beds is possible on palaeontological or lithological evidence, or by direct stratigraphical connection, and it seems to the writer that Park has relied mainly on the lithological evidence in establishing his Upper Hutchinsonian horizon. The following quotations will indicate his conception of the post-Ototaran beds.

(1.) *Awamoan Beds.*

"The Awamoan strata consist of blue or bluish-green marine sandy clays that in some places pass into bluish-green sea-muds, in other places into very soft sandstones. In most places they are interbedded at distant intervals with hard calcareous bands that are sometimes sandy, in others argillaceous and crowded with shells. In some places the hard bands are replaced by calcareous nodular concretionary masses and flaggy lenses, occurring in more or less well-defined horizons."

It will be shown that these hard calcareous bands in the Awamoan are referred by Park to the Upper Hutchinsonian in the Target Gully locality.

(2.) *Hutchinsonian Beds.*

The Hutchinsonian is subdivided lithologically, in descending order, into—(a) Glauconitic sandstone (Upper Hutchinsonian); (b) Glauconitic greensands (Lower Hutchinsonian); (c) Conglomerate, mainly basaltic.

The glauconitic sandstone (*a*) is said to represent the Waitaki stone of Upper Hutchinsonian age. He describes this horizon as follows: "The glauconitic sandstone follows the greensands conformably... it consists of soft glauconitic sandstone interbedded with hard yellowish brown sandstone bands... it is a compact yellowish-brown calcareous

described in the following extracts: "The glauconitic sandy beds at All Day Bay, Kakanui, Hutchinson's Quarry, and Grant's Creek are loose and incoherent, but at the upper end of Target Gully, at Landon Creek, and in the Waitaki area they form fairly compact glauconitic sandstones" (p. 78). Further, it is stated that "the fauna of this horizon [Lower Hutchinsonian] is distinguished by the abundance of the brachiopod *Pachymagas parki* (Hutt.), by the presence of the corals *Isis dactyla* Ten.-Woods and *Mopsea hamiltoni* (Thomson), and of the cup-shaped bryozoan *Celleporaria nummularia* Busk. Besides these there occur many pectens and other molluscs. *Pachymagas parki* (Hutt.) is present almost everywhere, but the other fossils mentioned may be abundant at one place and absent at another" (p. 78). "*Pachymagas parki* (Hutt.) occurs in great abundance in the Lower Hutchinsonian, usually to the exclusion of all other brachiopods except *Rhizothyris rhizoida* (Hutt.), which is nearly always present with it" (p. 109). "The Lower Hutchinsonian is the most distinctive and persistent horizon of the Oamaruan system; it always overlies the Oamaru stone. In the Oamaru area it consists of calcareous glauconitic greensands that at Landon Creek and the lower Waitaki Valley are partly or wholly replaced by calcareous glauconitic sandstone. But whether greensands or glauconitic sandstone, the characteristic brachiopod *Pachymagas parki* (Hutt.) and the peculiar corals *Isis dactyla* Ten.-Woods and *Mopsea hamiltoni* (Thomson) are always present. The Waitaki stone is underlain by the greensands" (p. 110).

It will be shown that these sandstone bands in the Landon Creek area are referred to the Upper Hutchinsonian, although from Park's description of the characteristic fossils they should belong to his Lower Hutchinsonian (Hutchinsonian of Thomson).

As pointed out by the present writer (1916, pp. 20–21), the fossil *Pachymagas parki* (Hutt.) occurs in abundance in a well-defined band of hard glauconitic sandstone. In the present paper this band is called the "*parki*" band. It is often accompanied by *Rhizothyris rhizoida* (Hutt.), to the exclusion of all other brachiopods. This hardened band is underlain in many places in the district by looser greensands, also glauconitic, but characterized also by a constant assemblage of fossils—*Aetheia gaulteri* (Morris), *Terebratulina suessi* (Hutt.), *Isis dactyla* Ten.-Woods, and *Mopsea hamiltoni* (Thomson), which are all very abundant. This bed usually contains many specimens of *Pachymagas parki* (Hutt.), but in these looser greensands the individuals of this species are on the average distinctly smaller than in the upper "*parki*" band, and their external characters are far more constant. In the hardened upper band, where it is usually accompanied by *Rhizothyris rhizoida* (Hutt.), the specimens assigned to the "*parki*" species are extremely variable in external shape. As pointed out by Park in the extracts quoted, above, this greensand horizon is a most distinctive one; it is, the typical Hutchinsonian of the Oamaru system, and always lies above a nodular band (Park's conglomerate). Park, however, would term these "*Isis*" greensands, and the "*parki*" greensands Lower Hutchinsonian; and states that they are separated from the Awamoan by the Upper Hutchinsonian (Waitaki stone). The

writer contends that the “*Isis*” greensands and the overlying “*parki*” greensands constitute the Hutchinsonian, and are followed directly by the Awamoan beds.

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In the localities discussed below an attempt is made to show that where the Awamoan beds are present, as in the Oamaru area, the hard calcareous bands at their base are called Upper Hutchinsonian; where the Awamoan beds are not present, as at Landon Creek (west branch), the “fairly compact glauconitic sandstone” (the “*parki*” band) is called Upper Hutchinsonian; where the “*parki*” band is absent, as in Landon Creek (Papakaio district), the upper glauconitic portion of the limestone is called Upper Hutchinsonian (p. 64). The various localities in which the post-Ototaran beds occur will now be discussed.

IV. Hutchinsonian and Awamoan Localities.

(1.) All Day Bay (p. 56).

The section in this locality has been described by the writer (1916, p. 20), and by Park in Bulletin No. 20. Both agree that the “darker and tougher greensands” (the “*parki*” band) are followed directly by the Awamoan beds. The section in this locality is most important, as it illustrates the typical character of the beds above the limestone. Here we have in one section, as shown by Park, the limestone much hardened towards its upper surface, which is corroded (nodular). This surface is immediately followed by the “*Isis*” greensands, capped by the hard “*parki*” band, which is directly overlain by the Awamoan beds. In this locality there is no Upper Hutchinsonian horizon, and Park's so-called Lower Hutchinsonian is conformably overlain by the Awamoan, which contains “hard sandstone layers.” Park does not recognize an Upper Hutchinsonian in this locality.

(2.) Deborah (p. 59).

In this section the highest bed exposed is the “*parki*” band, which is underlain by “6 ft. of greensands [which] contain many molluscs and brachiopods.” The brachiopods present in these underlying greensands are *Terebratulina suessi* (Hutt.) and *Aetheia gaulteri* (Morris), which are again accompanied by the same species of *Isis* and *Mopsea*. At the base of these greensands lies the nodular surface of the hard limestone which closed the Ototaran at All Day Bay. No Upper Hutchinsonian is present at Deborah.

(3.) *Coast North of Kakanui Quarry* (p. 70).

In this section Park shows the sequence of beds closed by a “hard semi-crystalline limestone.” The present writer has figured the complete section along the coast (1916, p. 23, fig. 2). The beds form a syncline, and to the north east this hard limestone is nodular at the surface, and followed by the “*Isis*” greensands, but the hard “*parki*” band has been denuded. The sequence is exactly similar to that at All Day Bay and Deborah. The surface of the hard limestone is nodular, and pieces of rolled volcanic rock occurs at the base of the “*Isis*” beds and represent Park's conglomerate at the base of the Hutchinsonian. In this coastal section the Upper Hutchinsonian is not stated to be present, though the limestone in this locality was formerly (1905, p. 510) called Waitaki stone (Upper Hutchinsonian).

(4.) *Oamaru Rifle Butts.*

In his discussion on the Hutchinsonian stage (chapter vii, p. 77) Park makes no reference to the Hutchinsonian beds at the Rifle Butts, but he

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gives a section (pl. ii, fig. A) in which are shown “the greensands with *Pachymagas parki*” followed by a glauconitic shell-bed (bed *i*), a hard brown limonitic sandstone (bed *h*), and soft glauconitic sands (bed *g*), and all these beds are classed as Hutchinsonian. These beds above the “*parki*” green-sands are Park's Upper Hutchinsonian. The Awamoan beds are said to lie above this so-called Upper Hutchinsonian. Now, the glauconitic sandy shell-bed (bed *i*) is crowded

with molluscan casts and extremely fragile shells, and there is no doubt that it is similar to the shell-beds at Target Gully and Ardgowan, which all geologists recognize as Awamoan, and its position immediately above the “*parki*” band confirms this (compare Park's section at All Day Bay, p. 56). These beds (*g, h, i*, of pl. ii, fig. A) are undoubtedly Awamoan, and there is, therefore, no Upper Hutchinsonian at the Rifle Butts.

(5.) **Hutchinson's Quarry (pp. 60–61).**

In this locality the junction of the greensands with the limestone is not clear, although they undoubtedly overlie it. As the Upper Hutchinsonian is not stated to be present, it is unnecessary to discuss the section further.

(6.) **Target Gully (pp. 79–80).**

In this locality the Awamoan and Upper Hutchinsonian are said to be present in the same section. From the description given it is difficult to judge exactly which beds are referred to the Upper Hutchinsonian. The following statement occurs on page 79: “The glauconitic sandstone [Upper Hutchinsonian] follows the greensands conformably at the shell-bed (Target Gully).” These greensands are Lower Hutchinsonian (p. 78). On the same page it is stated that “at the shell-bed, Target Gully, it [the glauconitic sandstone] consists of soft glauconitic sandstone interbedded with hard yellowish-brown sandstone bands.” In the section given on page 80 the horizons of the beds are not indicated; the fossiliferous greensands (bed *c*), which are the lowest greensands exposed in the section, must, according to Park's first statement quoted above, belong to his Lower Hutchinsonian, leaving a hard yellowish-brown glauconitic sandstone (2 ft. to 4 ft. thick) to represent the Waitaki stone (Upper Hutchinsonian). The fossils in this sandstone are in the form of casts, and no palaeontological or other evidence is offered to support the contention that the bed is at the horizon of the limestone in the Waitaki Valley (the so-called Upper Hutchinsonian). If Park refers all the greensands to his Upper Hutchinsonian, as would appear from the second statement quoted above, there is still no evidence to support this view. Of the seventy-two species of Mollusca listed from bed *c*, sixty-seven species occur in Park's list of Awamoan fossils (pp. 97–105), three forms are Recent, and the other two are not characteristic. The percentage of Recent species is said to be 40·3; and, as the percentage, of Recent species in the Awamoan of the Oamaru district is stated by Park to be 32·9, there would seem to be no justification for separating these beds from the Awamoan horizon. *Pachymagas parki* (Hutt.), however, is said to occur in the form of casts in bed *d*, and as the same fossil is recorded from bed *c*, and this is the characteristic fossil of Park's Lower Hutchinsonian, the beds might equally well be referred to his Lower Hutchinsonian. As a matter of fact, in the absence of a brachiopod fauna it is a difficult matter to distinguish the Hutchinsonian from the Awamoan. As Park says (p. 53), “the relationship existing between the Hutchinsonian and Awamoan is generally so close that it is difficult

to define where the one ends and the other begins."

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If, however, in addition to a molluscan fauna the brachiopods are present, the line of demarcation is a sharp one in the Oamaru and Papakaio districts, the close of the Hutchinsonian being marked by a glauconitic band crowded with *Pachymagas parki* (Hutt)., which is often accompanied by *Rhizothyris rhizoida* (Hutt.). The writer believes that the "parki" beds in the present locality are followed directly by the Awamoan, and, as the former beds are Park's Lower, Hutchinsonian, it follows that there is no Upper Hutchinsonian in the Target Gully locality. Yet Park states (p. 25) that "on palaeontological grounds the Hutchinsonian might be divided into two sub-stages—the lower or true Hutchinsonian including the glauconitic greensands, the upper comprising the glauconitic calcareous sandstone that forms the Waitaki stone or Waitakian." The writer has been unable to find in Park's latest work these palaeontological grounds.

When the writer examined the Target Gully section the junctions of the various beds were obscured by slope deposits, in which were collected fossils from the shell-bed (Awamoan), specimens of *Pachymagas parki* (Hutt.), and *Rhizothyris rhizoida* (Hutt.), and this would indicate that the true Hutchinsonian (Park's Lower Hutchinsonian) is present below the shell-bed. Putting aside this obscurity of the section, however, it is contended that no evidence has been adduced to justify any bed in the section being differentiated as a separate Upper Hutchinsonian horizon. The fossils from bed c are Awamoan, and the hard glauconitic sandstone is exactly similar to the bands that occur in Park's Awamoan at All Day Bay.

(7.) ***Upper Target Gully*** (p. 82).

Two sections are exposed in this locality. In fig. 37 a "rusty-brown glauconitic sandstone; 9 ft. exposed; contains *Pachymagas parki* (Hutt)." In fig. 38 a glauconitic sandstone is shown. It is said to be crowded with *Pachymagas parki*

(Hutt). According to Park's definition of the beds, neither the Awamoan nor the so-called Upper Hutchinsonian is present.

(8.) Ardgowan Shell-bed (p. 81).

The section in this locality (fig. 36) shows the Ardgowan shell-beds resting directly on a "soft brown sandstone," from which twelve fossils were collected; eleven of which are found in typical Awamoan localities. The other fossil, *Lima suteri* Dall, is apparently not found elsewhere in the Oamaru district. Park's Lower Hutchinsonian is not present in the section, and no reason is assigned for separating this "slightly glauconitic sandstone" from the Awamoan. As pointed out above, these sandstone bands are characteristic of the Awamoan, and there is no evidence to show why they should be placed at an Upper Hutchinsonian horizon.

(9.) Devil's Bridge (pp. 62, 82).

The section at the outlet end of Devil's Basin shows "a soft friable glauconitic sandstone, 12 ft. thick, crowded with *Pachymagas parki* (Hutt.)," and accompanied by *Rhizothyris rhizoida* (Hutt.), overlain directly by a brown calcareous glauconitic sandstone, 30 ft. thick, from which seventeen forms, were obtained, thirteen of which occur in the Awamoan, one is not found elsewhere, two are recorded from the "Lower Hutchinsonian" elsewhere (that is, from the "*parki*" greensands), while *Emarginula wannonensis* Harris occurs in the Ototaran. This so-called Upper Hutchinsonian cannot be separated from the Awamoan, particularly as it rests hard upon the "*parki*"

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greensands, its normal position as shown by Park in his section at All Day Bay (p. 56). The writer (1918b, p. 121) described this locality, and showed that the "*parki*" band lay some distance above the limestone, which was nodular at its surface, and according to Park the upper part of the limestone is "a hard semi-crystalline limestone from 2 ft. to 4 ft. thick." The sequence is similar to that at All Day Bay,

although the small exposure of looser greensands between the nodular surface of the limestone and the “*parki*” band has not yet proved fossiliferous. The sands above the “*parki*” band are glauconitic, and in this respect are similar to the Awamoan at All Day Bay. In the present locality no reasons have been adduced to show that the Upper Hutchinsonian is present.

All the localities in the Oamaru district where Park has described the Hutchinsonian have now been discussed, and the writer has attempted to show that the band of glauconitic sandstone (the so-called Upper Hutchinsonian of Park) is part of the Awamoan. The description in Bulletin No. 20 of the Awamoan beds shows that they may assume the character of an indurated sandstone. In the absence of palaeontological evidence, the placing of a thin band of sandstone in an Upper Hutchinsonian is unwarranted. The fossils that have been recorded by Park are Awamoan, as shown above. In his classification of the beds of north-east Otago, Thomson (1916, p. 35) defined the Hutchinsonian as the beds lying between the Ototara imestone and the shell-bed at Target Gully. This shell-bed undoubtedly forms the base of the Awamoan at the Rifle Butts, but from its very nature it is not likely to be a widely extended horizon (it is known to occur at only three places—Rifle Butts, Target Gully, and Ardgowan). These shell-beds appear to be the remains of shell-banks of the Awamoan seas, and, although confined to the lower part of the Awamoan, they may not always represent the basal bed. At All Day Bay the basal bed of the Awamoan, which lies directly on the “*parki*” band (Hutchinsonian), contains similar fossils to the shell-bed, but no shell-bed occurs in the locality. As pointed out above, the, “*parki*” band marks a definite horizon, the close of the Hutchinsonian, and it seems preferable to make this band the upward limit of this stage. This would mean that Park's Waitaki stone (Upper Hutchinsonian) would be driven into the Awamoan, but it would not in any way lower the value of the evidence he has brought forward to prove that this limestone is at a different horizon from the Ototaran stone.

(10.) *Landon Creek and Flume Creek.*

The Awamoan beds are not present in these localities, but certain hard glauconitic bands are present in the upper beds. Some of these are referred to the Upper Hutchinsonian horizon. The present writer contends that these so-called Upper Hutchinsonian bands represent the “*parki*” band, in other cases lower beds, and are therefore, according to Park's definition, his Lower Hutchinsonian. As the “*parki*” band is the highest horizon in the Landon Creek and Flume Creek areas, the so-called Upper Hutchinsonian cannot be present.

In fig. 25 (p. 63) a section is given showing “rusty-brown glauconitic greensands crowded with *Pachymagas parki* (Hutt.)” at the top of the sequence. According to Park's definition, this is his Lower Hutchinsonian horizon, and the Upper Hutchinsonian cannot be present. We must note, however, that a “brown calcareous glauconitic sandstone” 6 ft. thick is said to lie 4½ ft. below the “*parki*” bed. This band of sandstone is again shown in fig. 26, where the “*parki*” band is

not shown. In both figures

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this glauconitic sandstone lies directly on the Oamaru stone (Ototaran), and in fig. 25 is separated from the “*parki*” band by nodular greensands. In fig. 27 (p. 64) the “*parki*” band is not present, but 24 ft. of glauconitic sandstone is shown lying above the limestone and classified as Hutchinsonian, but whether Upper or Lower is not stated. In figs. 26 and 27, then, this glauconitic sandstone cannot represent the Upper Hutchinsonian.

In fig. 15 a section is given in Landon Creek showing at the top of the Hutchinsonian a “hard brown calcareous sandstone, thickness of 6 ft. exposed,” from which were obtained the brachiopods *Pachymagas parki* (Hutt.) and *Rhizothyris rhizoida* (Hutt.). This is Park's Lower Hutchinsonian, and the Upper Hutchinsonian is therefore absent. Fig. 15 is important, as it enables us to correlate the beds in the Landon Creek area with those in the Oamaru area. It will be noted that the upper part of the Oamaru stone is a bed of “hard semi-crystalline limestone,” which is overlain by looser greensands containing *Isis dactyla* Ten-Woods, and these are capped by “a hard brown calcareous sandstone containing *Pachymagas parki* (Hutt.) and *Rhizothyris rhizoida* (Hutt.).” The sequence is the same as at All Day Bay, only in the present locality the nodular surface of the hard limestone is not so evident.

On page 46 Park gives a classification of the beds in Landon Creek, and shows that the limestone beneath the “hard semi-crystalline limestone” is glauconitic. This is the case in the whole of the Landon Creek area, and it is extremely probable that bed *b* of fig. 25, bed *b* of fig. 26 (both of which underlie nodular greensands), and bed *b* of fig. 27 represent this upper glauconitic portion of the limestone. The nodular greensands (“*Isis*” beds) just referred to contain *Isis dactyla* Ten.-Woods, *Aetheia gaulteri* (Morris), and *Terebratulina suessi* (Hutt.), and they lie immediately beneath the “*parki*” band. The fossils collected by the writer from these beds have already been published (1918b, pp. 122, 123), and, although these lists are incomplete, they indicate that the sequence is similar to that of the

Kakanui district. In the Landon Creek area, then, the highest beds present are the “*parki*” beds (Park's Lower Hutchinsonian of the Oamaru-Kakanui areas discussed above), and his Upper Hutchinsonian is non-existent.

The writer has attempted to show that in the coastal district, where the Awamoan beds occur above the greensands, the base of the Awamoan is termed Upper, Hutchinsonian; that in the Landon Creek area, where the “*parki*” band is the highest horizon present, either this bed or underlying beds are termed Upper Hutchinsonian. In other words, the Hutchinsonian greensands with *Pachymagas parki* are overlain directly by the Awamoan beds, and the “Upper Hutchinsonian” of Park is applied to different horizons in different parts of the district, and is therefore inadmissible in classification.

On page 48 a section is given in which the Oamaru stone is shown capped by a bed of hard semi-crystalline limestone, which represents the upward limit of the Ototaran. The sequence is similar to that at All Day Bay (p. 56), west branch of Landon Creek (p. 46), Deborah (p. 59), Kakanui (p. 70). In the present locality and in the localities just mentioned the overlying greensands contain *Isis dactyla* Ten.-Woods, *Mopsea hamiltoni* (Thomson), *Aetheia gaulteri* (Morris), *Terebratulina suessi* (Hutt.), and there is no doubt that these greensands are all at the same horizon—the base of the Hutchinsonian. Now, these greensands (bed *m* of fig. 17) are said to be the same as bed *g* of fig. 28, and the latter bed is said to be Upper Hutchinsonian (Waitaki stone), which is impossible, as the fossils are the fossils of

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Park's Lower Hutchinsonian of the coastal area (see p. 78). Further, from Park's description of the beds at Big Flume Creek on page 48 and page 65, bed *m* of fig. 17 should be correlated with bed *f* of fig. 28, not bed *g*, as both lie hard on the “band of semi-crystalline limestone” and represent the “*Isis*” greensands, and the fossils of the latter horizon also occur in the lower portion of bed *g*. The writer was unable to find the glauconitic sandstone overlying these “*Isis*” beds, and after visiting the Big Flume Creek during the present year was only confirmed in his

own interpretation of the section as given in a former paper (1918, p. 123). As indicated there, the section is a discontinuous one, and the beds are probably faulted. The highest beds exposed in the section, which crop out on the right bank of the creek between the water-race and the Oamaru-Kurow main road, are the "*Isis*" greensands capping the "hard semi-crystalline limestone," and the writer found no beds above them.

In regard to this section Park (p. 65) says, "This section is important, as it shows not only the relationship of the Oamaru stone to the Hutchinsonian, but also—what is of greater significance—the relationship of the Oamaru stone to the Waitaki stone." Even if the glauconitic sandstone (bed g of fig. 28) does occur as shown in section above the "*Isis*" beds (the present writer was unable to find it), no evidence has been presented to show that it is the equivalent of the limestone of the Waitaki Valley near Duntroon. A section is given on page 83 of the rocks near Duntroon, where Park's typical Waitaki stone is shown overlying a fossiliferous glauconitic greensand. From the description of this stone in the legend it would appear that the rock is a very impure limestone, but it is as pure in many parts as the typical Ototaran limestone; it is certainly arenaceous and glauconitic in places, but it is undoubtedly a limestone. The analyses given on page 115 (especially analysis No. 4) confirm this.

Park gives a list of brachiopods from the glauconitic sandstone at the base of the Waitaki stone (p. 83). These brachiopods have also been collected from the upper part of the glauconitic limestone of Landon Creek. Wherever the limestone becomes very glauconitic the brachiopods appear. The upper glauconitic part of the limestone in the Landon Creek area and in the Flume Creek area increases considerably in thickness, and it is this portion that yields fossils similar to those at the base of the limestone near Duntroon. As pointed out in a former paper, these fossils are not restricted to this base. At White Rocks and at Duntroon the lower glauconitic part of the limestone increases considerably in thickness, and these brachiopods are found a considerable distance above the base of the limestone. Detailed correlation is not possible until we know the downward range of this brachiopod fauna in the Oamaru limestone, and its upper range in the rocks of the Waitaki Valley. At present all we can state is that the brachiopod fauna of the limestone in the Waitaki Valley and in the limestone of the Landon Creek area is undoubtedly Ototaran.

V. Bortonian and Waiarekan Localities.

(1.) *Bortonian*.

In his table of the Oamaruan Mollusca (p. 97) Park states that sixty-four species were obtained from the Bortonian and sixty-four species from the Upper Waiarekan (Waiareka tuffs). This subdivision of the Waiarekan of Thomson into a Lower Waiarekan (Bortonian) and an Upper Waiarekan has much to recommend

it. In many places in North Otago the coal-grits are overlain by fine micaceous quartzose greensands, and near their base hardened calcareous concretionary bands occur in which fossils are

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very abundant, but unfortunately mainly in the form of casts. From this horizon at Black Point, McKay and Park made extensive collections, and forty-three species were determined by the late Mr. Henry Suter, and referred by Park to his Bortonian. In another paper in this volume the writer has given a list of fossils, also determined by Suter, which were collected from an horizon about 30 ft. above the coal-grits, and almost certainly represent the Bortonian horizon. At Ngapara a similar fossiliferous bed is found lying a short distance above the coal-rocks. In the bed of the Kakanui River, near Gemmel's crossing, this fossiliferous horizon occurs beneath glauconitic greensands, which dip beneath the Waiarekan tuffs of the Oamaru district. The introduction of a Bortonian horizon should be favourably received by geologists. Park has stated that "for a classification to be a trustworthy standard of reference it is an essential requirement that the subdivision shall be made in a district where the component subdivisions are in such intimate association that their relationship to one another can never be in doubt." All will accord hearty approval to this dictum; but we may also add that, if an attempt is being made to work out a distinctive fauna for each of these component subdivisions, it is also an essential requirement that the fossils shall be definitely ascertained to have come from a definite horizon. This does not mean that fossil lists should be discarded merely because their horizon is doubtful, but it does mean that these doubtful fossils should be rejected, temporarily probably, when lists typical of the various stages of a system are being compiled. The species listed by Park as Bortonian and Upper Waiarekan call for some comment in the light of the principles just enunciated. The fossils from the beds at Black Point number forty-three species (p. 34), and were gathered from Park's typical Bortonian locality, and the horizon is undoubted. On page 35 a list of thirteen species of Mollusca is given from brown sandstones which lie "about 80 ft. above the lignitic quartzose beds of the Ngaparan stage, and may represent a somewhat higher horizon than the

Bortonian." On the same page is given a list of fossils gathered from fossiliferous blocks, but "these masses could not be traced to their source." As the horizon of the first collection is doubtful, and as the second was derived from rocks that were not *in situ*, these fossils cannot be included in the typical Bortonian. The list of sixty-four species must therefore be reduced to forty-three species.

(2.) *Upper Waiarekan.*

The writer (1918a, p. 107) attempted to define the horizons of the volcanic rocks in the Oamaru district, and concluded that there was a period of volcanic activity prior to the deposition of the Ototaran limestone, represented by the Waiareka tuffs (Upper Waiarekan of Park), and that there was a later period—perhaps two later periods—of activity represented by the volcanic rocks that occur interbedded with the Ototaran limestone near Oamaru. Park recognizes three periods, the second and third being Ototaran, while the first period is Upper Waiarekan. These volcanic rocks form fragmental tufaceous beds for the most part, and were probably all accumulations from submarine eruptions; they are often fossiliferous. Fossils gathered from tufaceous rocks may therefore be either Ototaran or Waiarekan, and before the fossils are assigned to either of these horizons the position of the bed must be indisputable. The fossils listed as Upper Waiarekan by Park have in nearly all cases been gathered from beds interbedded with limestone, and the writer believes that they belong to the limestone period—that is, they are of Ototaran age. Park himself indicates

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that his Waiarekan tuffs at Cape Wanbrow may be partially Ototaran, for he states that in this locality the Waiarekan tuffs are "over 600 ft. thick—though it is possible that a portion of the latter may belong to the Ototaran." The writer is in accord with this statement, and would assign to the Ototaran the interbedded tuffs and limestone bands in the Shirley Creek section near the Rifle Butts, which form the top of Park's Upper Waiarekan. The beds immediately below the lower pillow-lava near Boatman's Harbour should also be Ototaran. The various localities where the Waiarekan tuffs are said to occur will now be discussed.

(a.) *Kakanui South*.—In Bulletin No. 20, section 19, page 52, shows the tuffs lying beneath the Ototaran limestone, and they are doubtfully referred to the Waiarekan. Above them lie 71 ft. of limestone, 24 ft. of marly clays, and tufaceous matter is plentiful throughout the section. The limestone (bed *a*) is evidently at or near the base of the Ototaran. If so, the under-lying tuffs are probably Waiarekan, but they have yielded no fossils.

(b.) *Boatman's Harbour, Cape Wanbrow*.—Park in a measured section (pl. ii, sec. B) shows the beds in excellent detail. A well-marked break is shown below bed *h*². Discussing this unconformity, Park says that it is "apparently due to contemporaneous erosion." He further states that the Oamaru building-stone "is absent, and, if not wholly, is partly represented by the fossiliferous tuffs and limestones at Boatman's Harbour [*i.e.*, by the beds above the lower pillow-lava]. The brachiopods from the upper of the two limestone bands at that cove are mostly those of the Kakanui limestone horizon of the Ototaran [*i.e.*, Upper Ototaran], as also are the brachiopods from the lower of the two limestone bands underlying the pillow-lava." The beds referred to are shown in plate ii, section B, but in the legend these lower limestone bands and interbedded volcanic rocks are not referred to any horizon, although from the title of the section they are probably to be placed in the Waiarekan; yet the description of the beds does not indicate where the upper limit of the Waiarekan should be placed. From the quotation given above it is clear that the lowest fossiliferous band in the section contains characteristic Ototaran brachiopods, and underlying this band unconformably is a great thickness of volcanic tuffs which have not yielded any fossils. The fauna from this locality cannot be referred to the Waiarekan.

(c.) *Shirley Creek* (see pl. ii, fig. A).—Park states that "at Shirley Creek the Waiarekan tuffs are overlain unconformably by the Oamaru stone and associated beds.... The unconformity cannot be regarded as other than intra-formational." When the writer examined this section he formed the opinion that the beds above and below this so-called unconformity had the same dip (1918a, p. 110/fig. 2). It is true that the upper bed ([pl. ii, fig. A](#), bed *c*) is a limestone band containing masses of volcanic rocks, as shown by the writer in the paper just referred to; but this is a common feature in the limestone bands interbedded with tuffs, as shown by Park on page 37, where he writes in reference to the two bands below the pillow-lava that "these limestone beds are brecciated with angular blocks of vesicular basalt." The beds referred to the Waiarekan at Shirley Creek are calcareous tuffs interstratified with polyzoan limestone bands, and they contain the typical Ototaran brachiopod *Liothyrella oamarutica* (Boehm), and there would appear to be no reason for separating the beds between bed *q* and bed *w* from the Ototaran. At the top of bed *w* there is an undoubted physical unconformity, which probably represents the break at Boatman's Harbour below bed *h*² of plate ii, fig. B, as the beds that lie beneath these unconformities are unfossiliferous tuffs of similar composition.

(d.) *Awamoia Creek, near Deborah* (p. 41).—The base of the section (fig. 5) is a basalt showing pillow-structure similar to the lower pillow-lava at Boatman's Harbour. The two rocks have been described by the writer (1918a, p. 113), and there is little doubt that they are at the same horizon. The rock at Boatman's Harbour has been shown to be almost certainly Ototaran, and the pillow-lava in the present locality must be referred to the same stage. The highest bed of the section is a brecciated pillow-lava exactly similar to the highest bed in the section at Boatman's Harbour, while the intermediate beds are calcareous fossiliferous tuffs and limestones. The fossils recorded from the tufaceous beds above the lower pillow-lava in the present locality are in rather poor condition, and the percentage of Recent species as determined by Suter is 37.5. The evidence is scarcely sufficient to warrant these rocks being classed as Waiarekan.

(e.) *Grant's Creek* (p. 45).—In fig. 14 a section is given on the east bank of Grant's Creek, near Oamaru. It shows the Oamaru stone with interbedded bands of basaltic conglomerate, and the soft friable greenish glauconitic calcareous tuffs underlying are called Waiarekan. These beds are horizontal, and it is stated that "less than 50 yards higher up the stream, and on the same side, the Oamaru stone is followed by the Hutchinsonian greensands crowded with *Pachymagas parki* (Hutt.)." The maximum thickness of the rocks above the tuffs is 21 ft., and, as the rocks are horizontal, and the Hutchinsonian beds occur a short distance away capping the limestone, these tufaceous beds are certainly not Waiarekan. The development in the present section is very similar to the section exposed lower down the stream and described by the writer (1918b, p. 121, fig. 3). In that section 20 ft. of limestone separates the volcanic rocks of Oamaru Creek from the Hutchinsonian greensands, and Park rightly considers these volcanic rocks as Upper Ototaran (see geological map, Bulletin 20). The tufaceous beds in the present locality are therefore Ototaran. These beds mapped by him in the basin of Grant's Creek as Waiarekan are similar to those developed at Upper Target Gully which he has mapped as Upper Ototaran. A comparison of the sections shown on page 82 at Upper Target Gully (figs. 37 and 38) will indicate the similarity of the rocks in the basin of Grant's Stream to those at Upper Target Gully. Similar sections occur at Hutchinson's Quarry (1918a, p. 111) Lower Target Gully (Bulletin

20, p. 80), and Eden Street, Oamaru (Bulletin 20, p. 60). The present writer, in his description of the Hutchinson Quarry and neighbourhood (1918a, p. 112), showed that the fossiliferous beds at Boatman's Harbour which lie beneath the brecciated pillow-lava are certainly not Hutchinsonian, as contended by former geologists, and Park in his latest work has reached the same conclusion, as his geological map clearly shows. The writer's argument was based solely on the correlation of the upper volcanic rocks at Boatman's Harbour and Oamaru Creek near the junction of Grant's Stream, and as Park also correlates these volcanic horizons there can be no doubt that the volcanic horizon in the present section is not Waiarekan but Ototaran (Upper Ototaran).

In the localities that have been discussed, if these so-called Waiarekan tuffs are Ototaran tuffs, then Park's fauna of the Upper Waiarekan is reduced from sixty-four species to the seventeen species detailed on pages 43 and 44 of Bulletin No. 20. The brachiopods quoted there are characteristic Ototaran fossils, four of the Mollusca are new species, *Clio annulata* (Tate) is not found elsewhere in New Zealand, *Amusium zitteli* (Hutt.) is not recorded from any other locality in North Otago, and the remaining

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fossils are either found in higher beds or are Recent. The horizon of these tuffs is doubtful, but the association of these calcareous tuffs with chalky clays and marls is similar to the beds near the base of the Ototaran in the section exposed on the right bank of the Kakanui River (p. 57, fig. 19). The writer has also observed these marly beds and tuffs near the base of the limestone in the old quarry at Fortification Hill, near the village of Alma.

VI. Summary and Conclusion.

It has been contended that the sequence and subdivision of the Tertiary beds of North Otago as detailed in Bulletin No. 20 requires certain modifications, and the following conclusions have been reached by the writer:—

(1.) Park's Lower Hutchinsonian is the true Hutchinsonian of Thomson, and is characterized by the fossils *Pachymagas parki* (Hutt.), *Aetheia gaulteri* (Morris), *Terebratulina suessi* (Hutt.), *Isis dactyla* Ten.-Woods, and *Mopsea hamiltoni* (Thomson).

(2.) No evidence has been brought forward in the bulletin for the establishment of an Upper Hutchinsonian horizon in the area lying between All Day Bay and Upper Target Gully. The beds referred to this horizon are Awamoan, and lie immediately on the “*parki*” greensands.

(3.) The highest beds present in the Landon Creek area are the “*parki*” greensands, and in the Flume Creek area the “*Isis*” greensands, which constitute Park's Lower Hutchinsonian; there cannot, therefore, be an Upper Hutchinsonian horizon in these localities.

(4.) No evidence is presented in Bulletin No. 20 to show that the Ototaran limestone in the Oamaru and Papakaio districts correlates with the beds below the limestone in the Waitaki Valley. Both limestones contain several brachiopods which are restricted to the Ototaran of the typical Oamaru district, and must be classed as Ototaran.

(5.) The nature of the limestone (polyzoan limestone) interbedded with the tuffs beneath the lower pillow-lava at Boatman's Harbour and Shirley Creek, and the brachiopods obtained from these bands, strongly suggest that their age is Ototaran, not Waiarekan.

(6.) The occurrence of Awamoan fossils in the beds (Otiake beds) above the limestone of the Waitaki Valley, and the fact that the Awamoan and Hutchinsonian are “part and parcel of the same series,” as Hutton, McKay, and Park have asserted, further strengthens the argument that this limestone is Ototaran.

(7.) Nevertheless, the brachiopod fauna of the greensands in the Oamaru coastal district enables a clear line of demarcation to be drawn in that area between the Hutchinsonian and Awamoan.

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Art. XXV.—*Examples of Readjustment of Drainage on the Tararua Western Foothills.*

By. G. Leslie Adkin.

[*Read before the Wellington Philosophical Society, 8th October, 1919; received by Editor, 31st December, 1919; issued separately, 15th June, 1920.*]

Plate XI.

Contents.

- Introductory.
- The Major Physiographic Features of the Tararua Range.
- Topography of the Arapaepae Ridge and of “The Heights” Basin.
- Changes of Drainage in “The Heights” Basin.
- Changes of Drainage on the Poruriri Ridge.

1. Introductory.

In the long-settled and more-closely-studied countries of the Northern Hemisphere the processes and events of physiographic history genetically connected with the present geographical regime have been more or less thoroughly worked out, but in New Zealand the subject has been dealt with in detail in only a comparatively few isolated areas. During the last few years, however, New Zealand physiography has attracted ever increasing notice, and has come to be regarded here as elsewhere as being of considerable importance in the deciphering of the detailed geologic history of a country. I have therefore been led to contribute the following notes on the physiography of an area which has hitherto received but scant attention. While it is not claimed that the course of events outlined in section 4 is in any way unique, the constricted area in which the diverse changes took place may be deemed somewhat remarkable, comparable to some slight extent with the classical instance of drainage-readjustment in the district round Chur, in Switzerland (Heim).

2. The Major Physiographic Features of the Tararua Range.

The Tararua Range is that portion of the structural axis of the North Island extending from the headwaters of the Hutt River to the Manawatu Gorge, a distance of fifty-seven miles. The range consists of a series of parallel and subparallel longitudinal ridges so disposed that they collectively form an obtuse angle or wide arc convex to the west; thus it is that from south to north their trend changes from north-north-east to north-east by north. In addition to the longitudinal ridges there is a subsidiary series of transverse ridges which link the former together.

Another feature of the Tararua Range is its asymmetry. The highest ridge—that bearing the peaks of The Mitre and Mount Holdsworth—lies well to the eastern side of the range, and on that side the altitudes of the foothill ridges decrease more abruptly towards the subjacent lowlands than on the west. In general, both towards east and west, the longitudinal ridges decrease in height in succession as the respective piedmont lowland areas are approached, the outermost foothill ridge on either side being usually the lowest of the respective series. The whole is suggestive of a high-standing tilted earth-block, having a steep eastward-facing scarp and a back-slope declining towards the west. The initial intense compression and crumpling of the Trias-Jurassic (Marshall, 1912, pp. 127–29, 208) strata (the post-Hokonui deformation) was probably succeeded by peneplanation (Cotton, 1916, p. 246; Thomson, 1917, pp. 399–400), and

this was followed by secondary folding (the Kaikoura deformation) accompanied by block-faulting on a large scale, and also by the deep dissection of the penultimate erosion-cycle. The secondary folding corrugated the Tararua earth-block into broad anticlinal and synclinal forms, and these appear to have determined the trend of the principal drainage-lines, and to have guided the agents of erosion in the production of the high relief of the present topography. The initial drainage-pattern is thus considered to be mainly consequent on the secondary deformation, and only to a very slight extent due to adjustment to the original structure.

With reference to the hills near Wellington City, which may be regarded as a south-western extension of the Tararua Range, and perhaps also to the main range itself, the longitudinal ridges have been explained (Cotton, 1918, pp. 213–14) as being bands of resistant rock reinforced by a network of secondary mineral matter sealing the joints; and the valleys between the longitudinal ridges as belts of shattered rock—shattered by the ancient folding of the strata—along which the erosional action of the streams has been more effective.

While this hypothesis of resistant reinforced bands of rock is accepted as a probable contributory cause of the development of the longitudinal ridges,^{*} it appears to be inadequate when confronted by the notable linear persistence of the longitudinal ridges of the Tararua Range, and also by the associated physiographic features thereof—viz., the subsidiary transverse ridges,[†] and certain arresting characteristics of the hydrography. The present writer's explanation of the genesis of these land-forms may be presented in detail later, and it will suffice to state here that there are numerous and seemingly sound reasons for the belief that orogenic folding and uplift, synchronizing with the production of the existing stream-sculptured relief, is the most satisfactory explanation of the origin of the longitudinal and transverse ridges, and also of the notable peculiarities of the present hydrographical regime. Under this explanation the principal rivers must be classed as anteconsequent and in part antecedent.

3. Topography of the Arapaepae Ridge and of “The Heights” Basin.

On the western side of the Tararua Range the outermost foothill ridge is divided into sections by the vents of the rivers that issue from the mountains on to the plain. Locally the ridge-sections bear names usually corresponding to the trigonometrical stations situated on their highest points. The Arapaepae Ridge, on which is situated the more striking of the two examples of drainage-readjustment that form the subject of these notes, lies between the vents of the Ohau and Mangaore Streams, which cross the plain near Levin and at Shannon respectively.

Towards its northern end the Arapaepae Ridge is markedly asymmetrical. On its western side the spurs are deeply truncated, the hillside presenting a steep face composed of short blunted salients. These features mark the position of a former coast-line, they being ancient sea-cliffs (Adkin, 1911, p. 509; 1919, p. 109). On the eastern side of the ridge a different

[Footnote] * The topographic details as etched out by erosion are undoubtedly due to the presence of bands and patches of rock of varying resistance.

[Footnote] † The transverse ridges are not mere erosional features occurring at haphazard intervals. In some cases they extend from lowland to lowland right across the mountain-system, and therefore must be attributed to a more profound causation. Nor can it be due to mere chance that the principal transverse ridge of the Tararuas, if produced eastward across the Wairarapa lowland, there coincides with the water-parting from which the drainage of the lowland and adjacent mountains is directed north and south respectively.

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Fig. 1.—“The Heights” basin and adjacent lateral valleys of the Arapaepae Ridge at the present time, showing the readjustment of drainage at “The Heights” basin by piracy and by diversion by alluviation.

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set of land-forms occur: long fully-developed lateral spurs run out from the main divide like great buttresses for a mile or more, and between them lie broad, open stream-valleys, all diversified by a dendritic drainage-pattern. One of these broad valleys, locally known as "The Heights" basin, is situated at the junction of the Arapaepae Ridge with the transverse ridge that connects it with the inner ridges of the range. By virtue of its situation, this basin possesses such change-favouring features as superior altitude and shallowness to a greater degree than the adjacent eastward-facing lateral valleys of the Arapaepae Ridge.

"The Heights" basin, in which the changes of drainage took place, lies near the crest of the Arapaepae Ridge, its flat alluvial bottom ([Plate XI, fig. 1](#)) having an average altitude of 1,015 ft.—only 200 ft. below the trigonometrical station, Arapaepae No. 3, 1,210 ft., located at its north-western corner. The basin is roughly rectangular in shape, and about a mile and a half across from north to south. Forming its rim are hilly ridges, varying in height from a few feet to more than 400 ft. above the alluvial flat: on the west the Arapaepae Ridge, on north and south two lateral buttressing spurs of the same, and on the east the western end of the transverse connecting-ridge. To the north lies the catchment area of the Mangaore Stream; to the south and south-east that of the Makahika, a tributary of the Ohau River; and to the west that of the Koputaroa. Formerly "The Heights" basin had only one outlet; now there are no less than three.

4. Changes of Drainage in "The Heights" Basin.

Originally the whole of the drainage of "The Heights" basin was discharged through a comparatively narrow outlet situated at its south-east corner, by a single stream, tributary to the Makahika River. The origin of the basin is, in the present state of knowledge, somewhat problematical; but a tentative hypothesis is that it was formed by the denudation, first by the subaerial agencies in general and afterwards principally by stream erosion, of the crest of a broad anticlinal structure of crumpled strata possessing but little primary variation in hardness. Under this conception the weakened crest of the anticline was widely opened, while the limbs retained a sufficient degree of compactness to restrict erosion to

narrower limits. This hypothesis conforms to the conception of the orogenesis of the Tararua Range briefly outlined in section 2; the general topography of the Arapaepae and adjacent ridges is also favourable to its adoption.

An identical origin must be ascribed to the neighbouring eastward-facing lateral valleys of the Arapaepae Ridge ([fig. 1](#))—the Waireka ([Plate XI, fig. 2](#)), Wainui, &c. All these valleys are of the basin-like, bottle-neck type, being gorge-like and narrow at their outlets, and broad and open above. Valleys of similar form occur in the Blue Mountains* due west of Sydney (Taylor, 1919, p. 177).

It may be suggested that in the case of the Tararua foothills the broad arching of the secondary folding would be quantitatively insufficient to produce so sharp a distinction in the resistance to erosion of the crest and limbs of a fold as to determine the ultimate form of the bottle-necked valleys. For the present this may remain an open question, though the

[Footnote] * Professor David's and Griffith Taylor's explanation of the Blue Mountain bottleneck valleys appears to be applicable to those of the Tararua foothill ridge, though in the former locality this particular type of land-form was produced by a single rock stratum in the limb of a large anticlinal fold, and in the latter by the compacted and stronger strata of the anticlinal limb itself as compared with the weaker crest.

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Fig. 1.—“The Heights” basin, looking north-east, showing topography and present distribution of drainage. Remnant of original stream in foreground (centre to right), outlet of same on right beyond margin of view. Spill-over outlet on left. Gorge and trenches of pirate stream in distance (right to centre). Trig. station, Arapaepae No. 3, 1,210 ft, in distance on left. Fig 2—The valley of the Waireka Stream, looking east towards its narrow outlet. The old alluvial flat is now trenched by the slight rejuvenation of the stream.

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Fig. 2.—“The Heights” basin and the adjacent lateral valleys of the Arapaepae Ridge, showing the direction and probable character of the drainage towards the conclusion of alluviation. Approximate scale, 2 in. = 1 mile.

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available evidence appears to indicate that it was sufficient. There was, however, a contributory cause. The rejuvenated Makahika River has cut its present trench-like channel at the foot of the long eastward-trending lateral spurs of the Arapaepae Ridge, truncating them; and to maintain accordant junctions the Wainui and Waireka Streams were thereby forced to cut shorter, deeper gorges than they would have done had the Makahika River cut its present trench in the middle or on the opposite side of its former widely-opened valley. Of itself the action of the Makahika was quite insufficient to produce the bottle-neck, basin-like valleys of the tributary streams referred to, but, in conjunction with the broad arching of the secondary deformation, conditions came into existence that were favourable to the production of the tributary valleys in their present form.

When “The Heights” basin had been opened to nearly its present extent a period of alluviation followed. This alluviation covered the former valley-bottom to a

considerable depth, and ultimately formed a wide alluvial flat ([Plate XI, fig. 1](#)) having a very gentle surface slope to the south-east. The alluvium consists of stiff cream-coloured and yellow clays resting on a thick mass of fine gravel. Towards the close of the deposition of alluvium many of the exposed ends of the half-buried spurs round the rim of the basin were levelled off by lateral corrosion, and the flat was thus further enlarged. The current of "The Heights" stream was at this time extremely sluggish, flowing in meanders of small radius, and the surface of the flat must have been diversified by cut-off ox-bows and deserted swampy channels ([fig. 2](#)). On the whole, the topographic form of the basin at this stage was one of late maturity or even old age.

Alluviation of a somewhat similar character took place also in the Waireka, Wainui, and other adjacent bottle-necked valleys. Thick masses of clay containing scattered angular fragments of rock, often of large size, were laid down, the master streams became sluggish and winding, and the topography reached an advanced stage of maturity.* The alluviation of these tributary valleys took place in harmony with the alluviation of their trunk valley, that of the Makahika: this is proved by the corresponding accordant levels of the surfaces of the valley-fill in the several parts of the valley-system. The alluviation of the large river-valleys of the Tararua Range was caused by the failure of the rivers to transport the excessive amount of waste derived from the then more extensive alpine and subalpine areas in which these rivers took their rise during the "glacier period," the snow-line (and consequently the timber-line) being at that time, by reason, in part, of the greater elevation of the country, relatively very much lower than now.[†] In my previous papers (Adkin, 1911, pp. 497–98, 520; 1919, p. 112) it was shown that the building of the valley-plain of the Makahika and Ohau Valleys, and also the construction of the Ohau fan, took place during that period of great elevation of the North Island —viz., in the early Pleistocene (Park; 1910, pp. 156–57, 250; Marshall, 1912, p. 210). The initial opening - out by erosion of "The Heights" basin and the other adjacent bottle-necked valleys is therefore of some antiquity—certainly of not later date than middle or perhaps late Tertiary times.

The alluviation of "The Heights" basin was followed by further changes. The sources of a tributary of the Mangaore Stream, situated on

[Footnote] * The last physiographic event in each of these valleys except that of "The Heights" was rejuvenation, by which their alluvial bottoms were trenched to depths up to 100 ft.

[Footnote] † For fuller reference to this subject see "The Discovery and Extent of Former Glaciation in the Tararua Ranges, North Island, New Zealand," *Trans. N.Z. Inst.*, vol. 44, p. 315, 1912.

the northern side of "The Heights" basin, were actively extending their sources headward into the outer slopes of its rim. One of these streams finally cut back completely through the rim, and tapped a portion of "The Heights" stream. Invigorated by this success, it still further extended its course within the confines of the basin, ultimately capturing half of the drainage-lines therein. Proof of this act of piracy and the consequent reversal of drainage is furnished by the fact that the stream now flows in a direction contrary to the slope of the area it drains, as shown in [fig. 1](#). (Note altitudes—corrected aneroid readings—of the surface of the old alluvial flat.)

Simultaneously, or approximately so, a further change took place, this time in the south-west part of "The Heights" basin. There, one of the aggrading streams so far raised its bed that it at last overtopped a low place in the main Arapaepae divide, and a spill-over course resulted, by which its waters were diverted westward into the catchment area of the Koputaroa Stream. This type of stream-diversion has been described by Gilbert as "diversion by alluviation" The alternative possibility, that the spill-over course at "The Heights," and also that on the Poruriri Ridge (described in section 5), were caused through capture by the headwater erosion of streams rising outside the basins of the diverted streams, is rejected on the following grounds: (1.) Both the Arapaepae and Poruriri Ridges have fairly even, unnotched crest-lines, and headwater erosion of the streams draining their western slopes does not now, or at any previous period, appear to have caused, or even tended to cause, diversion by piracy. (2.) The original surfaces of the alluvial flats in the basins of the two diverted streams referred to above still overtop the former low parts of the Arapaepae and Poruriri ridge-crests respectively. In each case the notch cut by the spill-over course can be differentiated from the low part of the ridge-crest.

In this manner the former coalescent drainage of "The Heights" basin became divided into three distinct parts, each of which possesses either inherited or newly-acquired topographic characteristics. The remaining undiverted portion of the original drainage bears all the signs of advanced age, and still pursues a meandering course on the *surface* of the alluvial flat before flowing south-east to join the Makahika River. The streams captured by the pirate stream flow in narrow youthful trenches at a depth of from 15 ft. to 100 ft. below the old alluvial surface,

and then plunge into the deep and narrow gorge that forms the breach in the northern rim of the basin, and join the Mangaore. In one place part of this entrenched drainage lies only about 7 chains from the old meandering stream, and further captures are thus imminent. The stream diverted by alluviation has also entrenched itself to a slight extent into the alluvial flat, and then cascades down the steep western face of the Arapaepae Ridge to augment the waters of the Koputaroa. The changes described bear the marks of extreme youth, and further adjustments must eventuate before even a moderate state of stability is attained.

5. Changes of Drainage on the Poruriri Ridge.

The Poruriri Ridge is another section of the outermost western foothills, lying between the vents of the Mangaore and Tokomaru Rivers; and linearly it is the northward continuation of the Arapaepae Ridge. The diversion of drainage which took place on the Poruriri Ridge was similar to but less complex than that at "The Heights," since in the former locality the act of piracy was not committed. In the former locality the change was due to diversion by alluviation causing a spill-over course (now known as the

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Fig. 3.—The topography of the present and former catchment areas of the Mangaharakeke Stream, near Tokomaru.

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Mangaharakeke Stream: [fig. 3](#)) which produced the highest waterfall* yet recorded in the Tararua Range, and a ravine exhibiting all the criteria of extreme youth— precipitous, crumbling rocky sides, and a narrow ungraded stair-like bottom down which the stream plunges in a series of falls and cascades. The main fall is situated at the head of the ravine, and descends the 300 ft. of its height in three leaps, separated by narrow rock ledges.

The northern end of the Poruriri Ridge is even more asymmetrical than the Arapaepae Ridge, its spurs being so deeply truncated on its western side as to present an almost unbroken face, the exceptions being the gash-like Mangaharakeke ravine and some minor gullies. Like the Arapaepae Ridge in the vicinity of "The Heights," the Poruriri has long branching lateral spurs on its eastern side, and physiographically the two ridges have much in common.

Considered as a single feature, the former and present catchment areas of the Mangaharakeke Stream have a topographic form intermediate between that of the Waireka Stream ([Plate XI, fig. 2](#)) and that at "The Heights" ([Plate XI, fig. 1](#)). Some of the topographic details of this dismembered catchment area are of considerable interest, but only one which has a direct bearing on my argument can be touched on here. The sudden spilling-over of a fair-sized stream like the Mangaharakeke liberated an enormous amount of erosive power, with the result that the spurs on either side of the ravine were shorn away longitudinally, leaving them as half-spurs—*i.e.*, having a concave precipice on the one side and the normal form on the other. None of the spurs enclosing any of the neighbouring minor gullies possesses a similar configuration, a fact emphasizing the special origin of the ravine.

Formerly, the Mangaharakeke Stream took its rise on the northern side of the Poruriri Trigonometrical Station, and flowed north and north-east into the upper valley of the Tokomaru River. By the excessive alluviation of the upper part of its course a state of great instability ensued, and while swinging to and fro on its alluvial flat the stream found a low place in the main Poruriri ridge-crest and flowed down the western slope, there producing the ravine and falls described above. A sluggish shrunken remnant of its former trunk, tributary to the Tokomaru, still drains the eastern part of the deserted alluvial flat.

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[Footnote] * From the Wellington-Manawatu Railway line just south of Tokomaru this fall is a conspicuous and striking object.

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Art. XXVI.—*The Influence of Salts of the Alkali and Alkaline-earth Metals on the Solubility in Water of Calcium Carbonate (a) in the*

Presence of Air free from Carbon Dioxide, (b) in the Presence of Excess of Carbon Dioxide.

By E. A. Rowe, M.Sc.

[*Abstract communicated by W. P. Evans, M.A., Ph.D., to the Philosophical Institute of Canterbury, 6th August, 1919; received by Editor, 31st December, 1919; issued separately, 15th June, 1920.*]

The series of experiments herein described was carried out in order to determine how the solubility in water of calcium carbonate was affected by the presence of small quantities of the salts of the alkali and alkaline-earth metals, the temperature and pressure being approximately constant.

The quantities added varied from 0.0005 to 0.1 mole per litre, while the temperature lay between 11° and 12° C.

Apparatus.

The apparatus employed in the first series of experiments consisted of a number of wash-bottles connected in series. The air was sucked through these at a constant head, the flow being adjusted by a micrometer-screw in parallel with a pressure-gauge.

The air was freed from carbon dioxide by means of soda-lime followed by a solution of caustic potassium hydroxide.

In the second series of experiments carbon dioxide was passed through the wash-bottles direct from a cylinder the needle-valve of which replaced the screw-tap of the previous apparatus.

Conclusions.

1. The solubility of calcium carbonate in water *increases* regularly with the addition of increasing small amounts of (a) ammonium, sodium, potassium, and magnesium sulphates; (b) ammonium and sodium nitrates; (c) ammonium and magnesium chlorides.

2. The solubility of calcium carbonate in water *decreases* regularly with the addition of increasing small amounts of (a) ammonium, sodium, and potassium carbonates; (b) potassium nitrate; (c) potassium chloride; (d) disodium hydrogen phosphate.

- The solubility in water of calcium carbonate exhibits irregularities in the presence of small quantities of sodium chloride.
- The solubility in water of calcium bicarbonate *increases* regularly with the addition of increasing small quantities of (a) ammonium, sodium, potassium, and magnesium sulphates; (b) ammonium, sodium, and potassium nitrates; (c) ammonium, sodium, potassium, and magnesium chlorides.
- The solubility in water of calcium bicarbonate *decreases* regularly with the addition of increasing small quantities of (a) ammonium, sodium, and potassium bicarbonates; (b) calcium chloride; (c) disodium hydrogen phosphate.
- As regards the alkalies, calcium carbonate appears to be most soluble in the ammonium salt of a given acid and in the sulphate of a given base.

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Art. XXVII.—*Studies in the New Zealand Species of the Genus Lycopodium: Part IV—The Structure of the Prothallus in Five Species.*

By the Rev. J. E. Holloway, D.Sc., Hutton Memorial Medallist

[Read before the Philosophical Institute of Canterbury, 3rd December, 1919; received by Editor, 31st December, 1919; issued separately, 23rd June, 1920.]

**Plates XII-XV.
Introductory.**

In three previous papers (6, 7, 9) I have given general descriptions of the form and the manner of occurrence of the prothalli of eight New Zealand species of *Lycopodium*. In the last of these papers I also noted, without figures, certain details in the structure of the prothalli which bore upon the general subject of the great variability of the New Zealand species of *Lycopodium*. The eight species whose prothalli were described are *L. Billardieri* Spring, *L. Billardieri* var. *gracile* T. Kirk, *L. varium* R. Br. Prodr., *L. cernuum* Linn., *L. laterale* R. Br. Prodr., *L. ramulosum* T. Kirk, *L. volubile* Forst., *L. fastigiatum* R. Br. Prodr., *L. scariosum* Forst. These prothalli are representative of four out of the five known types. It is a striking fact that these eight species introduce no new types of prothallus beyond those which have become known through the researches—especially of Treub and Bruchmann, but they present some very interesting variations from those types. The prothallus of *L. cernuum* has been, of course, known to science since Treub's papers on several tropical species studied by him in Java were published, but the other seven mentioned above have only recently become known. Two other workers have published the results of their investigations on the prothalli of several of the New Zealand species—namely, Miss Edgerley (4) and Professor C. J. Chamberlain (3)—the former's paper dealing with *L. volubile*, *L. scariosum*, and *L. Billardieri*, and the latter's with *L. volubile*, *L. scariosum*, and *L. laterale*.

The present paper is on the structure of the prothallus of the five species *L. Billardieri*, *L. Billardieri* var. *gracile*, *L. varium*, *L. cernuum*, *L. laterale*, and *L. ramulosum*. I hope to publish a similar account with regard to *L. volubile*, *L. fastigiatum*, and *L. scariosum* in a fifth part.

The literature dealing with the various other species—European, Tropical, and American—which have been described is enumerated below at the beginning of the sections to which they respectively belong. Several of these papers I have not had access to, but have had to depend for my knowledge of them on brief summaries and figures copied from them in various standard books of reference. This is, of course, unfortunate, as it has made less possible for the purpose of this paper a full comparative study of the different types of *Lycopodium* prothalli.

I am glad to record my thanks to Dr. Charles Chilton, Professor of Biology at Canterbury College, for the interest he has always shown in my work, and for his kind permission to use the biological laboratory of Canterbury College from time to time. I desire also here to recall and acknowledge the guidance of Professor A. P. W. Thomas, who first suggested to me, when working under him in the biological laboratory at Auckland University College, the study of the New Zealand species of *Lycopodium*.

Section Phlegmaria.

L. Billardieri Spring; *L. Billardieri* var. *gracile* T. Kirk; *L. varium* R. Br. Prodr.

Literature.

The first papers published on the prothalli of this section were those of Treub (14, 15) dealing with the four tropical species *L. Phlegmaria* Linn., *L. carinatum* Desv., *L. Hippuris* Desv., and *L. nummularifolium* Blume. In a paper on the stem-anatomy of certain New Zealand species of *Lycopodium* I gave a very brief description of the prothallus of *L. Billardieri*, stating that it corresponded to the *Phlegmaria* type (6), and Miss Edgerley a few years later (4) described it more fully, with figures. In two papers of the present series (7, 9) I have given certain details concerning the external form and the structure of this same prothallus and of the two allied forms *L. Billardieri* var. *gracile* and *L. varium*. Literature dealing with two species of prothallus belonging to the closely related *Selago* section must also be mentioned—viz., Bruchmann's two accounts (1, 2) of the prothallus of *L. Selago* Linn., and a very brief description, with one figure, of that of *L. lucidulum* Michx. by Spessard (11).

General Form of the Prothallus.

The complete mature prothallus of all these three New Zealand forms, similarly to those of the four tropical epiphytic species described by Treub, consists essentially of a central body of tissue, which may be either bulky or more or less elongated, and a number of branches which arise adventitiously from this central body. In fig. 1 is shown such a complete mature prothallus of *L. Billardieri* var. *gracile* in external view, the natural size being also indicated in the illustration. The central body of the prothallus as here shown is somewhat slender and elongated, a condition which I have found generally to be the rule in this variety. It possesses two complete, and also two broken, thin vegetative branches; a young, stouter branch; and also, nearer the forward end, a short club-shaped "resting" process. The two complete branches on the left side of the figure have begun to put forth secondary branches, while one has also commenced to expand

at its growing end preparatory to there bearing sexual organs. The oldest end of the prothallus is intact, and shows clearly the original cone form with which the prothallus of the epiphytic type always begins. At the apex of the cone the cell first formed from the spore still persists. The main prothallial body shows the presence of fungus in its internal tissues, this fungal inhabitant occupying the whole of the tissues in the dark basal cone-like region, but being more irregularly distributed farther forward. The fungus is also present in the vegetative branches, being there also somewhat irregularly distributed, and the single club-shaped resting process is very dark with it. The ends of the branches are all quite free of fungus and are translucent in appearance. The forward end of the main prothallial body is slightly more bulky than the rest, and is quite clear of the fungus. This is the main generative region of the prothallus, and bears paraphyses, archegonia, and also a young plant. The whole prothallus is covered with long rhizoids inclining forward towards the growing apices, except on the terminal bulky region, which is wholly devoid of them, and on the basal cone-like region, from which they have decayed away, leaving only short, stubby projections. The description of this particular prothallus in its external

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appearance will suffice to illustrate the general features of the three New Zealand epiphytic species here dealt with.

L. Billardieri var. *gracile* grows abundantly throughout Westland on stems of the tree-fern *Dicksonia squarrosa*, and it has also been reported from various other parts of New Zealand in the same situation. The

Fig. 1.—*L. Billardieri* var. *gracile*. Complete mature prothallus in general view, showing basal cone intact, lateral branches, and plantlet. $\times 13$. The small figure represents this prothallus at $\frac{3}{4}$ natural size.

prothalli and young plants occur more especially on the younger stems of the

Dicksonia in between the bases of the stipites, which in this tree-fern run down the stem a considerable length before they begin to be overgrown by the mass of hard brittle aerial rootlets. It is in this more open part

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Figs. 2–5.—*L. Billardieri*. Central body of mature prothalli in general view, complete except for basal cone, with old and also young branches, bearing sexual organs and paraphyses. Figs. 2, 3, and 5, $\times 25$; fig. 4, $\times 10$.

Fig. 3a.—*L. Billardieri*. Old antheridium in surface-view.

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of the tree-fern stem-surface that the prothalli and plantlets of both *L. Billardieri* var. *gracile* and of *Tmesipteris* occur. As the tree-fern grows in height the covering of aerial rootlets spreads up the stem, and so plantlets of increasing age have to be carefully dissected out from the mass of the brittle rootlets. The prothalli of this species of *Lycopodium* are often to be found adhering closely to the hard black surfaces of the stipites, and are there readily found by tearing away the humus and the debris of old tomentum which collects between the bases of the stipites. Their rather delicate, attenuated form is probably the result of this particular

position of growth.

Fig. 6.—*L. varium*. Prothallus in general view, showing central body and branches, and a young plant. $\times 10$.

Fig. 7.—*L. varium*. Prothallus in general view, showing basal end, and young embryo in the generative region. $\times 10$.

Fig. 8.—*L. varium*. A branched “resting” process in general view. $\times 10$.

The prothalli of *L. Billardieri*, on the other hand, occur for the most part in masses of humus on elevated positions in the forks of the forest trees and of their main branches. The central prothallial body is generally more bulky than that of *L. Billardieri* var. *gracile*, but otherwise the prothallus is identical both in appearance and in structure. With regard to the tropical forms studied by him, Treub states that the prothalli of *L. Hippuris* are much larger and thicker than those of *L. Phlegmaria*, while those of *L. nummularifolium* are exceedingly thin. These epiphytic prothalli have very much the appearance of a mass of root-ends, but a little

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experience in dissecting soon leads one to detect the presence of a central region and so distinguish the prothalli from rootlets. Moreover, the root-ends and vegetable fibres so commonly to be met with in the humus are more dead-white or yellowish in appearance, the prothalli in their fungus-free regions being somewhat translucent. [Figs. 2–5](#) show the central bulky region of four prothalli of *L. Billardieri*, from all of which the oldest basal region is absent. The distribution of the fungus is indicated in these figures by dark shading. It will be seen that the forward region of the central prothallial body is the most bulky, and is wholly free from fungus. It is also quite devoid of rhizoids. It bears on one surface—the upper—paraphyses in large numbers, and also sexual organs. The archegonia and antheridia are not intermingled, but occur in clearly defined zones arising immediately behind the growing apex of the prothallus. The surface appearance

of an old antheridium is shown in [fig. 3a](#), the triangular opercular cell being a very distinct feature. The under-surface of the generative portion of the prothallus is always quite naked and smooth.

Lycopodium varium is closely allied to *L. Billardieri*, but grows terrestrially and has a somewhat different habit of growth. Its prothalli are in every respect identical with those of *L. Billardieri*. Three prothalli are shown in [figs. 6–8](#). That in [fig. 6](#) bears a young plant; its basal end is not seen. That in [fig. 7](#) shows the basal end dark and withered, and a very young embryo can be seen through the tissues of the forward generative region. In [fig. 8](#) is shown a branched “resting” process. In none of these figures is the distribution of the fungus indicated.

Position in the Soil

The prothalli belonging to these three forms have apparently no regular position relative to the surface of the soil in which they grow. The branches of the prothallus extend in any direction. Frequently they are inclined forward in the same direction as that of the growth of the main body, but this is not always the case. Bruchmann has shown that in the case of *L. Selago* the more deeply growing, elongated, cylindrical forms of prothallus extend in a vertical direction towards the surface. This is not the case with the prothalli of the terrestrially-growing *L. varium*, which are quite similar both in their form and in their indefinite position of growth to those of the ordinary epiphytic species. The prothalli of *L. Billardieri* and of the two other allied New Zealand forms are, however, quite markedly dorsiventral in structure. The paraphyses and sexual organs are to be found only along the uppermost side of the prothallus, whether they occur on the central region or on the lateral branches.

Early Stages in the Development.

The youngest prothallus found by me belonged to the form *L. Billardieri* var. *gracile*, and is shown in [fig. 9](#). This prothallus consisted of the first-formed, conical region, which was entirely infested with the fungus and was covered with the old bases of broken-off rhizoids, and a forward translucent region showing several young paraphyses and an antheridium immediately behind the apex. This younger portion of the prothallus also bore the usual long rhizoids. The fungus entirely occupied the main portion of the prothallus except in its epidermal cells. It also bore a young lateral process, on which rhizoids were beginning to arise by the outward growth

of epidermal cells. This lateral process was free of the fungus, except in certain isolated subepidermal cells which lay at the bases of the young rhizoids. From this latter fact it is apparent that, at any rate when the extension in length of a branch is rapid, infection may take place from without through the rhizoids, and that the distribution of fungus throughout the prothallus does not take place simply through its forward extension from the older regions. The original apex of the oldest conical region

Fig. 9.—*L. Billardieri* var. *gracile*. A young prothallus complete, in general view. $\times 60$.

Fig. 10.—*L. Billardieri* var. *gracile*. Longitudinal section of the basal cone of the prothallus illustrated in fig. 1, showing remains of spore on the first-formed cell. $\times 170$.

Fig. 11.—*L. Billardieri* var. *gracile*. Longitudinal section of central body of mature prothallus, showing general arrangement of tissues, and also foot of young plant. $\times 47$.

was intact, and the first-formed cells were clearly to be traced. Most of the mature prothalli of these epiphytic species which I found were incomplete in their basal region, probably on account of the decaying-away of these oldest tissues through age; but I also found several mature prothalli both of *L. Billardieri* and of the variety *gracile* in which the original end was intact. This was the case with that shown in [fig. 1](#). A highly

magnified view of the lower portion of the conical region of this particular prothallus is given in [fig. 10](#), in which the remains of the original spore can be seen still attached to the basal cell of the cone. Whether or not a filament ever is formed from the germinating spore, as is known to occur in the prothallus of *Tmesipteris*, cannot be here stated. The presence of the fungus in these basal cells serves to keep the latter from collapsing for a considerable period, and if a filament is ever formed in the epiphytic *Lycopodium* prothalli one would expect that, as in the case of *Tmesipteris*, it would not easily be lost. It is clear, at any rate, from [fig. 10](#) that in some cases at least the germinating spore gives rise immediately to the cone-shaped tissue body. In his description of the prothalli of *L. Selago* and *L. complanatum* Bruchmann figures a single cell at the basal point of the prothallus.

Main Body of the Prothallus.

The main body of the prothallus consists essentially of two regions, the hinder vegetative and the forward generative region. There is no such differentiation in structure in the fungus-bearing tissues of the central



Fig. 12.—*L. Billardieri* var. *gracile*. Transverse section of basal cone of mature prothallus, showing fungus throughout, also first branch in longitudinal section $\times 108$.

Fig. 13.—*L. Billardieri* var. *gracile*. Transverse section of mature prothallus above basal cone, showing initial development of the central strand. $\times 108$.

body of this prothallus as is found in those of the *clavatum* and *complanatum* types. In these latter prothalli the fungal tissues are clearly marked off into cortical and palisade zones, and in the case of the New Zealand species *L. volubile* and *L. fastigiatum* there is also a wide and very characteristic zone in which the fungal hyphae are also intercellular. The particular type of structure found in these deeply-growing terrestrial types can be put in connection with the general habit of growth of the prothallus. This is the opinion expressed by Bruchmann in his description of the prothalli of *L. clavatum*, *L. annotinum*, and *L. complanatum* (1,

pp. 18, 58). As will be seen below, even the prothalli of the *Cernua* section have attained to a certain degree of differentiation in their fungus-bearing regions. The fungus-infested cells in the main prothallial body of the three New Zealand species which belong to the *Phlegmaria* type are all practically similar to one another in their form and contents. In longitudinal section it is apparent that transverse divisions have taken place in them so that

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they are more equidimensional than are the adjacent cells ([fig. 11](#)). It is rather the centrally-placed, fungus-free cells which have become changed in form. They are always considerably elongated, and are somewhat narrower than the cells of the fungal zones ([fig. 11](#)). This is, of course, quite in accordance with the function of translocation which they are called upon to perform in these elongated prothalli. Certain of the epidermal cells grow out as rhizoids, a transverse wall separating the rhizoid proper from its parent cell. The width of the fungal zone in the main prothallus body varies in different parts, but, generally speaking, it diminishes towards the growing region. However, if lateral branches are borne well forward on the prothallus the fungus will be found well forward also. The fungus is always massed around the base of a branch, but in those portions of the main body which lie in between the branches

[Fig. 14.—*L. Billardieri*. Transverse section of the prothallus shown in fig. 3, at the point c. \$\times 60\$.](#)

[Fig. 15.—*L. Billardieri*. Transverse section of the prothallus shown in fig. 5, at the point a. Compare also fig. 2, c. \$\times 60\$.](#)

[Fig. 16.—*L. Billardieri*. Transverse section of the prothallus shown in fig. 3, at the point a. \$\times 135\$.](#)

the fungal zone may be no more than one or two cells in width. In the basal cone-like region the cells, which are all equidimensional, are all infested with the fungus, there being here no centrally-placed conducting strand. At the actual base

of the prothallus even the epidermal cells show the presence of the fungus ([fig. 10](#)). [Fig. 12](#) is a transverse section of the basal cone, showing the first-formed lateral branch in longitudinal section. It will be seen that in the central region in this figure the fungus is inter-cellular as well as within the cell-cavities, and the cells here consequently appear roundish in shape. Farther forward still the centrally-placed cells are free from fungus and represent the beginning of the conducting-strand ([fig. 13](#)). [Fig. 14](#) is a transverse section of the prothallus which is shown in [fig. 3](#) taken at the point marked c. In this region of the main body the fungus has extended forward so that it underlies the old antheridia. The rhizoids are here ventrally borne, and the fungus is aggregated along the ventral side so that the prothallus shows a dorsiventral structure. [Fig. 15](#)

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is a transverse section of the prothallus shown in [fig. 5](#) at aa, and represents the most forward position occupied by the fungus in this prothallus. It will be seen that the fungus in the lateral branch which is also included in this figure is not in connection with that in the main body. The same figure would also represent in transverse section the appearance of the prothallus shown in [fig. 2](#) at cc.

The generative portion of the central prothallial body is always the most bulky, and shows no differentiation of its tissues whatever. Immediately behind the growing apex of the prothalli shown in [figs. 2, 3, and 5](#) young antheridia are being produced. Fig. 16 represents a transverse

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Fig. 17.—*L. Billardieri*. Transverse section of the prothallus shown in fig. 3 at the point b. $\times 135$.

Fig. 18.—*L. Billardieri*. Transverse section of the dorsal side of the prothallus shown in fig. 2 at the point b. $\times 135$.

Fig. 19.—*L. Billardieri*. Oblique section through the prothallus shown in fig. 2 at the point a. $\times 135$.

section of the prothallus shown in fig. 3 at *a*. Fig. 17 is a transverse section through an older antheridial zone of the same prothallus at *b*, while fig. 18 shows the grouping of the archegonia in amongst the paraphyses on the prothallus illustrated in fig. 2 at *bb*. The sexual organs occur in large numbers in distinct zones. The close grouping of the antheridia, for example, is shown in fig. 19, which is an oblique section taken through the point of the prothallus illustrated in fig. 2 at *aa*. The generative region in transverse section bears evidence of repeated cell-divisions, and the cell nuclei and contents are very prominent, as if there had been extensive translocation of food material to this region of the prothallus. A longitudinal section of the generative region shows that the extensive development of sexual organs and paraphyses along the dorsal surface brings it about that

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the actual apical meristem is somewhat ventrally placed. Fig. 20 shows this forward region of a prothallus in longitudinal section, but the older vegetative region is not included, as the prothallus was curved in shape. The generative region in longitudinal section is also shown in [figs. 11](#) and 34, both of which prothalli bear a young, developing plant.

Fig. 20.—*L. Billardieri*. Central body of the prothallus, showing generative region in longitudinal section, and also a lateral branch. Basal cone of prothallus not included. $\times 70$.

The Lateral Branches.

The lateral branches or vegetative processes arise from the main central body when the vegetative region of the latter is ceasing to cope with its main function of nourishing the growing generative region. The examination of such prothalli as those given in [figs. 1, 9, and 10](#) shows both that the rhizoids on the older portion of the main body have decayed away and that the fungal coils in the cells of this

older region have given place to the fungal "spores." The cells are full of these spores, which in all the old prothalli that I have examined do not seem to disintegrate further. The lateral branches are thickly covered with rhizoids, and show the presence of a fungus distributed in the cells more or less along their entire length.

The tissues of the branch are similar to those in the vegetative region of the main body, except, of course, that in accordance with the smaller girth of the branch both the fungal zone and the centrally-placed con-ducting-strand are there correspondingly less in width. [Fig. 21](#) shows a well-developed branch in transverse section, and [fig. 22](#) in longitudinal section. In transverse section there is seen to be a central group of six fungus-free cells, surrounded by a single layer of larger fungus-bearing

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cells, some of which have divided. Outside this again is another single layer of somewhat smaller cells which may or may not contain the fungus, bounded peripherally by the epidermal layer, whose external walls are cuticularized. These same layers can also be distinguished in [fig. 22](#) in longitudinal section. Thinner branches show less cell-multiplication in the fungal zone. In longitudinal section it is apparent that the fungus-containing cells have divided transversely, so that they are more nearly equidimensional than those either of the central strand or of the epidermis. The fungus is present in the form of hyphal coils or clusters of oval dark-staining "spores." The fungus also extends between the cells, so that the latter are frequently roundish in shape.

Sooner or later a branch will show a thickening of its tissues at the apex, and on this swollen region paraphyses and sexual organs will arise ([figs. 6, 23, 24](#)). Such a swollen region will be free from the fungus, but the hyphal coils are often aggregated very thickly in that portion of the branch which lies immediately behind it ([fig. 24](#)). It is always antheridia which are first formed in such branches, the archegonia occurring only on the main central region of a prothallus. However, a branch may thicken and develop to such an extent that it practically

becomes a new prothallus. Probably not a few mature prothalli have arisen not from the germination of a spore, but by a branch having become detached from an older prothallus and having gone on growing in thickness. Such a branch will put forth lateral branches, and will eventually bear archegonia as well as antheridia on its main body. This will account for the fact that most of the mature prothalli found by me did not show the typical cone-like basal region. They are in fact prothalli which have arisen adventitiously. [Fig. 27](#) shows in external view the terminal region of a stoutish branch of *L. Billardieri* var. *gracile* which has begun to develop antheridia and paraphyses. Some of the detached branches which are dissected out of the humus are imperfect at both extremities, a fact which indicates that they may persist in the humus and remain self-nourishing for a considerable time.

In dissecting out prothalli of these species of *Lycopodium* from the substratum in which they lie, one frequently comes across detached prothallial branches which have probably arisen by the decaying-away of the parent prothallus. Three such branches of *L. Billardieri* var. *gracile* are shown in [figs. 28–30](#). In this particular species these branches are frequently very long and thin, and they may show the presence of paraphyses along extended portions of their length. Lateral branches frequently bear short club-shaped processes, sometimes in great numbers ([fig. 30](#)), which are quite dark with the fungal inhabitant. These processes are to be regarded as “resting” processes, and they may occur also on mature prothalli of the ordinary kind ([figs. 1, 11](#)). They are frequently met with detached in the humus, and are either of a simple nature or are branched ([figs. 8, 25](#)). The actual apex of the resting process is white and clear of fungus, but the rest is very dark, being thickly infested with it. [Fig. 31](#) represents such a resting process in transverse section, from which it will be seen that the central cells contain the fungus as well as those more medianly situated, and that the fungus is intercellular as well as intracellular. The apex of one of the branches of the stout resting process shown in [fig. 25](#) is given in longitudinal section in [fig. 32](#). Immediately behind the apex the fungus is hyphal only and does not penetrate between the cells. Farther back, however, the hyphal coils have to a large extent been replaced by the “spores,” and the fungus is also intercellular. Instances may be met with

Fig. 21.—*L. Billardieri*. Transverse section of lateral vegetative branch. $\times 170$

Fig. 22.—*L. Billardieri* var. *gracile*. Longitudinal section of a lateral vegetative branch. $\times 170$.

Figs. 23, 24.—*L. Billardieri* var. *gracile*. Swollen ends of lateral branches, bearing antheridia and paraphyses, in general view. $\times 22$.

Fig. 25.—*L. Billardieri* var. *gracile*. Branched detached “resting” process, in general view. $\times 22$.

Fig. 26.—*L. Billardieri* var. *gracile*. Detached “resting” process in general view, showing initiation of renewed growth. $\times 22$.

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Fig. 27.—*L. Billardieri* var. *gracile*. Growing end of lateral branch in general view, showing apical meristem, young antheridia, and paraphyses. $\times 80$.

Figs. 28–30.—*L. Billardieri* var. *gracile*. Detached branches in general view, bearing paraphyses and club-shaped “resting” processes, and showing disposition of fungus. $\times 7$

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in which a resting process is resuming its extension in length. Generally it proceeds immediately to form paraphyses and antheridia ([fig. 26](#)), and probably develops ultimately into a large prothallus. Thus these species are able to propagate themselves vegetatively. In this connection it will be remembered that Treub has described a rather different mode of vegetative propagation in the prothallus of *L. Phlegmaria*.



Fig. 31.—*L. Billardieri* var. *gracile*. Transverse section of a “resting” process. $\times 135$.

Fig. 32.—*L. Billardieri* var. *gracile*. Longitudinal section of one of the apices of the “resting” process shown in fig. 25. $\times 135$.

Fig. 33.—*L. Billardieri*. Longitudinal section of a very young lateral branch. $\times 135$.

Fig. 34.—*L. Billardieri* var. *gracile*. Longitudinal section of the generative region of the main prothallial body, showing suspensor, foot, and first root of plantlet in longitudinal section. $\times 42$.

Position of the Meristem.

In the young prothallus of *L. Billardieri* var. *gracile* shown in [fig. 9](#) it is apparent that the meristem is confined to the actual apex, and that more than one of the apical cells are meristematic. This position and form of the meristem holds throughout the life of the prothallus of this particular type. In [fig. 27](#) are shown the growing tips of lateral prothallial branches. However irregular in shape the central body of the prothallus may be, there is always a forward growing end to be found where the meristem is localized. In the prothalli shown in [figs. 2-5](#) the growing apex is easily to be distinguished, but it is not always so apparent. As I have mentioned above, the rapid formation of sexual organs behind the growing apex generally brings it about that the meristematic cells are somewhat displaced from the actual apex of the prothallus and lie slightly towards the underside, this being apparent in the longitudinal section shown in [fig. 20](#). Again, I must add

that in this particular figure the hinder region of the prothallus is not cut longitudinally, so that although the fungal tissue in the figure seems to bear some relation to the meristem this is really not the case. In the branches in which the fungus is found almost throughout the entire length it is absent from the whole of the tip of the branch, even in the case of the "resting" processes which are so packed with fungus ([fig. 32](#)). Thus the growing tips always appear clear and translucent. A lateral branch arises adventitiously on the central prothallial body by one or more of the externally-placed cells of the latter setting up a local meristem. This can be seen from [fig. 33](#), which shows in longitudinal section a very young lateral branch being formed alongside some old paraphyses. At first the process extends in length by the activity of a single triangular apical cell ([fig. 33](#)), but probably very early the apex broadens and more than one cell becomes meristematic. Miss Edgerley states that at the tips of the branches she found two initials (4, p. 105).

Relation of the Young Plant to the Prothallus.

In the epiphytic species, whereas the antheridia are frequently borne on certain parts of the lateral branches as well as on the central body of the prothallus, the archegonia are borne on the latter only. At the same time, it will be remembered that this central body may not have grown directly from the germinating spore, but may have originated by the development of a detached branch. This central body of the prothallus, as has been described, consists of a hinder vegetative region and a forward more bulky generative region, and it is to the latter that the young plant is attached ([figs. 1, 6, 7, 11, 34, 36, 37](#)) Not infrequently more than one developing plantlet is attached to the same prothallus ([fig. 37](#)).



Figs. 35–37.—*L. Billardieri* var. *gracile*. Prothalli bearing one or more young plants, in general view. [Fig. 35](#), $\times 3$; [figs. 36 and 37](#), $\times 6$.

The prothallus, being placed well below the surface of the humus, is called upon to nourish the young plant altogether until the latter can reach the surface and produce its first leaves. The naked stems of the developing plantlets are

sometimes as much as $\frac{1}{2}$ in. long before they reach the light. In accordance with this considerable degree of dependence of the young plant upon its parent prothallus, that part of the base of the plant which is in contact with the prothallial tissues functions as an absorbing "foot." This foot is a well-marked feature in the plantlets of the epiphytic species, although it does not there assume so large a size as it does in the plantlets

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which are borne on the *clavatum* and *complanatum* types of prothallus. In these latter species the prothallus is still more deeply buried, and the leaves on the young stem are also no more than scales, so that the prothallus functions as the source of food-supply for a lengthy period. The size of the foot in the New Zealand epiphytic species can be seen from [figs. 11](#) and [34](#), the foot being in transverse-section in the former figure and in longitudinal section in the latter. There is a well-defined epithelial cell-layer around the periphery of the foot where the latter is in contact with the prothallus, and the outer walls of these epithelial cells are strongly defined, staining darkly. The adjoining prothallial tissue is small-celled and contains abundant protoplasm and darkly-staining nuclei, extensive cell-division having taken place here contemporaneously with the development of the plant. The central cells in the foot are large, with their long axes directed towards the stem-apex. All of these features, of course, point to the fact that there is a well-established translocation of food material from the prothallus into the developing plantlet, and that the epithelial layer functions as an absorbing tissue.

The first root develops comparatively late. It may be recognized as a conical outgrowth at the base of the stem on the side which lies away from the prothallus even before the stem-apex has reached the surface of the soil, but it never seems to develop farther until the first leaves are being produced. [Fig. 34](#) shows the first root in longitudinal section, it being apparent from this figure that the main vascular tissues of the stem lead down bodily into the root, while just a few narrow conducting-elements connect the former with the central tissue of the foot. [Fig. 34](#), which is a drawing of the young plant of *L. Billardieri* var. *gracile* is strikingly similar to the figure which Bruchmann gives of the young plant of *L.*

Selago (1, pl. 7, fig. 43). I have observed a number of young plants of the New Zealand epiphytic species in this condition, so that it may be taken as representing characteristically this stage in the development of the young plant and its mode of dependence upon the prothallus in both the *Selago* and *Phlegmaria* sections.

Treub stated that in the young plant of *L. Phlegmaria* he had found an indication of a swelling which he regarded as a rudimentary protocorm. Bower, however, has questioned this, and Treub's statement has never been established. I have found no indication of a protocorm in any of the three New Zealand species which belong to this section of the genus. In his *Origin of a Land Flora* Bower says that he regards the *Selago* and *Phlegmaria* type of embryo plant as being the primitive type for the genus, as it certainly is the most simple. The *clavatum* and *complanatum* type of embryo, he says, is not very dissimilar to it, but has become more modified through the large development of the foot consequent on the deeply subterranean habit of the prothallus. The *cernuum-inundatum* type of embryo stands rather by itself. The intraprothallial swelling called the "foot" is here practically absent, but instead there is the extra-prothallial swelling which Treub called the "protocorm." Bower and others hold strongly that the protocorm is not a primitive character, as Treub had supposed, but merely a physiological modification.

Details of the Fungal Symbiont.

A symbiotic fungus occurs very commonly throughout the Pteridophyta in the subterranean forms of prothallus, and it has been carefully studied in most of those species of *Lycopodium* of which the prothalli are known.

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In the three New Zealand species dealt with above it is present at the actual base of the prothallus, having entered probably very early in its development. It occupies the whole of the tissues in the basal cone except at the meristematic apex, being found even in the epidermal cells at the basal point ([figs. 1, 9](#)). At first

the fungus is in the form of hyphal coils which are in actual connection with the mycelium in the outside soil by means of hyphae which are to be found running through the rhizoids. As these rhizoids die off from the older parts of the prothallus, each being cut off at its base by a strongly thickened transverse wall, the fungus in these older regions becomes isolated from that in the soil, and probably ceases to function. The fungal coils soon disappear in many of the cells, their place being taken by clusters of darkly-staining oval "spores" ([fig. 10](#)). I do not know whether or not the fungus is at all used up by the growing prothallus, but I should say not, as in even mature prothalli the cells in the basal cone are still occupied either by the coils or by the "spores."

A little forward from the basal cone the fungus has begun to penetrate between the cells as well as occupying their cavities, so that the cells appear roundish in section. It is especially present in this intercellular position at the centre of the prothallus, and produces its spores there also ([fig. 12](#)). A little higher up the prothallial body the fungus becomes more localized, avoiding the central core of cells which has begun to function in the translocation of food material. The cells of this fungal zone throughout the vegetative portion of the main prothallial body preserve their ordinary form and are in no way altered by the presence of the fungus. Their nuclei also appear large and healthy, showing that the fungus has exercised no harmful effect. I have not been able to distinguish in these prothalli the multinucleate vesicles which have been described as occurring in the fungal zone in the prothalli of the *clavatum* and *complanatum* types. All that are here apparent are the dense hyphal coils and the clusters of spores. As the prothallus grows, the fungus pushes forward, always occupying its particular zone, except that at length when the sexual organs and paraphyses are initiated it is confined to the ventral side of the prothallus body ([fig. 14](#)). In the forward, bulky, generative region the fungus is altogether absent. Its most forward position is shown in ([fig. 15](#)), and it will be observed that even here the coils have begun to be transformed into the spores.

The fungus is also present in the lateral branches, being confined there also to a particular zone, avoiding the centrally-placed conducting-cells and the epidermis. Here, too, it is intercellular as well as intracellular, and the clusters of spores are a well-marked feature ([figs. 20–22](#)). The distribution of the fungus in some of the long thin branches is discontinuous ([fig. 1](#)), from which it would appear that fresh infection can take place from without through the rhizoids (see also [fig. 9](#)). In those stouter branches which have begun to form sexual organs and paraphyses the fungus is only present along the opposite side of the branch ([figs. 28–30](#)), the branches thus being bilateral. Sometimes it is to be noticed that when a branch is beginning to swell at the apex preparatory to the formation of antheridia the fungus is thickly aggregated immediately behind this point, there occupying the whole of the tissues of the branch ([fig. 24](#)). The "resting" club-shaped branches are always very densely infected, there being no long narrow central conducting-cells ([figs. 1, 25, 26, 30](#)). The actual apex of the resting process is of course, clear of the fungus, but the latter reaches right up behind the apex, being found there as

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fungal coils ([figs. 31, 32](#)). Throughout the greater portion of these resting processes the coils have given place to the clusters of spores, as takes place also in the other parts of the prothallus.

I have not been able to trace how the spores are formed, or even what is their exact nature. It seems unlikely that they are used up by the developing prothallus as food, for they are more thickly present in the oldest parts of the prothallus than elsewhere. Nor have I observed the presence of oil globules in the fungal tissues, which is so well known a feature in the prothalli of the *clavatum* and *complanatum* types. Probably the prothallus benefits from the fungus only when the latter is in the form of hyphal coils, these coils being in direct connection with the external mycelium. The rapid growth in length of the prothallus and its branches accounts for there being no storing-up of food material in any of its vegetative parts. Even in the bulky generative region I have not been able to discover the presence of starch, although it is possible that it may there be present at certain stages in the development of the sexual organs or young plant, but there is abundant protoplasm and the nuclei are very large in the cells around the growing apex. The younger regions of the lateral branches are probably self-nourishing, in this matter being quite independent of the older parts of the prothallus. In fact, isolated branches or portion of branches are capable of continued growth, this being a very common method of propagation in these epiphytic species. The central conducting-strand in the branches functions in the translocation of food material from the younger regions of the branches down into the main prothallial body, the food being there needed in the forward generative region.

Miss Edgerley figures the clusters of spore-like bodies, stating that she found them very commonly in *L. Billardieri*, but that she observed no nucleated vesicles (4, p. 109).

Comparison of L. Selago and L. Billardieri (& c.).

In his description of the prothalli of *L. Selago*, Bruchmann (1, pp. 87 *et seq.*) shows that the more compact surface-growing forms which are found in this species possess a ring-like marginal meristem. This bears a close resemblance to that which is found in the prothallus of the *clavatum* and *complanatum* types. The elongated prothalli of *L. Selago* are found in deeper soil, and possess, according to Bruchmann an erect position of growth, as if striving to reach the surface. Bruchmann derives the peculiar growth of the latter from the ring-like marginal growth of the former, stating that the apparently apical meristem of the elongated forms represents a part of the margin which has grown forward. It will be necessary to compare this manner of elongated growth with that which takes place in the prothalli belonging to the *Phlegmaria* section.

The prothallus of both *L. Selago* and *L. Billardieri* (& c.) starts with the cone form, the cone being from the first richly occupied by the fungus. Judging from the arrangement of cells at the lowest part of the cone, growth at first takes place from a single apical cell, but this probably soon gives place to a group of apical meristematic cells. The girth of the cone is also probably increased by cell-divisions taking place in all the body-cells stimulated by the presence of the fungus. From this point onwards the further growth of the prothallus could either result in the extension of the cone form or the prothallus could pass out of the cone form into an elongated, cylindrical form. The first of these methods seems to

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be the normal rule in *L. Selago*—at any rate, in its surface-growing forms—and the latter in the prothallus of the *Phlegmaria* section. It is significant to note that both these methods of growth are represented in those New Zealand species which belong to the *Cernua* section, and which are described later in this paper, although in these species they are not so clearly differentiated as in the former. The prothalli of the *Phlegmaria* section represent the extreme attained within the genus by the elongated, cylindrical type of growth, and the prothalli of the *clavatum* and *complanatum* sections represent, on the other hand, the extreme

attained by the continued cone-like manner of growth. The prothalli of *L. Selago*, as Lang has pointed out (10, p. 305), show that these two main types are not fundamentally dissimilar, for they both here occur in the same species. In saying this, however, it must clearly be remembered that, according to Bruchmann's account, the elongated, cylindrical forms of the *L. Selago* prothallus do not altogether correspond to the elongated prothalli of the *Phlegmaria* section, for growth in them is not truly apical, but is rather a one-sided marginal extension from the cone. The elongated prothallus of *L. ramulosum*, as will be shown, is really more comparable to the prothallus of *L. Phlegmaria*, &c., although, even here, the comparison is not an exact one. The elongated bilateral extensions from the basal cone in *L. Selago* are better compared with the flattened extension from the margin which Bruchmann described and figured in *L. annotinum* (1), being of the same nature but much more pronounced.

The more compact surface-growing form of the *L. Selago* prothallus is nearer to a self-nourishing, chlorophyllous type of prothallus, which must certainly be regarded as more primitive than a wholly saprophytic one. The very young prothallus, as has been said, begins with the cone form, and next has to set apart a central conducting-core which reaches up behind the actual growing apex. The apex, of course, will be more or less conical in shape, and at this stage is certainly not broad. If the prothallus does not proceed to elongate rapidly, the stimulation to increase in size will be largely confined to increasing its girth, and this will take place not only by a broadening of the apical meristem, but also by divisions taking place in the body-cells generally. At the same time the fungus-free central core will extend in width as the apex broadens and the prothallus slowly extends in length, until it assumes above the form of a cushion of tissue. If chlorophyll is developed in it, this upper cushion will contain a general distribution of starch. In proceeding to explain how the original apical meristem could become transposed to a marginal ring it seems not unnatural to suppose that as the upper fungus-free tissue becomes more bulky, and so loses the tendency to a localized concentration of food material, the stimulation exerted by the supply of food is felt more in those parts of the prothallus where the fungus is youngest and therefore in its fullest functioning power. This will naturally be along the upper margin of the enveloping fungal zone which extends as a ring around the prothallus. Here, then, the meristematic activity of the prothallus will be localized. As the prothallus still continues slowly to increase in size the fungus will push forward bit by bit into the more newly formed cells, the prothallus still retaining the original cone form.

In the surface-growing prothallus of *L. Selago* this is what happens, and the sexual stage is fairly early initiated, the antheridia and later the archegonia arising from the meristem. A comparative study of the prothalli of the different species of *Lycopodium* shows that the cone type of

structure exhibits modifications in the different sections of the genus which are quite in accord with the conditions under which the prothalli of those sections live. There is no need for the surface-growing prothalli of *L. Selago* to increase in length, for they soon reach the light. Nor is there any great storing-up of food in their tissues, for the young plant when formed can quickly attain independance. Again, it is probably the inherited tendency towards the chlorophyllous, self-nourishing condition, which is strong in the prothallus of this species, which causes the more deeply buried individuals to adopt the peculiar and extensive prolongation of the upper margin of the cone into the cylindrical, bilateral, erect branches in the effort to reach the light. In the altogether subterranean humusloving prothalli of the *Phlegmaria* section the chlorophyllous habit has been completely lost, and the direction of growth of the prothallus bears no relation to the surface of the soil. These prothalli are greatly elongated and branched, and the extensive development of long rhizoids, as in the case of the humus-growing prothalli of *Tmesipteris* and *Psilotum*, shows that it is necessary for the fungus in the prothallus to be brought into intimate contact with as large an area as possible of the humus for its nourishment. The method of elongation is here altogether different from that adopted by the underground prothalli of *L. Selago*. Starting from the cone form, the prothallus quickly passes into the cylindrical form without increasing its girth, the meristem continuing in the original apical position throughout the life of the prothallus. In this way the main prothallus body is formed, that of *L. Billardieri* var. *gracile* being more elongated than that of the other species examined. The somewhat bulky nature of the forward generative portion of this body of tissue goes hand in hand with the need for the prothallus to support the young plant for a longer period than in the case of the prothallus of *L. Selago*, owing to the correspondingly greater depth at which the former is buried. The-lateral branches arise adventitiously from any part of the main prothallial body and grow from an apical meristem. They are primarily vegetative, the sexual organs being borne normally on the central body. The latter in its generative region possesses a bilateral structure which is always dorsiventral, the sexual organs being borne only on the upper side. Here again this is not strictly comparable with the bilateral structure of the processes of the *L. Selago* prothallus, for in the latter it is, according to Bruchmann, simply carried over from the margin of the original basal cone and always bears evidence of this. Thus

the modification of the original cone form in the epiphytic prothalli, as in those of *L. Selago*, is best explained in the light of the conditions under which the prothalli live.

The structure of the prothallus in the New Zealand species belonging to the *Cernua* section, and the modifications which there occur, will be considered in the next section of this paper, and a general comparative survey, including also the structure of the prothallus of the *clavatum* and *complanatum* types, will be instituted in the concluding remarks.

Section *Cernua*.

L. cernuum Linn.; *L. laterale* R. Br. Prodr.; *L. ramulosum* T. Kirk.

Literature.

In 1884 Treub (13) published his account of the prothallus of *L. cernuum*. Goebel's (5) account of the prothallus of *L. inundatum* followed next in 1887, and in the following year Treub (15) described his laboratory cultures of

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the prothallus of *L. salakense*. In 1902 Thomas (12) published a preliminary account of the prothallus of *Phylloglossum*. In 1910 (6) I noted the fact that I had found the prothalli of both *L. cernuum* and *L. laterale* in New Zealand, and stated that the latter was of the *cernuum*, type. In Part I of the present series of papers (7) I described and figured the external form of the prothalli and the structure of the young plant of

Fig. 38.—*L. cernuum*. Prothallus showing in general view lower part of shaft with two fungal regions. $\times 32$.

Fig. 39.—*L. cernuum*. Longitudinal section of prothallus shown in fig. 38. $\times 32$.

Fig. 40.—*L. cernuum*. Longitudinal section of prothallus, showing double basal tubercle and thick, short shaft. $\times 50$.

Fig. 41.—*L. cernuum*. Longitudinal section of upper fungal region of a prothallus, with lateral group of lobes. $\times 50$.

both these species, and also of *L. ramulosum*, noting especially the variations in form to be found in the prothallus of the latter. In 1917 Chamberlain (3) gave a brief description, with figures, of the prothallus and young plant of *L. laterale* from material which he had obtained in New Zealand. Lastly, in a third Part (9) I have enumerated the main results of my study of the three New Zealand species which belong to the *Cernua* section in connection with the plasticity to be observed in the genus as a whole.

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General Form of the Prothallus.

L. cernuum.—The typical prothallus of *L. cernuum* consists, according to Treub, of a basal "primary tubercle," a longer or shorter shaft, and a crown of lobes, immediately beneath which lies the meristem and the sexual organs. The prothallus is radial in build, erect in growth, and situated at the surface of the soil, being green in its lobes and in the upper portion of the shaft. It is the most delicate and the smallest of all the types of *Lycopodium* prothalli, the allied *L. salakense* possessing a still more

Fig. 42.—*L. cernuum*. Longitudinal section of prothallus of intermediate length, $\times 50$.

Fig. 43.—*L. cernuum*. Longitudinal section of basal fungal region of prothallus, showing lateral extension. $\times 50$.

Fig. 44.—*L. cernuum*. Longitudinal section of prothallus of thick, short form. $\times 32$.

Fig. 45.—*L. cernuum*. Longitudinal section of meristematic region of prothallus, with a fertilized archegonium. $\times 50$.

filamentous prothallus. Some of the prothalli of this species which I have found are comparatively long (7, fig. 17, and fig. 38 in the present paper). That shown in the latter of these two illustrations was broken at its upper extremity, so that I do not know its complete length. In others, again, the shaft is short and thick, and the general appearance of the prothallus more massive (7, fig. 20, and figs. 40 and 44 in the present paper). Forms of intermediate length are shown in a previous paper (7, figs. 18, 19, and 21) and in fig. 42 of the present paper. I have also found a considerable amount of variation in the distribution of the fungus, and, since the fungal regions are always more or less swollen, there is a corresponding variation in the

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general form of the prothallus. There is sometimes a single basal tubercle of rounded form (7, figs. 17–20); or this basal fungal region may be extended laterally for a distance up one side of the shaft, thus giving to the prothallus a somewhat lop-sided appearance (7, fig. 21, and figs. 42–44 in the present paper). Again, there may be a second fungal region quite unconnected with the first and situated higher up the shaft ([figs. 38, 39, 41](#)). Lastly, there may be two distinct fungal regions situated side by side, the two constituting the basal portion of the prothallus and giving it a markedly thickset appearance ([fig. 40](#)). I have sectioned several prothalli which showed this latter form. Rhizoids are borne on both fungal swellings in those cases in which two are present. The lobes which are borne at the crown of the prothallus are flattened extensions (7, figs. 17–21), being generally not more than one to three cells thick in transverse section ([figs. 40–42](#)). In one or two instances I noticed from my serial sections that there was a group of lobes situated laterally on the shaft of the prothallus. In [fig. 41](#), this is seen to be associated with the uppermost fungal region, as if the formation of this second fungal zone had initiated a meristematic activity in the adjoining regions of the shaft. The thickest part of the prothallus is always that situated at the base of the crown of lobes. Here is the meristem ([figs. 42, 45](#)) from which the lobes have arisen, and by whose continued activity the shaft of the prothallus can be extended in length and its upper region in width. Here, too, the sexual organs are to be found and the young plantlets ([figs. 40, 44, 45](#)). I have never found the

chlorophyll extending much more than half-way down the shaft. Sometimes the lobes are bright green, or they may show a very slight tinge of colour or be quite colourless, this variation possibly depending simply upon the age of the prothallus.

L. laterale.—The prothallus of this species corresponds very closely with that of *L. cernuum*. I have not found that there is such a marked variation in the length of the shaft as is to be found in the latter species, the majority of the prothalli of *L. laterale* being more of the intermediate length (7, figs. 13–16, and pl. 17, fig. 3). The longest prothallus I have found is that shown in [fig. 46](#). One prothallus of a very large size is shown in [fig. 48](#). It was exceedingly massive in form, and of irregular growth. Its greatest length was in a horizontal direction, and it possessed a crown of irregular short lobes all along the top. It was almost colourless, though perhaps this was the result of its age. It bore a young plant which was of a bright-green colour, the foot of the plant also being bright green and showing very conspicuously through the prothallial tissues. Chamberlain (3, p. 57) states that in the prothalli of this species examined by him he found no sharply differentiated primary tubercle like that described by Treub in *L. cernuum*. From his figures it would appear that this was because his prothalli are rather of the short, thickset form. The basal tubercle is always more distinct when the shaft is well developed. I have found that, as in *L. cernuum*, the basal, fungal region may extend laterally for a short distance up one side of the shaft, thus giving a lop-sided appearance to the prothallus as a whole (7, fig. 13). Also, as in the other species, there is sometimes a second fungal region higher up the shaft and quite distinct from the basal tubercle ([fig. 47](#)). The leafy expansions on the crown of the prothallus of *L. laterale* are more filamentous and less lobe-like than those of *L. cernuum* (7, figs. 13–16, and pl. 17, fig. 3, and [figs. 46](#) and [47](#) in the present paper). This appears also from Chamberlain's figures. A large proportion of the prothalli examined by me showed

Fig. 47.—*L. laterale*. Longitudinal section of prothallus, showing lobes and shaft, with an upper fungal region. $\times 42$.

Fig. 48.—*L. laterale*. Large massive prothallus with young plant in general view.

Also a very young prothallus entangled in the rhizoids of the former. $\times 16$.

Fig. 49.—*L. laterale*. The very young prothallus shown in fig. 48. $\times 70$.

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a lateral group of lobes borne on the shaft. I previously thought that this was a distinguishing feature between the two species *L. cernuum* and *L. laterale*, but have since found it also in the prothalli of the former. In one of the figures given in Part I of this series of papers (7, fig. 16) I showed that a long, thin, club-shaped process is sometimes to be found attached to the basal tubercle of the prothallus of *L. laterale*, and I there expressed the opinion that this was the first-formed part of the prothallus, as it so often is also in the prothallus of *L. ramulosum*. My serial sections of this prothallus unfortunately do not make this satisfactorily clear, but none the less I feel confident that this is the right interpretation. The base of this first - formed process (7, fig. 16) shows the presence of the fungus, and it may be compared with the corresponding parts of *L. ramulosum* illustrated in the present paper in [figs. 52–54](#). As in *L. cernuum*, the prothallus of *L. laterale* is normally short-lived, having decayed away by the time that its plantlet has developed two or three protophylls. Probably the large size of the prothallus in [fig. 48](#) was due to the fact that for a considerable time no embryo was formed on it. Moreover, in this case, on account of its large size, the prothallus would persist attached to the young plant for a much longer time than usual.

Fig. 50.—*L. ramulosum*. Complete mature prothallus of elongated form in general view, showing several swollen fungal regions. $\times 30$.

L. ramulosum.—The prothalli of this species vary very remarkably, both in form and structure. I have discovered these prothalli in several different localities and in considerable numbers, and so am able to give a fairly complete account of their

typical form and of the variations of it. The prothalli, as in the other species belonging to the *cernuum* type, are more or less green in their upper regions, being situated at the surface of the ground. Some of the prothalli of this species are very similar to those of *L. cernuum*, while others show on the one hand the elongated and on the other hand the compact, massive habit which I have described as occurring both in *L. cernuum* and in *L. laterale*, but here to a much more marked extent. [Figs. 50–55](#) illustrate prothalli of the elongated form



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Lycopodium ramulosum. Complete prothallus of elongated form, in general view.
× 33.



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Lycopodium ramulosum. Complete prothallus of elongated form, in general view.
× 33

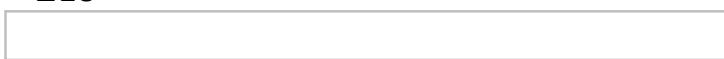


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Lycopodium ramulosum. Prothallus of elongated form (incomplete at basal end), in gereral view. $\times 33$.


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Lycopodium ramulosum. Longitudinal section of prothallus of massive form and young plant. $\times 46$.

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and figs. 56–60 prothalli of the compact, massive build. Some of these figures were

given in Part I of the present series of papers, but are here reproduced in greater detail. Photos of three elongated prothalli of this species in general view are also given in [Plates XII, XIII, and XIV](#), and



Fig. 51.—*L. ramulosum*. Complete mature prothallus of elongated form in general view, showing several fungal regions and a young plantlet. $\times 30$.

a photo of a more massive prothallus with its young plantlet is given in longitudinal section in Plate XV. The prothallus shown in Plate XII is the same as that given in [fig. 50](#).

In the elongated forms the fungal regions may be swollen so as to present the form of rounded tubercles, or, again, they may be scarcely swollen at all. Each fungal region invariably bears a group of rhizoids. In the massive forms the prothallus may be compact and show a certain

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similarity in general appearance to the surface-growing forms of the *L. Selago* prothallus, or they may be so irregularly extended in length that their build is difficult to distinguish. In the elongated forms, along with the development of a number of fungal areas, there goes a corresponding development of several distinct generative regions bearing sexual organs and filamentous or lobe-like processes. Frequently, in this latter form of prothallus, the first-formed generative regions are brown and withered, suggesting that the prothallus had resumed growth on one or more occasions at the close of a dry period or on account of there being no embryo developed. I have always found that a young plant when present was borne on the last-formed region of the prothallus, so that growth in length is apparently not continued after the development of a young plant. The prothalli sometimes persist attached to the developing plant for a much longer time than in *L. cernuum*. I have found several instances of a healthy prothallus still attached to a plantlet which showed as many as seven or eight protophylls

along an extended protocorm. The lateral processes are sometimes filamentous, and at others short and lobe-like. Owing to the fact that the prothallus of *L. ramulosum* is so variable in form, it is impossible to give many details in a general description of it. I will now proceed to enter more into detail in connection with the particular individuals figured in this paper.

The prothallus shown in [fig. 50](#) and in [Plate XII](#) possessed five fungal areas, quite distinct from one another, each being swollen and rounded in form and bearing a group of rhizoids. There are two generative regions showing the presence of archegonia and bearing filamentous processes. The basal fungal swelling bore no evidence of any original filamentous stage, and was probably formed immediately on germination of the spore. As will be described later, a first-formed filamentous stage is frequently to be observed in the prothalli of this species. The uppermost fungal region is, of course, the youngest. It occurs at the base of the meristematic apex of the prothallus, and it is evident that both this growing apex and its fungal region have just begun to form. Both from the figure and from the photo it will be seen that here, curiously enough, the fungus lies internally to the epidermal cells. There is no special apical cell or group of cells, the whole apical region of the prothallus being meristematic. The succession of five swollen fungal regions shows very clearly that it is the fungus which causes the swelling in the tissue of the prothallus, and that, at any rate in this prothallus, the primary tubercle is in no wise different from any of the later-formed tubercles.

The prothallus shown in [fig. 51](#) illustrates some interesting points in comparison with that just described. There are six distinct fungal areas, and the four lowest are closely approximated and are scarcely, if at all, swollen. There is a well-developed filament at the base of the prothallus, and the prothallus as a whole increases quite gradually in girth from this upwards. Even the first-formed fungal region is practically unswollen. I should judge that the extension in length of the prothallus in these early stages had been comparatively rapid, there being no cessation in growth in length consequent on the formation of a first generative region or of the storing of food material. This state of things can bear close comparison with what takes place normally in the cylindrical much-elongated epiphytic prothalli, in which growth is continuous and rapid and there is an entire absence of swellings in the fungal regions. The adoption, or rather the preservation, of the definite apical meristem in the epiphytic type is probably only the result of this habit of growth. The prothallus

of *L. ramulosum* shown in [fig. 51](#) may best be described in its entirety as a gradually widening filament. The young plantlet borne at its upper extremity was peculiarly diminutive in size. There were no antheridia



Figs. 52–54.—*L. ramulosum*. Complete mature prothalli of elongated form in general view. *a* is the basal fungal region; *a* and *a'*, secondary fungal regions; *b* and *b'* are generative regions bearing lobe-like outgrowths. In [fig. 52](#) there is a lateral outgrowth (*b*) associated with the basal fungal region. The shading on *b* and *b'* represents browning due to withering. × 20.

Fig 55.—*L. ramulosum*. Complete mature prothallus of elongated form in general view, showing branching above the second fungal region. × 20.

either on this prothallus or on that in [fig. 50](#). The photo of the prothallus given in Plate XIII also illustrates the nature of the elongated manner of growth with the formation of several fungal regions.

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The four prothalli outlined in [figs. 52–55](#) show at their base a distinct fungal tubercle, that in [fig. 53](#) bearing evidence of an original filament. The prothallus in Plate XIV shows a lower fungal region, which was, however, not the first-formed portion. The shaft is long, and bears a lateral process and also a terminal broad

generative region which is associated with a second fungal area. In [figs. 52 and 54](#) there is a fungal swelling located behind the growing end, it being evident also that in both these prothalli the apex is at the point of renewing its growth. A large number of prothalli of this species which I found were of the peculiar step-like form shown in [figs. 52–54](#). Here the generative regions are sometimes of considerable extent, and, relatively to the long axis of the prothallus, lie horizontally. The position of these elongated prothalli in the soil is always vertical. The older generative regions are frequently brown and withered, either as the result of a dry spell in the weather or because they have ceased to be supplied with food and have begun to decay. These generative regions are frequently fairly bulky. It is probable that the irregularly massive forms of prothallus described next have acquired their form through an exceptionally bulky development of one or more of these successive generative regions, the intermediate shaft-like stages of growth having been suppressed. Sometimes these massive prothalli show the remains of the lowest shaft and first-formed tubercle still attached to them. Those prothalli of *L. laterale* which bear club-like processes attached to the primary tubercle, as described in a previous paper (7, fig. 16), probably come under this category. [Fig. 55](#) shows a prothallus which has branched in its middle region, the two branches being borne on a particularly large fungal swelling. These two branches are clearly not to be regarded as processes of the kind usually borne on the generative regions. One of them showed a fungal region with rhizoids near its apex. Both are browned at the tip. It is certainly interesting to find that along with its power of cylindrical elongation the prothallus of this species is able also to branch, these variations suggesting that the *Lycopodium* prothallus is very plastic in character and that the several main types are by no means so fixed as has been supposed.

I pass now to the description of the massive and compact prothalli. Some of these show a very regular build ([figs. 56, 57, 60](#), and [Plate XV](#)), being comparable with the surface-growing forms of *L. Selago* (see 1, pl. 6, fig. 37). They do not, however, show the same internal structure as the latter. The prothallus illustrated in fig. 56 possesses one fungal region only, which occupies the whole of the base. This leads up into a short, massive shaft and a wide, upper, generative region. The whole of the uppermost region is meristematic, there being no localized marginal, ring-like meristem as is the case in the compact prothallus of *L. Selago*. At the base of this prothallus there is a filament consisting of one long cell bent in the middle ([fig. 56a](#)) which does not show the presence of fungus. It leads up into a swollen region which can be described as the basal tubercle, this latter passing gradually again into a higher and more swollen region. The prothalli shown in [figs. 57](#) and 60 and Plate XV are also of this same form, there being but one large basal fungal region. That in [Plate XV](#) is in longitudinal section, but the section does not pass medianly through either the base or the shaft, nor does it show the full width of the prothallus. This massive form of the prothallus of *L. ramulosum* is similar to that sometimes adopted by the prothallus of *L. cernuum* and *L. laterale*, howbeit in a more marked degree.

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Fig. 56.—*L. ramulosum*. Complete mature prothallus of compact, massive form in general view, bearing young plant. $\times 27$.

Fig. 56a.—*L. ramulosum*. Original end of prothallus shown in fig. 56 in general view. $\times 73$.

Fig. 57.—*L. ramulosum*. Complete half-grown prothallus of massive form, in general view. $\times 35$.

Figs. 58–60.—*L. ramulosum*. Mature prothalli of massive form, in general view. Those shown in figs. 58 and 59 have grown irregularly. $\times 14$.

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Another type of massive prothallus is that shown in [figs. 58 and 59](#), where the continued bulky growth has resulted in a very irregular form. The oldest part of the prothallus can be recognized in both these figures, although whether or not this part represents the actual original basal end of the prothallus cannot be said. In [fig. 58](#) there are two distinct generative regions, the uppermost of which is divided by a deep constriction. The foot of a young plant has been torn from one portion of this upper region. This particular prothallus is similar in its continued growth to those shown in [figs. 52–54](#), except that the great bulkiness has rather

obscured the typical cylindrical radial build. In [fig. 59](#) the prothallus has grown still more irregularly, and there are apparently two growing regions, one of which is broken. The sexual organs are distributed along the whole of the top of the prothallus, and are in this case archegonia only. This particular prothallus is best compared with the basal portion and first generative region only of those shown in [figs. 53 and 54](#). These massive, irregularly-grown prothalli usually show abundant chlorophyll.

Position in the Soil.

All the prothalli in these three species are situated at the surface of the soil and possess more or less chlorophyll. Their position in the soil is always erect. The chlorophyll is never present in the basal regions, but always in the lobes, and generally also in the upper part of the shaft. Consequent on this vertical position of growth, the prothalli never show such an elongated habit as do those of the epiphytic, subterranean type, but certain individuals, especially in *L. ramulosum*, show a marked tendency in this direction. I cannot say whether or not the more elongated forms in this species are more deeply buried in their basal part than the massive forms. They were all dissected out of humus consisting for the most part of a decaying short moss. In any case, the total length of even the most elongated forms is too small to have much significance in this respect. Probably the function of continued apical growth is due simply to the postponement of the formation of the embryo, the food-supply being maintained by the fungus through the infection of newer regions of the prothallus. The typical radial build is maintained by all these three species, although in some prothalli, more particularly in *L. ramulosum*, this is almost obscured by the adoption of a secondary, irregular manner of growth.

Early Stages in the Development.

I have been fortunate to secure several very young prothalli-of the two species *L. laterale* and *L. ramulosum*. No doubt the only perfectly satisfactory way of obtaining the youngest stages of growth in any prothallus is by the experimental germination of the spores in the laboratory under close observation. Even this method, however, is not above suspicion, for one can never be sure to what extent the artificial conditions influence the form of the young prothallus. Very young prothalli dissected out of soil collected in the field are open to the criticism that they may belong to some plant other than the one under consideration. I can only say that with regard to the young prothalli now to be described I am quite satisfied that they belong to the particular species of *Lycopodium* to which I have ascribed them, and the reasons will be stated.

In the case of *L. cernuum*, I have found no young stages. Treub has, however, described the germination of the spore in this species, having successfully carried this out in the laboratory. His figures, which I have

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seen only in certain standard books of reference, show that a tubercle is at once initiated, which is apparently at first devoid of fungus. This tubercle was called by Treub the "primary tubercle," and he supposed that it was a characteristic feature of the *Lycopodium* prothallus. He was also successful in experimentally cultivating the prothalli of *L. salakense*. This also begins with a globular body, the "primary tubercle," from which several thin filamentous branches arise, one of the latter eventually thickening and producing the sexual organs. This prothallus remains altogether free from a symbiotic fungus. Treub also germinated the spores of *L. curvatum* Sw., from which he obtained "primary tubercles," but he was unable to induce them to develop farther. All the mature prothalli of *L. cernuum* which I have found show the rounded basal tubercle, although in some instances this is somewhat pointed below (see 7, figs. 17-21, and [figs. 38-44](#) in the present paper).

I have dissected out a number of young prothalli of the species *L. ramulosum* along with the more mature forms, and some of these are shown in [figs. 61-65](#). I judge these to belong to this species since they are of the typical *Lycopodium* form and no other species of *Lycopodium* were present in the two localities from which they came. No other kind of prothallus was ever found by me in the turves from which I dissected out those of *L. ramulosum*, nor was any species of fern present in the near neighbourhood, except *Gleichenia dicarpa*. Finally, the individuals which are shown in [figs. 61-65](#) form a series which leads on to the more mature prothalli which undoubtedly belong to *L. ramulosum*. The youngest prothallus was that shown in [fig. 61](#). In it there was no basal swelling, nor was there any indication of the presence of a fungus. The lower half consisted of a single linear row of cells, whilst in the upper half there was a gradual increase in the number of cells and in the girth of the filament towards the apex. This upper half was not a flat expansion of cells as in the usual fern prothallus, but was radial in build. The cells at the apex were smaller than those farther back, and evidently functioned as the meristem. The whole filament contained chlorophyll corpuscles. The original spore-case was still attached to the basal cell. In [fig. 62](#) is shown a prothallus in which the first-formed filamentous stage was very short, passing almost immediately and suddenly into a globular mass of cells which

could be called the "primary tubercle." This prothallus also was quite free of fungus, being green throughout. The apical region consisted of small-celled tissue, and a young sexual organ was developing near by. A group of rhizoids was borne on the basal tubercle. In the formation of a fungusless primary tubercle this young prothallus corresponds very closely to those early stages in *L. cernuum*, *L. salakense*, and *L. curvatum* described by Treub. With regard to the mature prothallus of *L. ramulosum*, the conclusion I arrived at was that any swelling in the fungal regions was primarily due to the localized presence of the fungus. From these other three species, however, it is apparent that there may be at first a primary tubercle quite apart from the presence of the fungus, and this also appears in such a young prothallus of *L. ramulosum* as that shown in [fig. 62](#). However, this is not always the case, as in the particular prothallus shown in [fig. 61](#). The three young prothalli shown in [figs. 63–65](#) all possessed a primary tubercle, which was infested by fungus.

Are we to consider that a primary tubercle is a fundamental feature in the structure plan of the *Lycopodium* prothallus, or is it to be regarded as an added feature? Possibly we are to regard the radially-built filament

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as being the original typical condition, this filament being drawn out, or short and bulky, according to whether growth has taken place rapidly or slowly. The basal tubercle of the mature prothallus when present would, according to this view, be the result largely of secondary cell-divisions

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Fig. 61.—*L. ramulosum*. Very young prothallus, in general view, with spore still attached. $\times 75$.

Fig. 62.—*L. ramulosum*. Young prothallus, in general view, showing basal tubercle with no fungus. $\times 45$.

Figs. 63, 64.—*L. ramulosum*. Young prothalli, in general view, showing basal tubercle with fungus. $\times 30$.

Fig. 65.—*L. ramulosum*. Young prothallus, in general view, showing first-formed lobes and the initiation of a second fungal region. $\times 45$.

which had taken place in the first-formed basal cells owing to the stimulus excited by the storing of food material. Prothalli cultivated under artificial conditions seem generally to develop slowly, and this may explain why it is that none of Treub's prothalli showed a first-formed filamentous

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stage. There can be no doubt that the symbiotic association of a fungus with the *Lycopodium* prothallus is a further added feature, the mature form of the *Lycopodium* prothalli being determined mainly by the nature of this association.

I found one very young prothallus of *L. laterale* which was entangled in the rhizoids and lobes of the large prothallus shown in [fig. 48](#). This young prothallus is shown in [fig. 49](#). It consists of a filament of cells which is green throughout, the filament being one cell in width in its lower half and two cells in width in its upper. At the apex there is a single small cell which is clearly functioning as the apical cell. In this species also, as in *L. ramulosum*, the primary tubercle is thus not invariably present.

Main Body of the Prothallus.

L. cernuum.—The main body of the prothallus of this species consists, as has been described above, of one or more basal fungal regions, a longer or shorter shaft, and a crown of lobes, at the base of which lies the meristem and the generative region. Sometimes there is present also a lateral group of lobes. As I have not seen Treub's original papers, I do not know whether or not he has given in his description any indication of a differentiation of structure in the fungus-bearing tissue, but, judging from the short summaries of his results in various standard books of reference, this does not seem to be the case. In the prothallus of this species as it occurs in New Zealand. I have observed that there is in this tissue a well-marked differentiation. The fungal coils are invariably confined, so

far as their intracellular position is concerned, to the epidermal cells in the fungal area, but the fungus always extends also in between the cells of the adjoining tissue. This will be apparent from figs. 39–44, which show the fungal area in longitudinal section, and from figs. 66 and 67, which represent the basal tubercle in transverse section. Moreover, this layer of cells which shows the presence of the fungus in an intercellular position is always modified in structure, the cells being very narrow, with their long axes arranged at right angles to the peripheral fungal layer. A portion of the fungal region shown in fig. 41 is given in greater magnification in fig. 68. In describing the “palisade” fungal zone in the prothalli of *L. clavatum* and *L. annotinum*, Bruchmann (1, p. 18) suggests that its main function is to serve as a brace to the prothallus. This would seem to be the case also in *L. cernuum*. In this latter species its peculiar structure is more particularly developed in those fungal regions which extend up the shaft, and where the need of a strengthening-tissue is felt. In those prothalli in which a well-formed, rounded primary tubercle is present the whole of the internal tissue of the tubercle shows the intercellular fungus, but its cells are not so markedly differentiated (figs. 38, 39). In the elongated prothalli of *L. ramulosum*, in those cases in which the fungal areas are not much swollen, the tissue in which the fungus is intercellular does not show much modification in form. The fungus is chiefly apparent at the angles between the cells, but it also seems to enwrap the cells generally (figs. 66–68). I have not observed the presence of starch, as a rule; in the palisade cells, but it is frequently thickly accumulated in the adjoining part of the shaft. In the primary tubercle the cells are small and numerous (figs. 38, 39), and the rounded form of the tubercle is probably due mainly to the extensive cell-divisions, induced by the fungus, which there have taken place. In this species the intercellular fungus never spreads up the shaft to any great extent: As has been described above, in this species there

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is sometimes a second fungal region quite distinct from the first, which may be situated either higher up the shaft or at the base alongside the primary tubercle. The characteristic difference in structure between the basal tubercle and an upper fungal area is clearly shown in fig. 39. The details in the basal structure of

the other form are illustrated in [fig. 40](#), the right-hand tubercle here being cut not quite medianly.

The shaft is built up of large cells whose long axes are directed towards the growing apex. In some prothalli this shaft is long and thin ([figs. 38, 42](#)), but in others it is short and thick ([figs. 40, 44](#)). An instance in which a lateral group of lobes is borne on the shaft is given in [fig. 41](#), these lobes



Figs. 66, 67.—*L. cernuum*. Transverse sections of the basal tubercle of prothallus, showing distribution of fungus. $\times 42$.

Fig. 68.—*L. cernuum*. Longitudinal section of portion of fungal area shown in fig. 41. $\times 135$.

Fig. 69.—*L. ramulosum*. Median longitudinal section of basal tubercle of massive prothallus shown in Plate XV. $\times 42$.

Fig. 70.—*L. ramulosum*. *a* and *b*, longitudinal section of an elongated prothallus with three fungal regions, the basal tubercle being shown at *b*. $\times 48$. *c*, longitudinal section of apical head of the prothallus shown in fig. 70*a*. $\times 75$.

Fig. 71.—*L. ramulosum*. Longitudinal section of two adjoining fungal regions in a large elongated prothallus. $\times 42$.

here being in conjunction with a second fungal zone. At the top of the shaft is the crown of lobes, these being in transverse, section from two to four cells in thickness ([figs. 40–42, 44](#)). In amongst the bases of these lobes are situated the sexual organs ([figs. 40, 44](#)). Some of the prothalli bear organs of one kind only, that shown in [fig. 40](#) bearing numerous antheridia but no archegonia. Others, again, bear both, as in the case of the massive prothallus shown in [fig. 44](#).

L. laterale.—The structure of this prothallus corresponds more or less closely with that of *L. cernuum*. In the fungal regions, whether at the base of the prothallus or higher up the shaft, the hyphal coils are confined to the epidermal cells, and the hyphae penetrate the adjoining tissues in an

intercellular position ([figs. 46, 47](#)). In this species the cells which immediately adjoin the epidermal layer are not so clearly differentiated as a “palisade” layer as they are in the prothalli of *L. cernuum*. In the prothallus illustrated in [fig. 47](#) the intercellular fungus which belonged to the upper fungal zone occupied a considerable extent of the tissues of the shaft and had spread well up towards the meristem. I have not observed anything approaching this condition in any of the prothalli of *L. cernuum*. The terminal processes are filamentous rather than lobe-like, and are to be seen in longitudinal section in [figs. 46 and 47](#). Their characteristic appearance, however, is best seen in general view (7, figs: 13–16, and pl. 17, fig. 3). A group of lateral lobes is shown in [fig. 46](#), there being an archegonium present at their base.

L. ramulosum.—The internal structure here shows nothing differing at all markedly from that of the other two species described above, except that, as in *L. laterale*, the “palisade” tissue is not so well developed as in *L. cernuum*. A prothallus of the massive type is shown in longitudinal section in Plate XV. A true median longitudinal section of the basal tubercle of this same prothallus is given in [fig. 69](#). It will be apparent that this figure corresponds very closely to fig. 39, which shows the basal tubercle in *L. cernuum* in longitudinal section. The rest of the prothallus is free from fungus, and consists mainly of compact small-celled tissue. The crown of filaments in this prothallus is poorly developed. The structure of the elongated prothallus is shown in [fig. 70, a and b](#). The cell-layer in which the fungus is in an intercellular position is here very limited in extent, and is also little differentiated as a tissue. The lateral generative region is brown, and the filaments are here missing. The apical head of the prothallus bears numerous antheridia ([fig. 70, c](#)). [Fig. 71](#) shows in longitudinal section two adjoining fungal areas in an elongated prothallus of much larger build than the one last mentioned, and here it will be seen that the intercellular fungus spreads through a correspondingly greater extent of tissue, in which the cells are certainly arranged more palisade-like. The shaft portion of these elongated prothalli consists of large, elongated cells, but the various generative regions are of small-celled tissue. This is clearly seen in the prothallus shown in [fig. 70](#), this prothallus bearing antheridia only.

Position of the Meristem.

In the *cernuum* type of prothallus the meristem is of a more indefinite, unlocalized nature than in either the epiphytic, cylindrical type or the subterranean, cone-like type. In his figures of very young stages in the development of the prothalli of *L. cernuum*, Treub shows that, in his laboratory specimens, immediately on germination of the spore, a triangular apical cell is set apart, by whose all-round segmentation a globular mass of cells is formed—the "primary tubercle." However, this method of growth immediately gives place to a filamentous stage in which the filament is only one cell wide, new segments being formed by transverse walls appearing in the terminal cells of the filament. The filament next thickens by longitudinal walls appearing in all its cells. This also is what happens in *L. salakense*; but there several such filaments are formed from the primary tubercle, although only one proceeds to thicken.

From my material of the three New Zealand species which belong to this type of prothallus I have certainly found instances in which the spore seems to have given rise at once to a globular mass of cells, but others also in which there is an original filamentous stage. This filament extends at

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first by transverse walls arising in the terminal cell ([fig. 61](#)), but later it would seem from [fig. 49](#) that oblique walls in the terminal cell cut off segments alternately on one side and on the other, so that the filament becomes two cells in width. All indications that I have noticed point to the fact that this first-formed part of the filament does not subsequently thicken. It is to be found in this thin form still attached at the base of older prothalli ([figs. 51, 53, 56](#)), so that it has nothing to do with the "shaft" of the prothallus. Presumably the tubercle is formed by the activity of a single triangular apical cell as in Treub's material, though, of course, my material is not young enough to show this. The young prothalli of *L. ramulosum* given in [figs. 63–65](#) have grown on from the primary tubercle not in a filament one cell wide, but in a shaft of the same width as the tubercle. This shaft becomes progressively wider as it grows on. If a tubercle shows subsequently a distinct rounded form it must have been due to secondary cellmultiplication having taken place in it owing to the presence of the fungus. In the prothalli of *L.*

ramulosum shown in [figs. 62, 63, and 64](#) the whole of the small-celled terminal portion is clearly meristematic, so that here, possibly after a period of rest, the whole of the forward end of the tubercle has become meristematic. In the prothallus shown in [fig. 61](#) the original filament gradually thickens as it grows on, apparently by longitudinal walls appearing in the various cells, and the whole of the apex has taken on the function of growth.

In *L. cernuum* the apex of the shaft grows on and eventually gives rise to a crown of lobes. Some of Treub's figures seem to indicate that the lobes are initiated when the prothallus is not more than of middle age. The meristematic zone is then largely localized at the base of the lobes, and by its continued activity the lobes are extended in length, and also the length of the shaft is added to. At the same time the shaft can increase slowly in width by the division of its cells in a longitudinal direction. Under certain conditions, perhaps inducing quickness of growth, the shaft becomes somewhat elongated, and the lobes also are well developed ([fig. 42](#)). The opposite conditions bring about a thickening of the shaft unaccompanied by any great increase in its length ([fig. 44](#)). Thus in the prothallus practically the whole of the main body is more or less meristematic, and the localization of this function at the growing apex is not so definite as in the prothalli of the epiphytic or of the terrestrial subterranean types. Meristematic activity at the base of the lobes becomes most pronounced when the sexual organs are being formed, so that they are embedded in a small-celled tissue ([figs. 40, 45](#)).

In *L. ramulosum* the prothallus is capable of much more extensive growth, probably on account of its continued infection by the fungus. At a fairly early stage the apex gives rise to the lobe-like outgrowths, the initiation of which is shown in figs. 63 and 64. In the young prothallus in fig. 65 two outgrowths are well formed and a sexual organ is developing at their base. The lobes are browned and slightly withered, as if they had been touched by a dry spell in the weather. At the same time the shaft of the prothallus is proceeding to extend on past the lobes so that these latter will eventually come to occupy a lateral position. Immediately behind the developing shaft-apex three of the epidermal cells have become infected with the fungus and one epidermal cell has grown out as a rhizoid. It certainly seems as if this fresh infection by the fungus had been the cause of the renewed activity of the prothallus. The study of the prothallus given in fig. 50 suggests that the apical meristem has alternately

functioned in the extension in length of the prothallus and in the production of sexual organs and processes, the growth in length of the prothallus being renewed after the formation of each generative area. If an archegonium had been fertilized and an embryo formed, all the food-supply of the prothallus would have been concentrated around the growing embryo, and hence the prothallus would have ceased to elongate. In the prothallus shown in fig. 51 there has probably been no intermission in the functioning of the apical meristem, with the result that this prothallus approximates more to the cylindrical form of the epiphytic type. In the prothalli shown in figs. 52–54 there has been an exceptionally extensive development of generative tissue, giving to these prothalli the curious step-like form. From these elongated prothalli and from the irregularly-grown, more massive forms shown in figs. 58 and 59 it would appear that the repeated fresh infection of the prothallus by the fungus has enabled it to grow on far beyond its original *cernuum*-like form. In such a prothallus as that shown in fig. 51 the position and appearance of the meristem are similar to the ordinary *cernuum* type, although it has been able to function for a much longer period than in *L. cernuum*. In the other elongated prothalli shown in figs. 50 and 52–54 the position and form of the meristem is somewhat modified on account of the repeated development of the generative tissue, so that the actual growing apex is small and somewhat displaced. There is never a definite group of apical meristematic cells present, the whole of the growing head functioning in this respect as in *L. cernuum*. The very compact cone-like prothallus given in fig. 56 also shows the same type of meristem, there being no tendency to a localized, marginal, ring-like meristem as there is in the compact surface-growing forms of *L. Selago*. Thus, although the prothallus of *L. ramulosum* in its two forms may be compared on the one hand with the compact cone-like forms of *L. Selago* (*and so also of L. clavatum and L. complanatum*), and on the other hand with the elongated cylindrical form of *L. Phlegmaria, & c.*, this comparison is by no means a close one, for the position of the meristem shows that *L. ramulosum* belongs always to the *cernuum* type. It is significant to note that these main types of *Lycopodium* prothalli are in a plastic condition, and the variations which they show make it quite permissible to conjecture how the different methods of growth could have originated.

The mature prothallus of *L. laterale* also conforms to the *cernuum* type in the

position of its meristem, although here too the normal form of the main prothallial body is sometimes considerably modified by its continued growth.

Relation of the Young Plant to the Prothallus.

Since the prothallus of these species is always situated at the surface of the ground, the young plant possesses chlorophyll from a very early stage. As soon as it emerges from the tissues of the prothallus it proceeds to form the characteristic tubercle which Treub called the "protocorm," on which abundant rhizoids are produced. At the same time the first "protophyll" arises on the tubercle, showing numerous stomata. Thus the developing plantlet early becomes independent of the prothallus in the matter of food-supply. A protocorm is formed in the young plant of all three New Zealand species which belong to the *Cernua* section. Young plants attached to their parent prothalli are shown in fig. 72 (*L. cernuum*), in figs. 46 and 48. (*L. laterale*), and in figs. 51, 56, 58, 60, and Plate XV (*L. ramulosum*). Other figures are also given in Part I of this series of papers.

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The development of an embryo seems to bring all further growth of the prothallus to an end. The prothallus of this species is generally small and delicate, and does not long persist attached to its young plant. It has in most cases decayed away by the time that the plant has developed two or three protophylls. However, I have several times found prothalli of *L. ramulosum* still persisting, in one case healthily green in colour, attached to plantlets of seven or eight protophylls.

The intraprothallial portion of the embryo plant is developed as an absorbing-organ, but only to a slight extent as compared with the same organ in the young plant of the *Selago* and *Phlegmaria* types. Still less is it comparable in importance with the large "foot" of the *clavatum* and *complanatum* types. This progressive importance of the foot in the different types, taken in the order in which they are mentioned, goes hand

Fig. 72.—*L. cernuum*. Longitudinal section of prothallus and young plant showing foot. $\times 30$.

Fig. 73.—*L. cernuum*. Transverse section of suspensor and foot of young plant. $\times 42$.

Fig. 74.—*L. cernuum*. Longitudinal section of foot and part of protocorm of young plant. $\times 42$.

Fig. 75.—*L. ramulosum*. Oblique section of portion of basal fungal region showing three large "spore" capsules of undetermined nature. $\times 250$.

in hand with the increase in the size of the prothalli and of the extent of the dependence of the young plant upon its parent prothallus. From the figures mentioned above it will be seen that the surface cells of the foot in the three species of the *cernuum* type are only slightly developed as an epithelial layer. They are best illustrated in fig. 73, which is a transverse section of the foot and suspensor of the young plant of *L. cernuum*, and fig. 74, which shows the foot in longitudinal section.

In Part II of these papers (8, p. 92) I stated that I had never observed the presence of fungal hyphae in any of the protocorms which I had examined. This statement I must correct. The fungus is certainly never present as

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intracellular hyphal coils, as it is in the prothalli, but it seems to be always present in an intercellular position in the central tissues of the protocorm. These centrally-placed cells, which show abundant protoplasmic contents, are always roundish in form and are separated from one another, the intercellular spaces staining darkly with haematoxylin. The appearance of the fungus in the protocorm is thus in marked contrast to the definite epidermal fungal tissue of the prothallus, in which it occurs in hyphal coils. The hyphae can clearly be traced entering the protocorm through the rhizoids. They seem to cross the outer layers of cells mainly, if not entirely, through spaces between the cells and more especially at their angles, and they are not at all apparent in this zone. But when once one has learned to look for them, both the hyphae and also their "spores"

can be seen in the spaces between the cells throughout the whole of the central region of the protocorm (figs. 46, 74, and Plate XV; see also 7, fig. 61, and pl. 17, fig. 2, and pl. 18, figs. 1, 2). The fungal hyphae can best be studied outside the protocorm, around the base of which they form an open mat. They are branched and unseptate. Here, too, the spores are abundant, and it can be frequently and clearly seen that they originate by a length of hyphal thread dividing up into a number of the spores. This also can be seen in the intercellular spaces at the centre of the protocorm. It is certainly a striking fact that the fungus never occupies the cell-cavities in the protocorm. The fungus undoubtedly assists the young plant to become self-nourishing.

Treub and others have supposed the protocorm to be an organ of high phylogenetic importance. Bower, however, believed it to be a physiological modification, just as is the intraprothallial swelling called the "foot." My study of this organ as it occurs in the three New Zealand species certainly inclines me to accept Bower's suggestion. The *Lycopodium* plant in all its organs is in such a plastic condition that it is unlikely that any highly primitive structures should have been retained—at any rate, in its vegetative parts.^{*} The different sections into which the modern genus is classified are strikingly in accord with its biological divisions, as Lang, with regard to the prothallus, has pointed out. It might be added that this holds also for the other main organs of the *Lycopodium* plant. Each type of prothallus is correlated with a certain type of embryo plant. The protocorm is always associated with the *cernuum* type of prothallus, and apparently with no other. The comparative study of the different types of prothallial structure certainly leads one to the conclusion that the *cernuum* type is the least modified of all, and its chlorophyllous habit especially points to this; but it does not necessarily follow that the *cernuum* embryo is also the least modified. The presence of the symbiotic fungus seems to have been the dominant factor in determining the form of the different *Lycopodium* prothalli, and it is a significant fact that the protocorm is also infested with it.

[Footnote] * There has quite recently been described by Kidston and Lang (*Trans. Roy. Soc. Edin.*, vol. 52, pt. 3, pp. 603–27, 1920) a small plant from the Devonian of Scotland, which the authors have named *Hornia Lignieri*, whose basal portion consists of a protocormous rhizome. This plant the authors compare with the young plants of *Lycopodium cernuum*, *L. laterale*, and *L. ramulosum*, and with *Phylloglossum*. As they suggest, the demonstrated presence of the "protocorm" in archaic vascular cryptogams introduces quite a new argument into the discussion concerning the nature and origin of this peculiar organ. However, they also briefly point out (*ibid.*, note at bottom of p. 612) that fungal hyphae occur in an intercellular position in the tissues of the rhizome of *Hornia*.

Details of the Fungus.

There is not very much to say here with regard to the details of the symbiotic fungus in these three species of prothalli. The hyphal coils are present only in the epidermal cells of the fungal region, although the hyphae penetrate farther into the adjoining tissue in an intercellular position. I have seen no formation of clusters of "spores" as occurs in the epiphytic prothalli. Spores occur, however, in the interior tissue of the protocorm of the young plant along with hyphae in between the cells.

One prothallus of *L. ramulosum* showed in its lower basal tubercle a number of large, spherical, dark-staining bodies, three of which are illustrated in fig. 75. These bodies possessed thick walls, and in section were seen to be full of numerous very small oval lightly-staining "spores." My serial transverse sections of this tubercle showed that there were no fewer than twelve of these large bodies present. They lie within the cell-cavities in the region in which the fungus is intercellular. Each is large enough to completely fill a cell and bulge out its walls. In each of two other prothalli of this species I observed a single spore body of this nature. I was not able to determine their nature, but judge that they bear some relation to the symbiotic fungus.

General Remarks.

A special interest attaches itself to the study of the prothalli of the different species of *Lycopodium*, arising mainly from the fact that several types of prothallial structure are represented in the genus, and also that each of these types goes hand in hand with certain characteristic features in other organs of the plant. So different are these types of prothalli one from another that both Treub and Bruchmann have expressed the opinion that these differences date from a very ancient period. Treub states his belief that they can be explained in a small degree only by the different conditions under which the prothalli live. Bruchmann would divide the genus into as many new genera as there are distinct prothallial types. As opposed to this view, Lang has suggested that the different prothalli show a similarity in ground plan, and that they are all more or less profound modifications of an original *cernuum*-like form. As further species of

prothalli are found this interest is deepened, for it becomes clear that although the main types are all now probably known to us, yet there are many significant modifications of them, and also that further study of the genus will probably reveal more such. Instead of assuming that the different prothallial types are practically unrelated, it will probably be more productive of results to try to discover from the development of the individual prothalli and from their variations whether there is a fundamental plan of structure, and what has been the reason for its modification. Such a study will, at all events, help us to recognize which characters are of most importance.

The complete mature prothallus of all the sections of the genus except the *Inundata* and *Cernua* shows consistently at its basal, original end the form of an inverted cone, the apex of the cone being occupied by a single cell, to which the remains of the spore can sometimes be seen attached. It is, of course, possible that in some cases a brief filamentous stage may arise first from the spore before the cone form is attained, and that this drops away later and so becomes lost, but apparently it seems that the cone form is at once initiated. In the much-branched prothalli of the *Phlegmaria* type, which are radial in build but not upright in growth, the cone quickly

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passes over into the elongated cylindrical main body which bears sexual organs on the dorsal side, so becoming bilateral. The prothalli of *L. Selago* grow upright in the soil. They either preserve the cone form throughout their life—being, however, much smaller than the prothalli of the *clavatum* or *complanatum* types—or they give rise to elongated bilateral extensions of portions of the upper margin of the cone. In the upright prothalli of the *clavatum* and *complanatum* types there is practically no disposition towards elongation, the cone form being preserved throughout the life of the comparatively massive prothallus, any extra meristematic activity showing itself merely in irregular lobing of the upper margin or in adventitious budding. The angle of divergence of the cone from its apex upwards is different in these two types, being greater in the former than in the latter, so that the mature forms of the two prothalli are somewhat different. The

prothalli of the species which belong to the *Cernua* and *Inundata* sections are also upright in growth, and have a radial build, so that in transverse section the main body is circular in outline, but the cone form is not always present. Treub's description of the prothalli of *L. cernuum* suggested that a short cone-like stage always followed immediately upon the germination of the spore, and the "primary tubercle," as it was called by him, was thus looked upon as a characteristic feature in this type of prothallus. In all the species of this type whose prothalli are known a primary tubercle is, indeed, often present, but not invariably so, as appears, for example, in the prothalli, both young and old, of *L. ramulosum*.

The cone form adopted by the *Lycopodium* prothallus must be considered along with the presence in its tissues of the symbiotic fungus. It is, of course, well known that this fungus is one of its most characteristic features, just as it is also of other subterranean pteridophytic prothalli. Treub states that the prothallus of *L. salakense* shows no fungus, and it is quite possible that other species belonging to either the *Cernua* or *Inundata* sections may prove to be without it. From what we know of the young prothallus of *L. laterale* and *L. ramulosum* it would seem that in the sections *Cernua* and *Inundata* the infection may be postponed considerably, for the fungus is frequently absent altogether from young prothalli of quite fair size, and also not infrequently mature prothalli show signs of the same initial fungusless region at their base.

In the prothallus of *Tmesipteris* the fungus is found even in the basal filament, when that is present; but whether the infection is initiated from the very first or subsequently spreads back into the extreme lower parts of the prothallus is not known. I have found many prothalli of *Tmesipteris*, both young and also mature, which showed a short filament of cells at their base, and also, on the other hand, complete prothalli in which no filament was present, in the latter case the remains of the original spore being sometimes clearly apparent on the cell at the actual apex of the basal cone. Sometimes the *Tmesipteris* prothallus takes the form of a steadily tapering cone, and at others in its lowest regions it increases in girth by a progressive series of gentle swellings. One cannot avoid the suggestion that the dominating factor in the *Tmesipteris* prothallus is the presence of the fungus, the nature of the swelling being due to the consistency or intermittency, as the case may be, of its activity, and the omission of a filamentous stage being due to its very early entry into the germinating spore. When we turn to the prothalli of the Lycopodiaceae the same conclusion seems to be forced upon us. Large mature prothalli of *L. ramulosum* may show no primary tubercle at all, and the cone form may be altogether absent, so that the general form of this prothallus can then

best be described as a radially-built filament. The immediate effect of the presence of the fungus also can be clearly seen in the prothalli of this species. It almost invariably causes a swelling of the tissues of the prothallus at the infection spot, this swelling being due to the greater or less development of the internal fungal tissue in which the hyphae are intercellular. Sometimes the fungus is restricted to one place in the prothallus, this being towards or at its base, so that there is present a basal swelling. But in all three New Zealand species which belong to the *cernuum* type, and more especially in *L. ramulosum*, more than one distinct fungal area is frequently formed. Another form sometimes adopted by the prothallus of *L. ramulosum*, and to be seen also in those of *L. laterale* and *L. cernuum*, is that in which the usual shaft is practically absent, the crown of lobes immediately surmounting the basal fungal region. The latter is then more bulky than usual, the whole mature prothallus bearing more truly the cone form than is normally the case in the prothalli of these sections. That this particular massive form is not a fixed character appears from the fact that only infrequently are these bulky prothalli of regular shape and growth. However, just as the long-drawn-out, more filamentous form may bear some comparison with the epiphytic, elongated type, so may the massive form be compared with the deep-growing *clavatum* and *complanatum* types, and the prothallus of *L. ramulosum* is thus seen to possess as great significance as that of *L. Selago* in bearing witness to the plasticity of the *Lycopodium* prothallus.

When we turn to the epiphytic type of prothallus we find that there also the form of the prothallus must be considered along with the nature of the fungus-distribution in its tissues. The whole of the basal cone constitutes, as it were a primary tubercle which contains the fungal element throughout its tissues, being comparable to the first-formed tubercle in *L. cernuum*, when that is there present. The elongated, cylindrical regions of the epiphytic prothalli, have completely passed out of the cone form, nor do they show any localized swellings induced by the presence of the fungus. The fungus is distributed throughout the branches and the vegetative region of the central body, and the absence of swelling is probably due to the rapid elongation of the prothallus in all its parts. Even the discontinuous infection which is to be seen often in the branches does not result in any swelling of the tissues as it does in *L. ramulosum*. Thus, although the elongated prothalli of *L. ramulosum* may be compared with the epiphytic type,

yet they never attain to the characteristic form or structure of the latter. It will suffice here to allude quite briefly to the statement made by certain other writers, notably Lang, that this difference is probably merely the expression of the fact that in the *Cernua* and *Inundata* types fungal assimilation has not assumed the same degree of importance in the life of the prothallus as it has in the epiphytic types, for the prothallus is surface-growing and never gives up its chlorophyllous, self-nourishing habit. The epiphytic prothalli, however, live in soil of a different nature, and have adopted a wholly subterranean mode of life, in which they depend altogether upon the activities of the fungus for their nourishment. This has been the immediate cause of their extensive ramifications and their character of continuous cylindrical growth. In this respect, therefore, they are to be regarded as more specialized than the chlorophyllous type.

Although I have not in the present paper given any description of the prothalli of the species *L. volubile*, *L. fastigiatum*, and *L. scariosum*, which belong to the *clavatum* and *complanatum* types, yet it is appropriate here to compare briefly their form and structure with that of the other New

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Zealand species already dealt with. In these two types the cone form is at once initiated and is continued, throughout the life of the prothallus. There is no extension in length comparable even to that of the *Cernua* and *Inundata* types, although, as I mentioned in a former paper (7, p. 273) and hope to describe more fully in a later one, the young prothallus of *L. fastigiatum* branches after it has passed through the initial cone stage. It assumes the shape of the letter "Y," the arms of the prothallus being true branches, as indicated by the fact that in each of them there is a central core of fungus-free cells completely surrounded by the fungal zone, the meristem being located near, but not actually at, the apex of each arm. Although the mature prothallus in this species has the saucer form, yet it frequently bears evidence of this early branching. The prothalli of these two types have departed altogether from the self-nourishing, chlorophyllous habit, and have become wholly dependent upon the symbiotic fungus, although the prothallus of *L. volubile* is able to develop chlorophyll if it happens to grow at the surface of the

ground. We find that the external tissues in the whole of the vegetative portion of the prothallus have been given over to the fungal inhabitant, so that in form this vegetative region is one large regularly-shaped cone. The prothalli of the *clavatum* and *complanatum* types, owing to their terrestrial habit, occur in soil of a nature different from that of the humus-growing, epiphytic prothalli. There seems to be no need for the prothallus to elongate or branch in order to come in contact with a sufficient supply of food, although, judging from the branching by which the young prothallus of *L. fastigiatum* assumes the saucer form, it could do so if necessary. The fact that these types of prothalli are so much larger in size than the surface-growing form of *L. Selago* is obviously due to the much greater degree of dependence upon them of the young plant than in the latter species. They function largely as storehouses, the large quantities of starch and oil which they contain having been noted by all who have described them.

The compact, massive form of the prothallus in *L. ramulosum*, *L. laterale*, and *L. cernuum* must not be compared too closely with that of *L. Selago* or of the terrestrial subterranean types, for the position of the meristem in the latter is altogether different from that in the former. Nor can the elongated form of *L. ramulosum* be compared exactly, with that of *L. Billardieri*. It would seem, however, that the difference between the marginal meristem of the *Selago* prothallus and the apical meristem of the epiphytic types is not so great. The prothalli of both these types invariably begin with the cone form, and the subsequent manner of growth of each, and the form which the meristem takes, can be explained quite naturally (as I have attempted to do earlier in this paper) as resulting simply from the position of the prothallus in the soil. That there is a somewhat close relationship between these two types appears also from the fact of their similarity in the embryo plant and in the presence of paraphyses. The *clavatum* and *complanatum* types of prothallus also seem to be allied to that of the *Selago* type, possessing the same kind of marginal meristem, although they lack paraphyses. Moreover, the embryo plant of these deeply subterranean forms differs from that of *L. Selago* only in the abnormal development of the "foot," a character which has quite obviously resulted from their position in the soil.

The prothalli of the *Cernua* and *Inundata* sections seem to stand rather apart from the rest of the genus. The meristem is of a quite different nature, the fungal habit has not been adopted to the same extent, the filamentous manner of growth is largely present, and the form of the

young plant is very peculiar. Any similarities in detailed structure between this type and any of the others are perhaps best regarded as instances of parallel development, such as the fungal "palisade" tissue in the prothallus of *L. cernuum* and of *L. clavatum* and *L. complanatum*, and also the elongated manner of growth in *L. ramulosum* and *L. Billardieri*. The varieties in form and structure which occur in the prothalli of the *cernuum* type are chiefly interesting as evidences of the great plasticity of the *Lycopodium* gametophyte. It is in the *Cernua* and *Inundata* sections that we meet with the least evidence of a permanently fixed type of prothallus. These prothalli have also proceeded the least of all to a saprophytic mode of life, and generally show the least extent of specialization. The epiphytic prothalli have become thoroughly specialized to the epiphytic habit, and the *clavatum* and *complanatum* types to the subterranean terrestrial habit. We are justified, therefore, in regarding the *Cernua* and *Inundata* types as showing more nearly the original structure plan of the *Lycopodium* prothallus than the others.

Thus we may conclude from a comparative study of the general form and structure of the different *Lycopodium* prothalli that they are all more or less modified from some primitive type of structure, and that the chief factor in this modification has been the presence in them of the symbiotic fungus. This primitive type of structure was probably a more or less bulky filament of radial build, situated at the surface of the ground, and possessing chlorophyll. The adoption of a fungal habit opened the door to possibilities of modification of this simple type of structure, and gave to the *Lycopodium* prothallus its quality of plasticity. It was able to establish itself in new positions and soils, the different types of habitat resulting in different types of modification of the original structure. When the fungal habit was thoroughly adopted the early filamentous stage became lost, but in all its forms the *Lycopodium* prothallus has never departed from the radial build.

It seems clear from a comparative survey of all the main characters of the *Lycopodium* sporophyte and gametophyte that the different sections of the genus are natural ones, and that their characters are all interdependent. It is possible that the varied aspect of the genus as it exists to-day has been due largely to the phenomenon of symbiotic association with a fungus exhibited by its

gametophyte generation, the varied structure of the sporophyte as regards the form adopted by the mature plant, the form of its spore-bearing regions, and its stem-anatomy following as a natural consequence from the spread of the gametophyte to different stations and soils.

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Art. XXVIII.—Notes on the Indigenous Vegetation of the North-eastern Portion of the Hokonui Hills, with a List of Species.

By D. L. Poppelwell..

[*Read before the Otago Institute, 14th October, 1919; received by Editor, 24th October, 1919; issued separately, 23rd June, 1920.*]

The Hokonui Hills consist of the high country which lies within the triangle formed by the Gore-Invercargill section of the Main Trunk Railway, the Invercargill-Lumsden section of the Invercargill-Kingston line, and the Waimea Railway. They are roughly triangular in form, Gore, Lumsden, and Winton being the corners. Each side of the triangle is about thirty miles long, the total area being therefore about 300,000 acres. The highest point (Bare Hill) is 2,260 ft. above sea-level. The most southerly point is not more than a few miles from the sea, whilst the northern end extends about thirty miles inland. The Hokonui Hills are isolated from the surrounding chains, being bounded by the valley of the Oreti on one side, the Mataura valley on another, and the Southland Seaward Plains on the

third side. It is palpable that the different parts of a stretch of country such as this must show considerable difference in their plant covering, as they extend from near the sea to quite beyond what is usually accepted as the littoral belt. This block contains several thousand acres of bush, but most of it consists of uplands divided by several more or less open valleys with constant streams. Every class of soil and situation is therefore presented, and consequently the plant-life is of a very varied kind. To attempt to give a complete report would be a task quite beyond the time at my disposal at present, hence I will confine my remarks to that portion of the Hokonuis nearest Gore, locally known as Croydon Bush, and the uplands in the vicinity. I have also to point out that these notes do not profess to be exhaustive. Numerous introduced plants are also found, but are not further mentioned. The highest point in the area dealt with is East Peak (2,000 ft.) and an unnamed peak to the westward thereof, which is slightly higher than the former.

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From the list of species the curious fact will be noticed that *Nothofagus* is completely absent from the area dealt with, and, so far as my observations go, from the whole Hokonuis. This is difficult to account for, especially as this genus is common on all the surrounding hill-groups.

In time to come, when the botanical districts of New Zealand are divided into subdistricts, the absence of *Nothofagus* alone will almost justify the setting-apart of the Hokonuis as a subdistrict of the South Otago Botanical District.

In the meantime I do not propose to describe the plant formations, but merely append a list of species observed during many visits to the north-eastern portion of the Hokonuis. The list contains 285 species comprising 146 genera, and spread over 57 families.

List of Indigenous Plants.

Pteridophyta.

Hymenophyllaceae.

- *Hymenophyllum sanguinolentum* (Forst. f.) Sw. Common in forest.
- —— *dilatatum* (Forst. f.) Sw. Common in forest.
- —— *flabellatum* Lab. Common in forest.
- —— *demissum* (Forst. f.) Sw. Common in forest.

Cyatheaceae.

- *Dicksonia squarrosa* (Forst. f.) Sw. Fairly common in forest.
- —— *fibrosa* Col. Common.
- *Hemitelia Smithii* (Hook. f.) Hook. Not uncommon.
- *Alsophila Colensoi* Hook. f. Not uncommon.

Polypodiaceae.

- *Polystichum vestitum* (Forst. f.) Presl. Common.
- —— *Richardi* Diels. Fairly common.
- *Lindsaya linearis* Sw. Tussock meadow.
- *Asplenium bulbiferum* Forst. f. Abundant in forest.
- —— *flaccidum* Forst. f. Abundant in forest.
- —— *flabellifolium* Cav. Not uncommon, but local
- —— *Hookerianum* Col. Rocky places in open bush.
- —— var. *Colensoi* Moore. Rocky places in open bush.
- *Blechnum Patersoni* (R. Br.) Mett. Common in damp gullies.
- —— *discolor* (Forst. f.) Keys. Abundant in dry places.
- —— *lanceolatum* (R. Br.) Sturm. Moist gullies.
- —— *capense* (L.) Schlecht. Fairly common.
- —— *penna marinum* (Poir.) Kuhn. Abundant.
- —— *fluviatile* (R. Br.) Lowe.

- *Hypolepis tenuifolia* (Forst. f.) Bernh. Fairly common.
- *Histiopteris incisa* (Thunb.) J. Sm. Abundant
- *Pteridium esculentum* (Forst. f.) Cockayne. Plentiful.
- *Polypodium Billardieri* (Willd.) C. Chr. Tree-trunks, & c., in forest.
- —— *diversifolium* Willd. Plentiful in forest.
- —— *grammitidis* R. Br. Rare on tree-trunks, & c.
- —— *punctatum* Thunb. Common.
- *Botrychium ternatum* Swartz. Rare.

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Gleicheniaceae.

- *Gleichenia Cunninghamii* Hew. In patches; local.

Osmundaceae.

- *Leptopteris hymenophylloides* (A. Rich.) Presl. Damp gullies in forest.
- —— *superba* (Col.) Presl. Damp gullies in forest.

Ophioglossaceae.

- *Ophioglossum lusitanicum* L. Tussock meadow.

Lycopodiaceae.

- *Lycopodium Billardieri* Spring. Not uncommon.

- —— *fastigiatum* R. Br. Plentiful.
- —— *scariosum* Forst. f. Not plentiful.
- —— *volubile* Forst. f. Not plentiful.
- *Tmesipteris tannensis* Bernh. On logs, & c.

Spermophyta.

Taxaceae.

- *Podocarpus Hallii* T. Kirk. Common in forest.
- —— *totara* D. Don. Rare; in forest.
- —— *ferrugineus* D. Don. Fairly abundant.
- —— *spicatus* R. Br. Fairly abundant.
- —— *dacrydioides* A. Rich. Plentiful.
- *Dacrydium cupressinum* Sol. Plentiful.

Potamogetonaceae.

- *Potamogeton Cheesemanii* A. Benn. In pools.

Gramineae.

- *Microlaena avenacea* (Raoul) Hook. f. Common in forests.
- *Hierochloe redolens* (Forst. f.) R. Br. Fairly common.
- *Agrostis parva* Petrie. Bush tracks.
- *Dichelachne crinita* (Forst. f.) Hook. f. Mountain meadow.
- *Danthonia Cunninghamii* Hook. f. Common in uplands.
- —— *Raoulii* Steud. Abundant.
- —— *flavescens* Hook. f. Steppe. Not so common as *D. Raoulii*.
- —— *pilosa* R. Br. Not uncommon in meadow.
- —— *semiannularis* R. Br. Not uncommon in meadow.
- *Arundo conspicua* Forst. f. Common.

- *Poa caespitosa* Forst. f. Common on hills.
- —— *imbecilla* Forst. f. Not uncommon.
- —— *Colensoi* Hook. f. Fairly plentiful in meadow.
- —— var. *intermedia* Cheesem. Fairly plentiful in meadow.
- *Festuca rubra* L. Lower steppe. Common.
- *Agropyron scabrum* (R. Br.) Beauv. In upper meadow.

Cyperaceae.

- *Scirpus aucklandicus* (Hook. f.) Boeck. Swamps.
- *Carpha alpina* R. Br. In swamps.
- *Cladium Vauthiera* C. B. Clarke. Wet places.
- *Gahnia procera* Forst. f. In forest; common.
- *Oreobolus pectinatus* Hook. f. In boggy places; not common.

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- *Uncinia compacta* R. Br. Mountain meadow.
- —— *uncinata* (L. f.) Küken. In forest.
- *Carex secta* Boott. Lowland swamps.
- —— *ternaria* Forst. f. Damp lowland swamps.
- —— *dissita* Sol. Forest.

- —— *lucida* Boott. Swampy places.
- —— *pseudo-cyperus* Linn. Damp places in bush.

Typhaceae.

- *Typha angustifolia* L. Lagoon on north side.

Restiaceae.

- *Hypolaena lateriflora* Benth. Lowland swamps.

Juncaceae.

- *Juncus polyanthemos* Buchen. Damp places; common.
- —— *bufonius* L. Damp places; common.
- —— *planifolius* R. Br. Damp places; common.
- *Luzula campestris* DC. Several varieties; common.

Liliaceae.

- *Enargea parviflora* Kunth. Rare; only one plant noted, in manuka heath.
- *Cordyline australis* (Forst. f.) Hook. Not plentiful.
- *Astelia linearis* Hook. f. Boggy places, lowland meadow.
- —— *nervosa* Banks & Sol. Common in forest.
- —— *montana* (T. Kirk) Cockayne. Not uncommon in swamps.
- *Phormium tenax* Forst. Common on foothills.
- —— *Cookianum* Le Jolis. Abundant on uplands.
- *Chrysobactron Hookeri* Col. Common in damp situations.
- *Herpolirion novae-zelandiae* Hook. f. Common in meadows.

Iridaceae.

- *Libertia ixiooides* Spreng. Not uncommon.
- —— var. with creeping stolons. This variety is common in lowland tussock

meadow. It differs in having stolons. The leaves are wider and more striate, the peduncles much shorter than the leaves, and the flowers larger. Perhaps it should be accorded specific rank.

Orchidaceae.

- *Earina mucronata* Lindl. Not plentiful.
- *Thelymitra longifolia* Forst. Common.
- —— *uniflora* Hook. f. Common on banks, & c.
- *Microtis uniflora* (Forst. f.) Rochb. Common in steppe meadow.
- *Prasophyllum Colensoi* Hook. f. Common in steppe meadow.
- *Pterostylis Banksii* R. Br. Not common.
- —— *australis* Hook. f. Fairly abundant in damp meadow.
- *Caladenia bifolia* Hook. f. In manuka heath.
- —— *Lyallii* Hook. f. In manuka heath at 1,000 ft.
- *Corysanthes rotundifolia* Hook. f. Common on creek-banks.
- —— *macrantha* Hook. f. Damp places in forest.
- —— *triloba* Hook. f. Damp places in forest.

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Urticaceae.

- *Urtica incisa* Poir. Common on bush tracks.

- — *ferox* Forst. Rare; in northern part of forest.
- *Paratrophis microphylla* Blume. Rare in forest.

Loranthaceae.

- *Loranthus micranthus* Hook. f. Plentiful in forest.
- *Tupeia antarctica* Cham. & Schl. Abundant.
- *Korthalsella Lindsayi* (Engl.) Van Tiegh. Common.
- — *clavata* (Cheesem.) Van Tiegh. Not common.

Polygonaceae.

- *Rumex flexuosus* Sol. Not plentiful; north side chiefly.
- *Muehlenbeckia australis* (Forst. f.) Meissn. Abundant; forest-margin.
- — *complexa* (A. Cunn.) Meissn. Abundant; forest-margin.
- — *axillaris* Walp. Dry situations in meadow.

Caryophyllaceae.

- *Colobanthus acicularis* Hook. f. In boggy ground.
- *Stellaria parviflora* Banks & Sol. In open places in forest.
- *Scleranthus biflorus* (Forst.) Hook. f. Dry meadow; common.

Ranunculaceae.

- *Clematis indivisa* Willd. Plentiful.
- — *hexasepala* DC. Not uncommon.
- — *foetida* Raoul. Common on forest-margin.
- *Ranunculus hirtus* Banks & Sol. Fairly common.
- — *rivularis* Banks & Sol. Common in damp places.
- — *lappaceus* Sm: Plentiful.
- — *multiscapus* Cockayne. Common.

- — *foliosus* T. Kirk. Not common.

Magnoliaceae.

- *Drimys colorata* Raoul. Plentiful.

Cruciferae

- *Cardamine heterophylla* (Forst f.) O. E. Schultz. Plentiful.
- — *depressa* Hook. f. Not uncommon.

Saxifragaceae.

- *Carpodetus serratus* Forst. Very abundant in forest.

Pittosporaceae.

- *Pittosporum tenuifolium* Banks & Sol. Abundant.
- — *Colensoi* Hook. f. Common.
- — *eugeniodes* A. Cunn. Common.

Cunoniaceae.

- *Weinmannia racemosa* L. f. Not uncommon in southern forest.

Rosaceae.

- *Rubus australis* Forst. f. Abundant.
- — *subpauperatus* Cockayne. Common.
- — *schmidelioides* A. Cunn. Not plentiful.

- *Rubus cissoides* A. Cunn. Not plentiful.
- *Potentilla anserina* L. var. *anserinoides* (Raoul) T. Kirk. Not plentiful.
- *Acaena novae-zelandiae* T. Kirk. Not uncommon.
- —— *Sanguisorbae* Vahl. Common throughout.
- —— var. *pilosa* T. Kirk. Hilltops.
- —— *microphylla* Hook. f. Hilltops only.

Geraniaceae.

- *Geranium microphyllum* Hook. f. Common in tussock meadow.
- —— *sessiliflorum*. Cav. var. *glabrum* Kunth. Common in steppe.
- *Oxalis magellanica* Forst. Rare. On bank of Otamete Stream at 1,000 ft.
- —— *corniculata* L. Abundant.

Rutaceae.

- *Melicope simplex* A. Cunn. Plentiful in forest.

Olacaceae.

- *Pennantia corymbosa* Forst.

Callitrichaceae.

- *Callitricha verna* L. In pools, & c.

Coriariaceae.

- *Coriaria ruscifolia* L. Plentiful.
- —— *thymifolia* Humb. & Bonpl. Common.

Leguminosae.

- *Sophora tetraptera* J. Mull. var. *microphylla* Hook. f. Fairly abundant.
- *Carmichaelia subulata* T. Kirk. Creek-banks.

Elaeocarpaceae.

- *Aristotelia racemosa* (A. Cunn.) Hook. f. var. with red berries. Plentiful in forest.
- —— *Colensoi* Hook. f. Creek-banks.
- —— *fruticosa* Hook. f. On creek-banks above 1,000 ft.
- —— var. with white flowers. On creek-bank; rare.
- *Eleocharpus Hookerianus* Raoul. Fairly abundant.

Rhamnaceae.

- *Discaria toumatou* Raoul. Common on stony faces.

Malvaceae.

- *Plagianthus betulinus* A. Cunn. Plentiful; forest-margins.
- *Hoheria populnea* A. Cunn. var. *vulgaris* Hook. f. Forest-margins.
- —— var. *angustifolia* Hook. f.

Violaceae.

- *Viola Cunninghamii* Hook. f. Plentiful in steppe.
- —— *filicaulis* Hook. f. Plentiful in steppe.
- *Melicytus lanceolatus* Hook. f. Fairly common but local.
- *Hymenanthera dentata* R. Br. Forest-margin.
- —— var. *alpina* T. Kirk. Hilltops.

[View Image](#)

Thymelaeaceae.

- *Pimelea prostrata* Willd., one or more varieties. Plentiful.
- —— *sericeo-villosa* Hook. f. Not plentiful.
- *Drapetes Dieffenbachii* Hook. f. In elevated boggy places.
- —— *Lyallii* Hook. f. In elevated boggy places.

Myrtaceae.

- *Leptospermum scoparium* Forst. Plentiful.
- *Myrtus pedunculata* Hook. f. Plentiful in lowland forest.
- *Metrosideros lucida* (Forst. f.) A. Rich. Plentiful in forest.
- —— *hypericifolia* A. Cunn. Plentiful but local in forest.

Onagraceae.

- *Epilobium chionanthum* Haussk. Boggy places
- —— *pictum* Petrie. Plentiful.
- —— *Hectori* Haussk. Common.
- —— *confertifolium* Hook. f. Common.
- —— *alsinoides* A. Cunn. Common.
- —— *Billardierianum* Ser. Common.

- —— *juncinum* Sol. var. *hirtigerum* A. Cunn. Not uncommon.
- —— *pubens* A. Rich. Plentiful.
- —— *nummularifolium* R. Cunn. Bush tracks.
- —— *linniaeoides* Hook. f. Bush tracks.
- —— *insulare* Haussk. Common.
- *Fuchsia excorticata* L. f. Plentiful.
- —— *Colensoi* Hook. f. Common.

Halorrhagaceae.

- *Halorrhagis depressa* Walp. Fairly abundant.
- —— *micrantha* (Thumb.) R. Br. Meadows.
- *Myriophyllum elatinoides* Gaud. Pools.
- *Gunnera flavidia* Col. Swamps.
- —— *prorepens* Hook. f. Swamps.

Araliaceae.

- *Nothopanax simplex* (Forst) Seem. Abundant in forest.
- —— *Edgerleyi* (Hook. f.) Harms. Not uncommon.
- —— *Colensoi* (Hook. f.) Seem. Abundant.
- *Pseudopanax crassifolium* (Sol.) C. Koch. Common in forest.
- —— *ferox* T. Kirk. Dry situations in forest.
- *Shefflera digitata* Forst. Not uncommon in damp gullies.

Umbelliferae.

- *Hydrocotyle novae-zealandiae* DC. Abundant in damp places.
- —— *asiatica* L. Plentiful.
- *Apium filiforme* (A. Rich.) Hook. Tolerably rare.

- *Aciphylla Colensoi* Hook. f. Rare; only two plants noted.
- —— *squarrosa* Forst. Fairly common.
- *Angelica Gingidium* Hook. f. Abundant on banks, &c.

Cornaceae.

- *Griselinia littoralis* Raoul. Plentiful.
- *Corokia Cotoneaster* Raoul. Abundant near lower edge of forest.

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Ericaceae.

- *Gaultheria antipoda* Forst. f. Fairly common in heath.
- —— *erecta* (Cheesem.) Cockayne. On creek-banks; rare.
- —— *depressa* Hook. f. Abundant from 1,500 ft. upwards.
- —— *perplexa* R. Br. Plentiful.

Epacridaceae.

- *Pentachondra pumila* (Forst.) R. Br. Mountain-heaths.
- *Styphelia Fraseri* (A. Cunn.) F. Muell. Throughout heath.
- *Cyathodes empetrifolia* Hook. f. Sphagnum bogs with *Hypolaena*.
- *Dracophyllum longifolium* (Forst. f.) R. Br. Mountain-heath
- —— *Urvilleanum* A. Rich. Not very common.

Myrsinaceae.

- *Rapanea Urvillei* (A. DC.) Mez. Plentiful in forest.
- *Suttonia divaricata* (A. Cunn.) Hook. f. Fairly abundant.

Gentianaceae.

- *Gentiana Grisebachii* Hook. f. Not uncommon on upland heath.

Apocynaceae.

- *Parsonsia heterophylla* A. Cunn. Abundant.
- —— *capsularis* R. Br. Fairly common.

Convolvulaceae.

- *Calystegia tuguriorum* Forst. f. Forest-margins; rare and local.

Labiate.

- *Mentha Cunninghamii* Benth. Creek-banks, &c.

Scrophulariaceae.

- *Veronica salicifolia* Forst. f. Lowland forest; abundant.
- *Mazus radicans* Cheesem. Abundant in damp meadow.
- *Euphrasia Dyeri* Wettst. Damp meadow.

Plantaginaceae

- *Plantago Raoulii* Decne. Not plentiful.

Rubiaceae.

- *Coprosma rotundifolia* A. Cunn. Plentiful near creeks in forest.
- —— *areolata* Cheesem. Not uncommon.
- —— *parviflora* Hook. f. Plentiful; creek-banks.
- —— *crassifolium* Col. Fairly common.

- —— *rigida* Cheesem. Fairly common.
- —— *foetidissima* Forst. Abundant.
- —— *rhamnoides* A. Cunn. Not plentiful.
- —— *Colensoi* Hook. f. Rare.
- —— *acerosa* A. Cunn. Dry banks, & c.
- —— *brunnea* (T. Kirk) Cockayne. Creek-banks
- —— *propinqua* A. Cunn. Creek-banks.
- —— *lucida* Forst. f. Not abundant.
- —— *linariifolia* Hook. f. Plentiful; dry hills in forest.
- —— *ramulosa* Petrie. Common.

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- *Nertera depressa* Banks & Sol. Common on damp logs.
- —— *dichondraefolia* (A. Cunn.) Hook. Not plentiful.
- —— *setulosa* Hook. f. (?). In damp bog.
- *Galium umbrosum* Sol. In meadow; not uncommon.
- *Asperula perpusilla* Hook. f. Lowland meadow.

Campanulaceae.

- *Pratia angulata* (Forst. f.) Hook. f. Abundant.

- *Wahlenbergia albomarginata* Hook. Abundant.
- —— *gracilis* (Forst. f.) A. DC. Not uncommon.
- —— var. with very short stems and small flowers. Lowland heath.

Styliaceae.

- *Forsteria tenella* Hook. f. Fairly plentiful above 1,800 ft.

Compositae.

- *Lagenophora pumila* (Forst. f.) Cheesem. Dry banks.
- —— *petiolata* Hook. f. Common in meadows.
- *Brachycome Sinclairii* Hook. f. Plentiful in upper meadows.
- *Olearia virgata* Hook. f. Fairly common; creek-banks, &c.
- —— var. *lineata* T. Kirk. Fairly common.
- —— *ilicifolia* Hook. f. In subalpine scrub in southern parts.
- —— *arborescens* (Forst. f.) Cockayne and Laing. Common on heath, &c.
- —— *odorata* Petrie. On margin of forest.
- —— *Hectori* Hook. f. On margin of forest.
- —— *fragrantissima* Petrie. Stony faces in north.
- *Celmisia longifolia* Cass. Abundant.
- —— var. *alpina* T. Kirk. Swampy places.
- —— *coriacea* Hook. f. (?). Rare; only one plant noted, on rocks.
- *Gnaphalium luteo-album* L. Abundant.
- —— *trinerve* Forst. f. Common on clay banks, &c.
- —— *Traversii* Hook. f. Wet, sour ground.
- *Raoulia australis* Hook. f. Not abundant.
- —— *glabra* Hook. f. Plentiful.

- —— *subsericea* Hook. f. Mountain meadows.
- *Helichrysum bellidioides* (Forst.) Willd. Abundant.
- —— *filicaule* Hook. f. Plentiful in meadows.
- —— *glomeratum* Benth. & Hook. Rocky faces, &c.
- *Cassinia Vauvilliersii* Hook. f. Abundant.
- —— var. *rubra* T. Kirk. Not uncommon.
- *Craspedia uniflora* Forst. f. Plentiful in meadow.
- *Cotula australis* Hook. f. Damp places.
- —— *dioica* Hook. f. Damp meadows.
- —— *manioto* Petrie. Damp tracks, &c.; plentiful.
- *Senecio bellidioides* Hook. f. Common throughout.
- —— *southlandicus* Cockayne. Abundant.
- *Erechtites prenanthoides* (A. Rich.) DC. Plentiful in forest tracks.
- *Taraxacum magellanicum* Comm. Not uncommon.
- *Microseris Forsteri* Hook. f. Not uncommon in steppe.
- *Sonchus asper* Hill. Fairly common.

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By D. L. Poppelwell.

[Read before the Otago Institute, 14th October, 1919; received by Editor, 24th October 1919; issued separately, 23rd June, 1920.]

Ben Lomond is so well known as one of the side trips from Queenstown as not to require any further definition. It has, naturally, been visited by many botanists, but so far no list of its species has been published. I therefore propose to publish such a list, which is of interest both from the point of view of plant-geography and on account of the district being so frequently visited by tourists. The attached list has been compiled from notes taken on many visits to the locality. While it does not profess to be exhaustive, it contains, I think, most of the plants, and should form the basis of a list which can be completed by additions in the future. The list contains 164 species, spread over 92 genera, and belonging to 49 families.

List of Indigenous Species.

Pteridophyta.

Hymenophyllaceae.

- *Hymenophyllum tunbridgense* (L.) Sm. (?). Rocky faces over creeks.

Polypodiaceae.

- *Dryopteris punctata* (Thunb.) C. Ch. Not common.
- *Polystichum vestitum* (Forst. f.) Presl. Not plentiful.
- *Asplenium bulbiferum* Forst. f. Rare.
- —— *flabellifolium* Cav. In shade of rock, 1 mile.
- —— *Richardi* Hook. f. (?). Very rare.
- —— *flaccidum* Forst. f. On trees, &c.
- —— *Hookerianum* Col. In rocky situation; not common.
- —— *trichomanes* L. Rare; base of hill.
- *Blechnum penna marinum* (Poir.) Kuhn. Not uncommon.
- —— *capense* (L.) Schlecht. Dry banks of creeks.
- —— *fluviatile* (R. Br.) Lowe. Reservoir creek.
- —— *lanceolatum* (R. Br.) Sturm. Creek-banks.

- — *vulcanicum* Christ. Rocky faces, in shade.
- *Adiantum diaphanum* Blume. Shaded rock-faces, 2 miles.
- *Hypolepis tenuifolia* (Forst. f.) Bernh. Open faces near forest.
- *Pteridium esculentum* (Forst. f.) Common throughout.
- *Paesia scaberula* (A. Rich.) Kuhn. On mountain-side.
- *Polypodium Billardieri* (Willd.) C. Chr. Tree-trunks in forest.
- — *diversifolium* Willd. Common in forest.
- *Cystopteris fragilis* Bernh. Rocky crevices, & c.
- *Pellaea rotundifolia* Hook. Base of hill near Queenstown.

Lycopodiaceae.

- *Lycopodium Billardieri* Spring. At 1 mile.
- — *fastigiatum* R. Br. Dry heath.
- — *ramulosum* T. Kirk. Heath, & c.

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Spermophyta.

Taxaceae.

- *Phyllocladus alpinus* Hook. f. On forest-margin at 2,400 ft.
- *Dacrydium Bidwillii* Hook. f. Creek-bank at 4,400 ft.

- *Podocarpus nivalis* Hook. Mountain-side at 2,500 ft.

Gramineae.

- *Danthonia flavescens* Hook. f. Steppe; common.
- —— *Raoulii* Steud. Steppe; common.
- —— *crassiuscula* T. Kirk. Steppe; common.
- *Poa caespitosa* Forst. f. Not common in steppe.
- —— *Colensoi* Hook. f. Not common in steppe.
- —— *intermedia* (Hook. f.) Cheesem. Not common in steppe.
- *Festuca rubra* L. Not common in steppe

Cyperaceae.

- *Carex lucida* Boott. About 2,700 ft.
- —— *ternaria* Forst. f. About 2,700 ft.

Juncaceae.

- *Juncus polyanthemos* Buchen. Damp places.
- *Luzula campestris* DC. Mountain meadow, 2,400 ft.

Liliaceae.

- *Cordyline australis* (Forst. f.) Hook. Not plentiful.
- *Astelia nervosa* Banks & Sol. Not abundant.
- —— *montana* (T. Kirk) Cockayne. At 2,750 ft.; not abundant.
- *Phormium Cookianum* Le Jolis. 3,400 ft., at edge of forest.

Orchidaceae.

- *Corysanthes macrantha* Hook. f. Creek-banks.
- *Gastrodia Cunninghamii*, Hook. f. Rare.

Fagaceae.

- *Nothofagus fusca* Oerst. Common at low levels.
- —— *Menziesii* Oerst. Not very plentiful.
- —— *Solanderi* Oerst. Abundant.
- —— *cliffortioides* Oerst. Abundant.
- —— *Blairii* (Oerst.) T. Kirk. Near lake-side.
- —— *apiculata* Col. Near 1 mile.

Urticaceae.

- *Urtica incisa* Poir. In forest.

Loranthaceae.

- *Loranthus micranthus* Hook. f. On Coprosma.

Polygonaceae.

- *Rumex flexuosus* Sol. Not common.
- *Muehlenbeckia complexa* (A. Cunn.) Meissn. Forest-margin.
- —— *axillaris* Walp. Gravelly creek-banks, & c.

Portulacaceae.

- *Claytonia australasica* Hook. f. Not uncommon.

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Caryophyllaceae.

- *Stellaria parviflora* Banks & Sol. Not uncommon.
- *Hectorella caespitosa* Hook. f. Mountain-side.

Ranunculaceae.

- *Ranunculus hirtus* Banks & Sol. Damp places.
- —— *lappaceus* Sm. Common.
- —— *multiscapus* Cockayne. Fairly common.

Cruciferae.

- *Cardamine heterophylla* (Forst. f.) O. E. Schultz. Creek-banks.

Saxifragaceae.

- *Carpodetus serratus* Forst. Fairly common.

Pittosporaceae.

- *Pittosporum tenuifolium* Banks & Sol. Lake-side.

Rosaceae.

- *Rubus australis* Forst. f. Common.
- —— *subpauperatus* Cockayne. Dry places.
- *Geum parviflorum* Sm. Tolerably common.
- —— *leiospermum* Petrie. Not uncommon.
- —— *pusillum* Petrie. Not uncommon.
- *Acaena Sanguisorbae* Vahl. Common.
- —— var. *pilosa* T. Kirk. Common.
- —— *novae-zelandiae* T. Kirk. Common.
- —— *microphylla* Hook. f. Abundant.

Geraniaceae.

- *Geranium sessiliflorum* Cav. Common in meadow.
- —— *microphyllum* Hook. f. Common.

Coriariaceae.

- *Coriaria ruscifolia* L. Common on lake-side, & c.
- —— *angustissima* Hook. f. At 2,500 ft.

Leguminosae.

- *Sophora microphylla* J. Mull. Lake-side.

Elaeocarpaceae.

- *Aristotelia racemosa* (A. Cunn.) Hook. f. Near lake-side.
- —— var. with red berries. Rare.

Rhamnaceae.

- *Discaria toumatou* Raoul. Dry places near lake.

Malvaceae.

- *Gaya Lyallii* J. E. Baker. In reservoir creek.

Violaceae.

- *Viola Cunninghamii* Hook. f. Common in damp places.
- —— *filicaulis* Hook. f. Not uncommon.

Thymelaeaceae.

- *Pimelea prostrata* Willd. Fairly common.
- *Drapetes Dieffenbachii* Hook. f. Common.
- —— *Lyallii* Hook. f. More rare than *D. Diffenbachii*.

Myrtaceae.

- *Leptospermum scoparium* Forst. Common.
- *Metrosideros lucida* (Forst. f.) A. Rich. Rare on lake-side.

Onagraceae.

- *Epilobium Hectori* Haussk. Common on tracks, & c.
- —— *linnaeoides* Hook. f. Damp places.
- —— *pictum* Petrie. Common.
- *Fuchsia excorticata* L. f. Damp forest.
- —— *Colensoi* Hook. f. Not uncommon.

Araliaceae.

- *Nothopanax Colensoi* (Hook. f.) Seem. In damp forest.
- *Pseudopanax crassifolium* (Sol.) C. Koch. Not plentiful.

Umbelliferae.

- *Hydrocotyle novae-zealandiae* DC. Damp places.

- *Aciphylla Colensoi* Hook. f. Above 3,000 ft.
- —— *pinnatifida* Petrie. Rare; in boggy places at 4,400 ft.
- *Angelica decipiens* Hook. f. In alpine meadow.
- *Anisotome imbricatum* Hook. f. High elevation only.

Cornaceae.

- *Griselinia littoralis* (Raoul). Lake-side.
- *Corokia Cotoneaster* Raoul. Forest-margin.

Ericaceae.

- *Gaultheria antipoda* Forst. f. var. *erecta* Cheesem. Dry banks.
- —— *depressa* Hook. f. Abundant.
- —— *rupestris* R. Br. Common.

Epacridaceae.

- *Pentachondra pumila* (Forst. f.) R. Br. Not abundant.
- *Styphelia Fraseri* (A. Cunn.) F. Muell. Abundant.
- —— *acerosa* Sol. Plentiful near lake.
- *Dracophyllum rosemarinifolium* R. Br. Abundant.
- —— *prostratum* T. Kirk. Common near summit.
- —— *muscoides* Hook. Not uncommon.

Myrsinaceae.

- *Rapanea Urvillei* (A. DC.) Mez. Rare in forest.

Gentianaceae.

- *Gentiana corymbifera* T. Kirk. Common.
- —— *bellidifolia* Hook. f. Not uncommon.

Boraginaceae.

- *Myosotis Goyeni* Petrie. Rocks near Queenstown.

Labiateae.

- *Mentha Cunninghamii* Benth. Creek-banks, & c.

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Scrophulariaceae.

- *Veronica salicifolia* Forst. f. Lake-side and creek-banks.
- —— *Bidwillii* Hook. Dry creek-banks; plentiful.
- —— *Lyallii* Hook. f. Near creek; common.
- —— *buxifolia* Benth. At 2,400 ft.
- —— *Hectori* Hook. f. At 4,350 ft.
- *Ourisia caespitosa* Hook. f. Damp creek-bank.
- *Euphrasia zelandica* Wettst. Wet places near creek.

Rubiaceae.

- *Coprosma linariifolia* Hook. f. Not common.
- —— *propinqua* A. Cunn. Creek-banks.
- —— *lucida* Forst. Reservoir creek.
- —— *rigida* Cheesem. Ben Lomond Gully.
- —— *crassifolia* Col. Creek-bank, & c.

- — *repens* Hook. f. Alpine meadow.
- *Nertera depressa* Banks & Sol. Damp places at 4,400 ft.
- *Galium umbrosum* Sol. Alpine meadow.

Campanulaceae.

- *Pratia angulata* (Forst. f.) Hook. f. Tolerably common.
- *Wahlenbergia albomarginata* Hook. Abundant.
- — *gracilis* (Forst. f.) A. DC. Comparatively rare.
- *Lobelia linnaeoides* Petrie. Somewhat rare.

Styliidaceae.

- *Phyllachne Colensoi* (Hook. f.) Berggr. In bogs; rare.
- *Forsteria sedifolia* L. f. Tolerably plentiful.
- — *Bidwillii* Hook. f. At 2,500

Compositae.

- *Lagenophora petiolata* Hook. f. Not very common.
- *Brachycome Sinclairii* Hook. f. In subalpine meadow.
- *Olearia arborescens* (Forst. f.) Cockayne and Laing. Common in forest.
- — *avicenniaeefolia* Hook. f. Near lake-side.
- — *moschata* Hook. f. At 2,750 ft.
- — *Haastii* Hook. f. Near creek at 4,000 ft. elevation.
- *Celmisia Lyallii* Hook. f. From 4,300 ft. upwards.
- — *discolor* Hook. f. Rocky cliff protected from stock.
- — *laricifolia* Hook. f. Damp ground above 4,000 ft.
- — *Walkeri* T. Kirk. Above 4,000 ft.
- *Gnaphalium trinerve* Forst. f. Not common.

- —— *Traversii* Hook. f. Damp places.
- *Raoulia australis* Hook. f. Common.
- —— *glabra* Hook. f. Common.
- —— *Parkii* Buch. Comparatively rare.
- *Helichrysum bellidioides* (Forst.) Willd. Common.
- —— *filicaule* Hook. f. Fairly abundant.
- —— *glomeratum* Benth. & Hook. Dry places near lake.
- *Cassinia Vauvilliersii* Hook. f. Fairly abundant.
- *Craspedia uniflora* Forst. f. Not plentiful.
- *Senecio Lyallii* Hook. f. Creek-banks.
- —— *bellidioides* Hook. f. Creek-banks.
- —— *southlandicus* Cockayne (?). Not plentiful.
- —— *revolutus* T. Kirk. Common.

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Art. XXX.—Notes from Canterbury College Mountain Biological Station, Cass.

No. 7.—The Rosette Plants: Part I.

By M. Winifred Betts, M.Sc.

[Read before the Otago Institute, 9th December, 1919; received by Editor, 31st

At the end of 1918 the author was able, through the kindness of Dr. Chilton, of Canterbury College, to pass a short time at the Canterbury College Mountain Biological Station, at Cass. During this visit material was collected for an account of all the rosette plants of the district, but the author has been able to study only a few of the plants; hence in the present paper the anatomy only is dealt with. The author hopes, in a subsequent paper, to work out the anatomy of the rest of the rosette plants, and to consider the conclusions drawn from such anatomical study.

The following list gives the names of all the indigenous rosette plants to be found in the vicinity of the station. This list is taken from the list of species compiled by Cockayne and Foweraker.^{*}

Ranunculaceae.

- *Ranunculus multiscapus* Hook. f.
- —— *depressus* T. Kirk var.

Cruciferae.

- *Cardamine heterophylla* (Forst. f.) O. E. Schulz var.

Rosaceae.

- *Geum parviflorum* Sm.

Geraniaceae.

- *Geranium sessiliflorum* Cav. var. *glabrum* Kunth.

Violaceae.

- *Viola Cunninghamii* Hook. f.

Umbelliferae.

- *Anisotome filifolia* (Hook.f.) Cockayne and Laing.
- —— *aromatica* Hook. f. var.
- *Angelica montana* (Forst.) Cockayne.

Gentianaceae.

- *Gentiana corymbifera* T. Kirk var.

Boraginaceae.

- *Myosotis australis* R. Br. var.

Plantaginaceae.

- *Plantago spathulata* Hook. f.
- —— *triandra* Berggr.

Campanlaceae.

- *Wahlenbergia albomarginata* Hook.

Compositae.

- *Brachycome Sinclairii* Hook. f.
- *Celmisia spectabilis* Hook. f.
- —— *Lyallii* Hook. f.
- *Gnaphalium Traversii* Hook. f.
- *Senecio bellidoides* Hook. f. var.
- *glabratus* T. Kirk.
- —— *Lyallii* Hook. f.
- —— *lautus* Forst. f. var. *montanus* Cheesem.
- *Microseris scapigera* Sch. Bip.
- *Taraxacum magellanicum* Comm.

[Footnote] * L. Cockayne and C. E. Foweraker, Notes from the Canterbury College Mountain Biological Station: No. 4—The Principal Plant Associations in the Immediate Vicinity of the Station, *Trans. N.Z. Inst.*, vol. 48, pp. 166–86, 1916.

1. *Geum parviflorum* Sm.

This plant is found in rocky situations. The appearance of the plant is shown in figs. 1 and 2, fig. 1 being that of a plant growing in a shaded, damp station, fig. 2 of a plant growing in a more exposed position. The leaves are 1½–6 in. long, either erect or more or less prostrate; they are imparipinnate, the leaflet at the end being a large, crenate leaf, while the



Fig. 1.—*Geum parviflorum*. Plant from sheltered position (half natural size).

lateral leaflets are small, most of them being quite minute. The leaves are hirsute on both surfaces, and also on the petiole; while on the petiole, especially near the base, there are long, brown, silky hairs. The root-system is well developed, and consists of a mass of tough, wiry, fibrous roots, which bear many branches.

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Anatomy.

Leaf ([figs. 3–10a](#)).—In the leaf all the large veins, especially the midrib, are

prominent on the under-surface. The upper epidermis ([figs. 4 and 5](#)) consists of fairly large cells, more or less oval in transverse section, which have thickened walls, the outer walls being the more thickened. In surface view these cells are irregular in outline. Stomata are numerous, there being

Fig. 2.—*Geum parviflorum*. Plant from exposed position (half natural size).

about 75 per square millimetre on the upper surface. The lower epidermis is similar to the upper, except that the cells are somewhat flatter as seen in transverse section, and as seen in surface view they are more irregular in shape, the cell-walls having a wavy outline. On the lower surface stomata are more numerous, there being about 230 per square millimetre. The stomata are at the same level as the epidermal cells, and the guard-cells have thick walls. On both surfaces of the leaf there are hairs, which are

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Fig. 3.—*Geum parviflorum*. Transverse section of leaf ($\times 36$). *a*, upper epidermis; *b*, palisade tissue; *c*, spongy tissue; *d*, xylem; *e*, phloem; *f*, aqueous tissue; *g*, long unicellular hair; *h*, short unicellular hair.

Fig. 4.—*Geum parviflorum*. Transverse section of leaf ($\times 175$). *a*, upper epidermis; *b*, stoma; *c*, palisade tissue; *d*, spongy tissue.

Fig. 5.—*Geum parviflorum*. Upper epidermis of leaf ($\times 175$). *a*, cells round base of hair; *b*, base of hair.

Fig. 6.—*Geum parviflorum*. Lower epidermis of leaf ($\times 36$). *a*, club-shaped hair; *b*, long unicellular hair; *c*, cells above vascular bundles.

Fig. 7.—*Geum parviflorum*. Club-shaped hair ($\times 175$).

Fig. 8.—*Geum parviflorum*. Base of long unicellular hair ($\times 175$). *a*, hair; *b*, cushion round base.

Fig. 9.—*Geum parviflorum*. Transverse section of petiole ($\times 36$). *a*, aqueous tissue; *b*, bundle-sheath; *c*, xylem; *d*, phloem.

Fig. 10a.—*Geum parviflorum*. Transverse section of base of petiole ($\times 24$). *a*, tannin-containing cells; *b*, bundle-sheath; *c*, xylem; *d*, phloem; *e*, sclerenchyma.

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of several kinds ([figs. 5–8](#)). There are on both surfaces of the leaf long, stiff, bristly, unicellular hairs, which are prolongations of epidermal cells and which have thick walls. Hairs of this type are scattered over the upper surface of the leaf, also on the petiole, and on the lower surface of the leaf they arise from the epidermal cells in the vicinity of the vascular bundles ([fig. 6](#)). The epidermal cells round many of these are somewhat larger than the others, forming a kind of cushion round the base of the hair ([figs. 5 and 8](#)). In addition to the above-described unicellular hairs, there are much shorter, thinner unicellular hairs, both on the leaf (especially the lower surface) and the petiole ([figs. 3, 6, 10](#)). Hairs of a third kind ([figs. 6 and 7](#)) are found near the vascular bundles on the lower surface of the leaf: these are club-shaped, multicellular, glandular hairs; they consist of 3 or 4 cells, of which the basal cell is thick-walled and contains only a small amount of protoplasm; the other 2–3 are thin-walled and filled with granular protoplasm. The end cell is much larger than the others.

The chlorenchyma ([figs. 3 and 4](#)) is differentiated into palisade and spongy tissue. The former consists of two layers of cells which are fairly compactly arranged; the spongy tissue is nearly twice as wide as the palisade, and is composed of rounded or irregular cells with larger air-spaces between them. In both the cell-walls are slightly thickened, and there are numerous large oval chloroplasts.

In the midrib ([fig. 3](#)) there are usually three vascular bundles, of which the central one is the largest. Each vascular bundle is surrounded by a small amount (a layer about 3 cells deep) of colourless parenchyma. Practically the whole of the midrib is filled with an aqueous tissue consisting of large cells with slightly thickened walls; these cells are circular in transverse section and are closely arranged. Just above the vascular bundle some of these cells contain a few chloroplasts. In the midrib, the lower epidermis consists of cells which are small, thick-walled, and, in transverse section, circular. The cuticle here is somewhat thicker. The layer of cells

next to this epidermis has thicker walls than the rest of the aqueous tissue, and the cells themselves are smaller. The xylem consists of vessels which are circular in section, of small diameter, and with thick walls; with the vessels there is xylem parenchyma; the phloem is composed of sievetubes, companion cells, and a little parenchyma. Below the phloem there is a small mass of sclerenchyma.

Petiole ([fig. 9](#)).—This diagram is of half the petiole. The epidermis consists of very small cells in which all the walls are thickened, especially the internal and external walls; a cuticle somewhat thicker than that in the leaf is present. Stomata are found on both surfaces. Some of the epidermal cells are produced into the two kinds of hairs described in connection with the leaf. The short hairs are much more numerous than the long ones. Practically the whole of the ground-tissue forms an aqueous tissue in which the cells are large, rounded or polygonal, with slightly thickened cellulose walls, and are closely arranged so that there are only minute air-spaces between the cells. The three layers of cells just inside the epidermis are smaller, and have thicker walls; in these cells there are a few chloroplasts.

The vascular bundles are arranged in the form of a crescent, the largest being at the centre. Each vascular bundle is surrounded by a sheath of cells, which is clearly distinguished owing to the fact that the cells contain tannin. Round the sheath the cells of the ground-tissue are much smaller. The vascular bundles are the same as in the leaf, except that wood-vessels

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are more numerous, of larger diameter, and more irregular in section. Surrounding the xylem and phloem (between these and the sheath) is small-celled tissue—above the xylem parenchyma, and below the phloem sclerenchyma.

Base of Petiole ([fig. 10a](#)).—The epidermis of the upper surface consists of small cells, usually oval in transverse section, with thin lateral walls but thicker internal and external ones. A thin cuticle is present, and there are no stomata. The cells of the lower epidermis are smaller than those of the upper, and have thicker walls. In

the upper surface the cells of the layer adjacent to the epidermis are large, oval or irregular in shape, with slightly thickened walls. The rest of the ground-tissue consists of large, more or less circular, closely packed cells, many of which contain tannin. Near the lower epidermis there is a layer of smaller cells with thickened walls, also containing tannin; the lower epidermal cells contain tannin. The vascular bundles, of which there are three, all large, are of the same structure as in the upper part of the petiole. In this part, however, the cells of the bundle-sheath are suberized. The parenchymatous elements of both xylem and phloem contain tannin.

Fig. 10b.—*Geum parviflorum*. Transverse section of root ($\times 230$). *a*, dead cortex; *b*, old cork cells; *c*, young cork cells; *d*, cortex; *e*, phloem; *f*, xylem; *g*, starch-containing cells; *h*, pith.

Root (fig. 10b).—This is a diagram of a section of one of the older roots. On the outside are the remains of the old cortical cells. Then comes a layer of cork-cells, all of which contain tannin, and have thick walls; which are, however, only slightly suberized. Internal to the phellogen is cortex, consisting of irregular cells which have thick cellulose walls, and most of which contain tannin. The pith consists of closely arranged rounded or polygonal cells which have thick walls, and many of which contain tannin. Some of the cells also contain starch, in the form of large rounded grains. The xylem and phloem form a continuous cylinder, the amount of phloem being small. In the xylem the number of vessels is few; these are oval or circular in section, and thick-walled. The rest of the xylem consists of wood-fibres, which are thick-walled and polygonal in shape, almost free from tannin, but containing a large amount of starch.

2. Cardamine heterophylla (Forst. f.) O. E. Schulz var.

This plant is a slender, almost glabrous herb. Practically all the leaves are radical; these are 1–4 in. long, and are imparipinnate, the terminal leaflet being much larger than the others, of which there are usually two

Fig. 11.—*Cardamine heterophylla*. Entire plant (two-thirds natural size).

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pairs. The leaflets are rounded or irregularly lobed, with entire margin. A few of the leaves, the shorter ones, have only one leaflet. The flowering-stems are 1–5 in. high, and usually bear a few small leaves, which have usually only 1–3 leaflets (fig. 11). The root-system is well developed, consisting of a main tap-root, which gives rise to numerous branches.

Fig. 12.—*Cardamine heterophylla* Transverse section of portion of leaf ($\times 175$). *a*, small guard-cell of stoma; *b*, hair; *c*, palisade tissue; *d*, xylem; *e*, phloem; *f*, spongy parenchyma; *g*, large epidermal cell.

Fig. 13.—*Cardamine heterophylla*. Upper epidermis in surface view ($\times 175$).

Fig. 14.—*Cardamine heterophylla*. Lower epidermis in surface view ($\times 175$).

Anatomy.

Leaf (figs. 12–14).—Both the upper and the lower epidermis consist of cells which vary considerably in size, both in section and in surface view; some of the cells are

small, others very large, and slightly convex on the outer surface, so that they project somewhat beyond the level of the other

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cells. The cell-walls are thin in both upper and lower surfaces, especially the latter, and here the cells, as seen in surface view, are even more irregular in outline than those of the upper (figs. 13 and 14). Stomata, in which the guard-cells are very small, are found on both surfaces, but are more numerous on the lower; on the upper surface there are about 65 per square millimetre, and on the lower about 105. A few of the cells of the upper epidermis (fig. 12) are produced into long, unicellular, thick-walled hairs, the walls of which are covered with small excrescences of calcium oxalate. On both surfaces is a thin cuticle.

The chlorenchyma is differentiated, although in parts not too clearly. The palisade parenchyma consists of large, thin-walled, more or less oval cells which vary in size and which contain numerous small oval chloroplasts. This layer is usually only one cell deep. The spongy tissue, which occupies the greater part of the leaf, consists of oval or irregular cells which are loosely arranged, so that there are large intercellular air-spaces. This tissue also contains numerous chloroplasts.

The vascular bundles are small, and each is surrounded by a little thin-walled colourless parenchyma. The xylem consists of vessels which in section, are small, circular, and thick-walled; associated with the xylem is a small amount of xylem parenchyma. The phloem is of the usual form.

The leaf is thickened at the midrib, where there is an aqueous tissue, consisting of large, roundish or irregular thin-walled cells, in which there are a very few chloroplasts.

Fig. 15.—*Cardamine heterophylla*. Transverse section of petiole ($\times 72$). *a*, furrow of upper surface; *b*, chlorenchyma; *c*, aqueous tissue.

Petiole ([fig. 15](#)).—The petiole is convex on the lower surface, and on the upper is more or less flattened, with a groove running down each side of the midrib. The epidermis is the same as in the leaf, consisting of small cells, together with much larger, somewhat projecting cells. Stomata are found

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on both surfaces. There are three vascular bundles—a small one near each, margin, and a larger one, which, is surrounded by a well-marked endodermis, occupying the centre of the petiole. Some of the cells of this endodermis are slightly suberized. The structure of the vascular bundle is the same as in the leaf.

The mesophyll consists of large, thin-walled, more or less circular cells which are closely packed together. At the margin—that is, in the vicinity of the small vascular bundles—the cells are smaller, and they contain abundant chloroplasts. In the other part of the ground-tissue, especially near the epidermis, there are a few chloroplasts, but most of this tissue is the colourless aqueous tissue.

Fig. 16.—*Cardamine heterophylla*. Transverse section of flower-bearing stem ($\times 230$). *a*, chlorenchymatous cortex; *b*, endodermis; *c*, pericycle; *d*, phloem; *e*, xylem-vessel; *f*, wood-fibre; *g*, pith.

Flowering-stem ([fig. 16](#)).—The epidermis consists of small oval or rectangular cells in which all the cell-walls, but especially the inner and outer, are thickened; there is a thin cuticle. Stomata are present, the guard-cells being somewhat larger than in the leaf; they are protected by small guard-cell ridges. The whole of the cortex, with the exception of the endodermis, is chlorenchymatous. It consists of oval, thin-walled cells which vary in size and which contain numerous small chloroplasts.

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The endodermis is a single layer of cells; opposite the vascular bundles the cell-walls in this layer are suberized, but not in the vicinity of the medullary rays. The pericycle consists of small, thin-walled, parenchymatous cells.

There are five vascular bundles, arranged in a circle. The xylem consists of vessels of fairly large diameter, together with small wood-fibres.

Fig. 17.—*Cardamine heterophylla*. Transverse section of root ($\times 175$). *a*, suberized cells; *b*, cortex with starch; *c*, phloem; *d*, xylem-vessel; *e*, xylem parenchyma.

The phloem group is nearly as wide as the xylem. Between the bundles the medullary rays are lignified, consisting of small, rounded, thick-walled cells; the xylem and these lignified elements together form an undulating band. The pith is not lignified, and consists of large, thin-walled, circular cells.

Root (fig. 17).—Diagram is from a section of the tap-root. On the outside are a couple of layers of small, irregular, thin-walled, dead cells which

composed of cellulose, are very much thickened; the tissue is compact, with only small intercellular air-spaces. The cortical cells vary considerably in size: in the outer part of the cortex they are large, and irregular in shape; in the inner part they are much smaller, and more or less oval in section. A large amount of starch is stored up in the cortex.

The endodermis and the pericycle are not clearly defined. The xylem occupies the whole of the centre of the root, and is surrounded by a continuous zone of phloem. The vessels of the xylem are scattered; they are of large diameter and have thick walls. Accompanying the vessels there is a large amount of xylem parenchyma which consists of rectangular or irregular thick-walled cells.

3. *Plantago Triandra* Berggr.

This plant is illustrated in fig. 18. It is a small plant, with a short, thick rootstock bearing numerous radical leaves. These leaves are $\frac{1}{2}$ –2 in. long, with irregularly and remotely serrate margins, and sparingly pilose on the

Fig. 18.—*Plantago triandra*. Entire plant (natural size).

upper surface with short hairs, the lower surface being glabrous. The root-system is short, and consists of a mass of fibrous roots which do not branch very much.

Anatomy.

Leaf ([figs. 19–22](#)).—The upper epidermis is sparingly pilose, the hairs being long, jointed ones, consisting of about 6 cells (fig. 21). The basal cell is very large and is more or less circular; its diameter is 2–4 times that of the other epidermal cells. This basal cell is thin-walled at the bottom, but at the outside the wall is much thickened. The rest of the cells of the

hair are large, about twice as long as broad, and the apical cell is wedge-shaped; these cells are thick-walled throughout, but are not cuticularized; they contain protoplasm in the form of primordial utricle and protoplasmic strands, and the nucleus is large and oval. The average length of hair is 0.5 mm. The upper epidermal cells are large, with slightly thickened walls, and somewhat irregular in outline ([fig. 20](#)). Stomata are numerous (about 155 per square millimetre); the guard-cells have thickened walls, are protected by fairly prominent guard-cell ridges, and are at the same level as the epidermis.



Fig. 19.—*Plantago triandra*. Transverse section of leaf ($\times 230$). *a*, hair; *b*, basal cell of hair; *c*, stoma; *d*, palisade parenchyma; *e*, spongy parenchyma; *f*, hydathode.

The lower epidermis is similar to the upper, except that the cells are a little longer, but are smaller in section, and stomata are more numerous (about 200 per square millimetre). A very thin cuticle is present on both surfaces. In addition to the hairs described for the upper surface there are hydathodes—sparingly developed on the upper but more numerous

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on the lower surface. They are of the capitate form (Haberlandt^{*}). They consist of two parts—(1) the basal portion or foot; (2) the head, of about 2 cells. The cells of this latter portion have thickened, non-cuticularized walls ([fig. 19](#)).

The chlorenchyma is differentiated. The palisade tissue consists of 1–3 rows of cells-large, broad cells, the outer layer being composed of cells about twice as deep as broad, the inner layer or layers of cells about as broad as deep. The cells are thin-walled, fairly closely arranged, and contain numerous small ellipsoidal chloroplasts. The spongy tissue also consists of large, thin-walled, oval or somewhat irregular cells, containing a smaller number of chloroplasts. The chloroplasts in the palisade tissue are slightly larger than in the spongy tissue. Beneath each stoma there is a fair-sized air-space.

The vascular bundles are not numerous and are very small. In the midrib there is, between the vascular bundle and the lower surface, a small amount of aqueous tissue, consisting of rounded cells which are

Fig. 20.—*Plantago triandra*. Upper epidermis of leaf ($\times 230$). *a*, guard-cells; *b*, base of hair.

Fig. 21.—*Plantago triandra*. Jointed hair ($\times 48$).

either colourless or contain a few chloroplasts. The mesophyll above the vascular bundle is not differentiated, and consists of very large cells which contain chloroplasts. Below the midrib the cells of the lower epidermis are much smaller, are circular in transverse section, and have all their walls thickened. Above the lower epidermis, in the midrib, is a single layer of colourless collenchyma.

The vascular bundle of the midrib is small, and is surrounded by a bundle-sheath of fairly large, thin-walled cells, in a few of which there is a small number of chloroplasts. The xylem consists of vessels of small diameter, together with xylem parenchyma. There is also parenchyma with the phloem. Above the xylem and below the phloem there is a small amount of sclerenchyma, consisting of small irregular cells with thick walls.

[Footnote] * Haberlandt, *Physiological Plant Anatomy* (English translation), p. 491; London, 1914.

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Leaf-base (fig. 22).—The leaf-base is elongated and sheathing, colourless, and thickened considerably near the centre, but thin and membranous

Fig. 22.—*Plantago triandra*. Transverse section of petiole ($\times 48$). *a*, aqueous tissue; *b*, xylem; *c*, phloem; *d*, bundle-sheath.

at the margins. The upper epidermis consists of large, thin-walled, colourless cells, without any stomata. The outer walls are slightly thicker than the others. The lower epidermis is composed of smaller cells than the upper, and the walls are somewhat thicker.

The ground-tissue consists of large, rounded, thin-walled cells in which the protoplasm is reduced to a very thin layer lining the walls; this tissue is for water-storage. The vascular bundles are small, and of the same structure as in the leaf.

Fig. 23.—*Plantago triandra*. Transverse section of root ($\times 175$). *a*, suberized cells; *b*, cortex; *c*, endodermis; *d*, pericycle; *e*, phloem; *f*, xylem.

Root (fig. 23).—The vascular cylinder is small, consisting of a central mass of xylem, composed of elements of small diameter, and with thickened, pitted walls; surrounding the xylem is a narrow band of phloem. The pericycle is a single layer of thin-walled cells. The endodermis is well marked, and consists of cells somewhat larger than the cells of the pericycle and with thicker, slightly suberized walls.

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The cortex consists of fairly large, thin-walled cells; in an old root, as illustrated, the hairs of the piliferous layer have disappeared, and the subdermal layer of cortical cells have their walls slightly suberized.

4. **Brachycome Sinclairii Hook. f.**

The appearance of a single rosette is given in fig. 24. The plant is more or less succulent, 1–3 in. high, and practically glabrous. The plant has a short, thick, branching rhizome, and it is by this means that the plant is

able to form mats. The leaves are $\frac{1}{4}$ –2 in. long, broad and rounded at the tip, and gradually narrowed into the flat petiole; they are deeply toothed, and in some cases appear even pinnatifid.

Anatomy.

Leaf (figs. 25–27).—In transverse section the cells of the upper epidermis are seen to be large and somewhat squarish, with all their walls thickened, the outer ones considerably, the thickening being equal to about half the depth of the cell-cavity. The stomata, which are numerous, are raised above the cavity of the epidermal cells, but are at the same level as the thickened external walls. The guard-cells have thickened walls and guard-cell ridges. In surface view (fig. 26) the cells of the upper epidermis are seen to be large and irregular or polygonal. A thin, unevenly but not deeply ridged cuticle is present. On the upper surface there are about 220 stomata per square millimetre.

The cells of the lower epidermis (fig. 27) are similar to those of the upper, except that the cell-walls are not so much thickened; in surface view these cells are more irregular in outline than the cells of the upper epidermis. Stomata are not as abundant as on the upper surface; there are 150 per square millimetre. The guard-cells of the stomata of the lower surface are a little smaller than in the upper surface.

The chlorenchyma is differentiated; the palisade tissue occupies about one-third and the spongy parenchyma two-thirds of the mesophyll. In both the cell-walls are very thin. The palisadic cells are oval or oblong in transverse section, about twice as deep as wide, fairly compactly arranged, and containing numerous small rounded chloroplasts. The spongy tissue consists of large, more or less rounded cells, with small air-spaces between the cells; they contain a much smaller number of chloroplasts than the palisade-cells, and form an aqueous tissue.

The vascular bundles are small, and are surrounded by a sheath of thin-walled, colourless cells. The xylem consists of vessels round in section, with thick walls, and of xylem parenchyma. The amount of phloem is small. The leaf is much thicker in the midrib, where the vascular bundle is accompanied by a mass of large, rounded, thin-walled, colourless cells. There is a smaller amount of this colourless tissue with the other bundles.

Petiole ([fig. 28](#)).—The petiole is thick and fleshy, being used for water-storage. The upper epidermis consists of large cells in which the lateral walls are thin, and the inner and outer thickened, but not so much as in the leaf-lamina. A cuticle as in the leaf is present. Many of the epidermal



Fig. 25.—*Brachycome Sinclairii*. Transverse section of leaf ($\times 230$). *a*, ridged cuticle; *b*, thick epidermal wall; *c*, palisade tissue; *d*, spongy tissue; *e*, guard-cell ridge.

Fig. 26.—*Brachycome Sinclairii*. Upper epidermis of leaf ($\times 230$).

Fig. 27.—*Brachycome Sinclairii*. Lower epidermis of leaf ($\times 230$).

cells contain chloroplasts, and near the centre of the petiole, above the midrib, a few of them are produced into long, unicellular hairs which contain protoplasm. At the margin of the petiole are found a few capitate glandular hairs. The lower epidermis is similar to the upper, except that it does not produce any hairs, and the cells are smaller and contain more chloroplasts. There are stomata on the upper but not on the lower surface.

There are five vascular bundles—a large one at the centre, and four very small ones. The bundle-sheath is not clearly marked off from the small-celled parenchyma surrounding the bundle. The structure of the bundles is the same as in the leaf.

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The ground-tissue consists of large, rounded, thin-walled, closely arranged cells.

The 1–2 layers of these cells adjacent to the epidermis are chloren-chymatous, as also in the tissue in the margin of the petiole. The main bulk of the ground-tissue is, however, colourless, forming an aqueous tissue.

Rhizome ([fig. 29](#)).—The epidermis consists of cells which are oval or rounded in transverse section, and which have all their walls slightly thickened, the external being the most thickened. A very thin, uneven, ridged cuticle is present. The cortex consists of large, rounded, colourless cells which have their walls slightly thickened and which form a water-storage tissue. In the inner part of the cortex there are, at intervals, a few secretion-canals which are lined with a layer of thin-walled epithelial cells.



Fig. 28.—*Brachycome Sinclairii*. Transverse section of petiole ($\times 72$). *a*, unicellular hair; *b*, chlorenchyma; *c*, aqueous tissue; *d*, xylem; *e*, phloem.

The endodermis is well marked, consisting of a layer of irregular cells with thin suberized walls. There is no continuous pericycle, but this layer is represented by a number of groups of pericycle fibres, in which the cells have thick, lignified walls and small lumen. The phloem forms a fairly wide band and is continuous round the xylem; it consists of sieve-tubes, companion cells, and a fairly large amount of phloem parenchyma. The xylem joins a practically continuous band of vessels and of wood-fibres with fairly thick walls. It is interrupted by a few uniseriate medullary rays, also with thickened, lignified walls. The pith is solid, and consists of thin-walled, large, round cells.

In an older part of the rhizome the epidermis has disappeared, and the outer layer of the cortex is suberized.



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Root ([fig. 30](#)).—The central cylinder is small, and is surrounded by a clearly marked endodermis, which, as in the rhizome, consists of irregular, thin-walled, suberized cells. The pericycle consists of a single layer of cells about the same size

as the endodermal cells, and with thin cellulose

Fig. 29.—*Brachycome Sinclairii*. Transverse section of rhizome ($\times 175$). *a*, cortex; *b*, canal; *c*, epithelial layer; *d*, endodermis; *e*, pericycle fibres; *f*, phloem; *g*, xylem; *h*, medullary ray.

Fig. 30.—*Brachycome Sinclairii*. Transverse section of root ($\times 175$). *a*, suberized cells; *b*, cortex; *c*, endodermis; *d*, pericycle; *e*, phloem; *f*, xylem.

walls. The xylem forms a compact triangular-shaped mass, and its elements have thick walls. The phloem forms three large masses, and consists of sieve-tubes, companion cells, and phloem parenchyma, all of which have their elements of small diameter.

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The cortex is a wide band of tissue, consisting of large, more or less circular cells, compactly arranged, and with slightly thickened walls.

5. *Gnaphalium Traversii* Hook. f.

The plant is a small perennial herb $\frac{1}{2}$ – $1\frac{1}{2}$ in. high. The plant produces a large number of runners ([figs. 31 and 32](#)), which give rise to new plants at a short distance from the parent plant, so that fairly compact mats are formed by the runners going in all directions. The leaves are $\frac{1}{4}$ – $1\frac{1}{2}$ in. long,

Fig. 31.—*Gnaphalium Traversii*. Plant (half natural size) to show root-system.
Fig. 32.—*Gnaphalium Traversii*. Plant (half natural size) to show runners.

spatulate in shape, and clothed on both surfaces, also on the petiole and runner, with a silvery tomentum. The root-system is a mass of tough, fibrous roots.

Anatomy.

Leaf ([fig. 33](#)).—From the transverse section it is seen that the leaf is very much thickened at the midrib, where there is a large amount of aqueous tissue. The upper epidermis consists of large cells, in which the lateral and inner walls are thin, but the outer are thickened. There is a thin cuticle on both surfaces. The cells of the lower epidermis are much smaller than those of the upper. On both surfaces many of the epidermal cells are produced into long, two-celled hairs, the outer cell being much longer than the basal cell. Stomata are confined to the lower surface, where they are raised above the epidermal cells. The guard-cells are small and have thick walls. Owing to the dense mass of tomentum it is impossible to find the number of stomata per square millimetre.

The mesophyll consists of palisade and spongy tissue. The palisade tissue consists of a single layer of oval cells in which are numerous elongated chloroplasts. The spongy parenchyma, which is compactly arranged, is composed of rounded or oval cells, also containing chloroplasts. All the mesophyll cells are thin-walled.

The aqueous tissue in the midrib consists of large, thin-walled, rounded cells, with small air-spaces between them. Above the lower epidermis in the midrib a single layer of these cells contain chloroplasts.

In addition to the hairs described above, there are club-shaped, glandular hairs, which consist of about 5 cells.

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Petiole.—The petiole is very much thickened at the midrib, but is thin at the margin. The upper epidermis consists of fairly large cells, in which the lateral walls are thin, the inner and outer somewhat thickened. Many of these cells are produced into hairs as in the leaf. Stomata are confined to the lower surface.

The mesophyll consists for the most part of large, thin-walled, rounded or polygonal, closely arranged cells. This tissue is for water-storage. Near the flattened margins of the petiole the cells are smaller and contain a few flattened

chloroplasts.

Fig. 33.—*Gnaphalium Traversii*. Transverse section of leaf, passing through midrib ($\times 175$). *a*, palisade tissue; *b*, spongy tissue; *c*, two-celled hair; *d*, stoma; *e*, glandular hair; *f*, xylem; *g*, phloem; *h*, aqueous tissue.

There are three vascular bundles, the one in the midrib being large, the others smaller. Each is surrounded by a small amount of thin-walled, colourless parenchyma; the bundle has the same structure as in the leaf.

Runner (fig. 34).—This is cylindrical in transverse section. The epidermis consists of small cells, much smaller than in the petiole, which have all their walls slightly thickened. Some of these cells are produced into hairs like those in the leaf, except that, while in the leaf they are usually two-celled, in this case they are three-celled.

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There are a few stomata, the guard-cells of which are level with the other epidermal cells and have thickened walls.

The cortex consists of large, thin-walled, rounded or somewhat irregular cells which have small air-spaces between them and which form a water-storage tissue. In the outermost layers there are a few chloroplasts, which are smaller than those in the leaf.

Fig. 34—*Gnaphalium Traversii*. Transverse section of runner ($\times 230$). *a*, cells with chloroplasts; *b*, colourless cortex; *c*, endodermis; *d*, pericycle; *e*, phloem; *f*, xylem; *g*, pith.

The central cylinder is fairly small, occupying less than half the diameter of the

stem. It is surrounded by a well-marked endodermis in which all the cells are large and have suberized walls.

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The pericycle is a single layer of small thin-walled parenchymatous cells. The phloem and xylem form a continuous cylinder round the pith, which consists of large, rounded cells with somewhat thickened walls. In the xylem the vessels and fibres are polygonal in section and are thick-walled.

Root ([fig. 35](#)).—The diagram is of an old root, in which the piliferous layer has been worn off, exposing the cortex; the outermost layer is of


Fig. 35.—*Ghaphalium Traversii*. Transverse section of root ($\times 230$). *a*, suberized cortex; *b*, cortex; *c*, endodermis; *d*, phloem; *e*, xylem.

small cells with the walls, which are thin, slightly suberized. The rest of the cortex consists of oval or irregular cells with thicker walls, and small air-spaces between the cells.

The endodermis is a single layer of small oval cells with thin suberized walls. The xylem forms a compact central mass, in which the elements are polygonal in transverse section and have thickened walls. The phloem forms a narrow band surrounding the xylem.

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Art. XXXI.—Notes on the Autecology of certain Plants of the Peridotite Belt, Nelson: Part I—Structure of some of the Plants (No. 3).*

By M. Winifred Betts, M.Sc.

[*Read before the Otago Institute, 10th December, 1919; received by Editor, 31st December, 1919; issued separately, 30th June, 1920.*]

25. *Cyathodes acerosa* R. Br.

Habit.—This plant is an erect, branching shrub, 1–2 ft. high; the branches are woody and spreading, and the bark is black. The leaves are spreading, $\frac{1}{4}$ – in. long, acerose, linear, rigid, pungent-pointed, glaucous beneath, with 3 to 7 parallel veins.

Anatomy.

Leaf.—The upper epidermis is composed of very regular rectangular cells which have the longer sides at right angles to the surface of the leaf. These cells have very thick mucilaginous cell-walls, and their cavities are very small and contain tannin. There is a thick cuticle.

The lower epidermis consists of small cells which have thick walls (but not nearly as thick as in the upper epidermis). There is a thick cuticle on this surface also. Most of the cells of the lower epidermis are produced into short papillae with very thick, cutinized walls. Stomata are confined to the lower epidermis; the guard-cells are small, and are at the same level as the other epidermal cells.

The chlorenchyma is differentiated into palisade and spongy tissue. The palisade tissue consists of 3 or 4 rows of narrow, elongated cells. The outermost layer has all the cells full of tannin; the others contain small chloroplasts. The outer layer is very compact, but there are small inter-cellular air-spaces in the inner layers.

The spongy tissue occupies about a quarter of the width of the leaf. It is composed of small, irregular, thin-walled cells, many of which contain tannin. There are small intercellular air-spaces in this tissue.

The number of vascular bundles varies from 3 to 7. The xylem and the phloem are both small in amount, and in the parenchymatous elements there is tannin. Below the phloem there is a mass of stereome, consisting of small cells with their walls so much thickened that their cavities are almost obliterated. Above the upper part of the bundle there is a sheath of small cells with unlignified walls.

Stem.—The cork forms a narrow band; it is composed of very small, thick-walled cells which are very closely arranged.

The cortex consists of oval, thin-walled cells, which contain tannin, and which form a compact tissue with very small intercellular air-spaces.

The phloem is composed of small elements; the medullary rays passing through it contain tannin.

The xylem is composed of a moderate number of vessels which have thick walls. The rest of the xylem consists of wood-fibres which have very thick cell-walls and small lumen.

[Footnote] * For Nos. 1 and 2 see *Trans. N.Z. Inst.*, vol. 50, pp. 230–43, 1918, and vol. 51, pp. 136–56, 1919.

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The medullary rays are uniseriate, frequent, and have thickened, lignified walls, and contain tannin.

The pith is solid, and is composed of large polygonal cells with thick, lignified, and pitted walls. The cells contain tannin.

26. **Gentiana corymbifera T. Kirk.**

Habit.—The plant is a perennial herb. The root is stout, long, and tapering. The stems are simple and rarely branched from the base, stout, erect, terete, 6–20 in. high. The leaves are both radical and caudine. The radical leaves are numerous, rosulate, 1–2½ in. long, ¼–½ in. broad, narrowed into a short petiole. The blade is coriaceous, and rather thick and fleshy. The caudine leaves are few in number, ¾–1½ in. long, linear-lanceolate, and sessile.

Anatomy.

Leaf.—The upper epidermis is composed of large cells which in transverse section are oval. They have all their walls, and especially the external ones, thickened. These cells contain drops of oil. There is a thin, rough cuticle.

The lower epidermis is the same as the upper, except that the cells are somewhat smaller. There is a thin cuticle on this surface also. Stomata are found on both surfaces, but are much more numerous on the lower. The guard-cells are small, and have very thick walls. The stoma is protected by guard-cell ridges which are rather large.

The chlorenchyma is differentiated into palisade and spongy tissue. The palisade tissue consists of 5 rows of large cells with slightly thickened walls. These cells contain very numerous small chloroplasts, and there are small air-spaces between the cells.

The spongy tissue is composed of large, irregular cells, the walls of which are only slightly thickened. There are quite large intercellular air-spaces in this tissue. These cells contain a thin layer of protoplasm in which are embedded small chloroplasts, which are not nearly as numerous as in the palisade tissue; these cells serve as water-storage cells.

The vascular bundles are small and numerous; associated with both the phloem and the xylem there is parenchyma. The bundle is surrounded by a sheath of thin-walled parenchymatous cells which contain a few chloroplasts. Below the main bundle there is a small amount of collenchyma.

Stem.—The epidermis is composed of cells which are large and rounded in transverse section. They have all their walls very much thickened, and there is also a moderately thick, rough cuticle. Some of the epidermal cells contain drops of oil.

Below the epidermis there is a well-marked hypoderma. This consists of cells which are the same as the epidermal cells, and they also have their external walls cuticularized. The hypoderma is in places separated from the epidermis by a large air-space.

The cortex is a wide band; it is composed of large, more or less oval cells which have their walls somewhat thickened. There are very small intercellular air-spaces

in this tissue. In the outer part of the cortex the cells contain a few small chloroplasts. All the cortical cells form an aqueous tissue. The endodermis is well marked; it is a layer of large cells with thin suberized walls.

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The phloem is a fairly wide band of tissue; the sieve-tubes are of small diameter, and there is a large amount of phloem parenchyma. There are also small groups of sieve-tubes on the inside of the xylem.

The xylem is a wide band; it is formed for the greater part of very regular rows of wood-fibres with slightly thickened walls. There are no medullary rays. On the inside of the band of fibres there are a few small vessels.

The pith is composed of large thin-walled cells which have small inter-cellular air-spaces between them.

27. *Myosotis Monroi* Cheesem.

Habit.—This plant is a small perennial herb which is more or less hispid with short, stiff, white hairs. The radial leaves are numerous, $\frac{3}{4}$ –2 in. long, narrow obovate-spathulate, narrowed into a rather long slender petiole, hispid with short, stiff, white hairs on the upper surface, more sparingly so beneath, and sometimes glabrous except the midrib. The caudine leaves are smaller and narrower.

Anatomy.

Leaf (fig. 1).—The upper epidermis consists of large roundish or squarish cells with thin walls, except the external, which are slightly thickened.

Fig. 1.—*Myosotis Monroi*. Transverse section of leaf ($\times 175$). *a*, unicellular hair; *b*, stoma; *c*, palisade parenchyma; *d*, spongy parenchyma; *e*, xylem; *f*, phloem.

A very thin cuticle is present. Numerous epidermal cells are produced into long, stiff hairs with small protuberances on their outside walls. Stomata are found on both surfaces of the leaf; the guard-cells are small

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and have thickened walls, and are level with the surface of the leaf; there are guard-cell ridges.

The lower epidermis is the same as the upper, except that the cells are somewhat smaller. There is a thin cuticle on this surface also. The hairs are not nearly as numerous as on the upper surface.

Fig. 2.—*Myosotis Monroi*. Transverse section of stem ($\times 175$). *a*, unicellular hair; *b*, chlorenchyma; *c*, aqueous tissue; *d*, phloem; *e*, xylem; *f*, pith.

The chlorenchyma is differentiated into palisade and spongy tissue. The palisade tissue consists of 4 rows of cells—the 3 outer layers are of oval cells, while the 4th consists of cells which are more or less rounded in transverse section. These cells contain numerous large chloroplasts, and there are air-spaces between the cells.

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The spongy tissue consists of very large, irregular, thin-walled cells which are loosely arranged, so that there are large air-spaces. These cells also contain numerous chloroplasts, which are, however, smaller than in the palisade tissue. Just above the lower epidermis there is a single layer of more closely arranged roundish cells with abundant large chloroplasts like those in the palisade tissue.

Surrounding the vascular bundle there is a sheath of small, irregular, thin-walled, colourless, parenchymatous cells. Between the sheath around the midrib and the lower epidermis the cells are smaller, compactly arranged, and contain fewer chloroplasts. The vascular bundle contains only a small amount of lignified tissue.

Stem ([fig. 2](#)).—The epidermal cells are small and roundish, and have their external walls somewhat thickened. There is a very thin cuticle. Some of the epidermal cells are produced into hairs like those on the leaf. The stomata are level with the surface; the guard-cells have thickened walls.

Below the epidermis there is a layer of small round cells which have thin walls and which contain numerous chloroplasts. Between this layer of cells and the rest of the cortex there is in most parts a large air-space. Below the air-space the cortical cells vary considerably in size. The first layer consists of roundish cells with fairly numerous chloroplasts; then the cells become much larger. They are more or less polygonal and fairly compactly arranged, so that there are only small intercellular air-spaces. These cells contain a few small chloroplasts; these are found near the corners where three cells meet. Just above the phloem the cells are smaller. All the cortical cells have thin walls.

The amount of phloem is small; the sieve-tubes and the phloem-parenchyma cells are of small diameter.

The xylem forms a continuous band; it consists chiefly of wood-fibres with somewhat thickened walls, and also of a few vessels of small diameter.

The pith is wide and is solid; just below the xylem the cells are smaller, but as we pass inwards the cells get very large; they have thin walls, and are arranged so that there are small intercellular air-spaces.

28. Euphrasia Monroi Hook. f.

Habit.—The plant is a small perennial herb with stems erect or decumbent below, 3–8 in. high, leafy above and sparingly branched. The leaves are rather close-set, spreading, — in. long, obovate or obovate-spathulate, obtuse, narrowed to the base but not evidently petiolate, coriaceous, glabrous, and having one short obtuse tooth on each side.

Anatomy.

Leaf ([figs. 3—6](#)).—On examining the leaf one observes on both surfaces some well-marked grooves. These are shown in figs. 3 and 4. These grooves are dark brown in colour, and are much more numerous on the lower than on the upper surface. On the upper surface there are only two; these pass from the midrib to the single tooth on each margin of the leaf. On the under surface there is a groove running almost round the leaf close to the margin. This groove is somewhat irregular in outline; from it numerous other grooves branch off. Cheeseman (*Manual of the N.Z. Flora*, 1906, p. 554) in describing this plant does not mention these grooves. When transverse sections are taken of the leaf it is seen that the grooves are lined with cells which are water-absorbing cells.

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Figs. 5 and 6 show schematically a section through the upper part and the middle of the lamina respectively. From these diagrams it will be seen that small vascular bundles go to the ventral grooves and end just under the cells lining them. It is reasonable to suppose that these cells are for the purpose of absorbing water and not exuding it.

Fig. 7 gives the structure of the leaf in more detail.

Both the upper and the lower epidermis consist of large, regular cells, those of the upper surface being larger than those of the lower. These cells have their external walls slightly thickened, and there is a thin cuticle. Stomata are found on both

surfaces; the guard-cells are small, have thickened walls, and are level with the surface. There are small guard-cell ridges.

Fig. 3.—*Euphrasia Monroi*. Upper surface of leaf ($\times 4$). *a*, groove.

Fig. 4.—*Euphrasia Monroi*. Lower surface of leaf ($\times 4$). *a*, groove.

Figs. 5, 6.—*Euphrasia Monroi*. Transverse sections through leaf ($\times 30$). *a*, vascular bundles; *b*, cells in grooves.

The chlorenchyma is differentiated, but only to a small extent. Practically the whole width of the leaf is occupied by spongy tissue; the cells just above the lower epidermis are more like spongy tissue, but the transition between the two types of tissue is not very marked. The 3 layers of cells just below the upper epidermis consist of smaller cells which are more or less rounded and have their walls slightly thicker than do the rest of the mesophyll cells. The next 5 or 6 layers of cells are very large, long cells. Just above the lower epidermis the cells are more irregular. All the mesophyll cells contain numerous oval chloroplasts.

In the furrows there are numerous projections for water-absorption. These are formed of 2 cells which have their walls slightly thickened.

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Fig. 7.—*Euphrasia Monroi*. Transverse section of leaf ($\times 175$). *a*, stoma; *b*, upper epidermis; *c*, mesophyll; *d*, vascular bundle; *e*, cell of groove.

Fig. 8.—*Euphrasia Monroi*. Transverse section of upper epidermis just above the midrib. *a*, excretory hair.

Fig. 9.—*Euphrasia Monroi*. Surface view of upper epidermis above midrib. *a*, water-absorbing cell; *b*, stoma; *c*, excretory hair.

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Fig. 10.—*Euphrasia Monroi*. Transverse section of stem ($\times 230$). *a*, epidermis; *b*, dead cortex; *c*, phloem; *d*, xylem; *e*, medullary ray; *f*, pith.

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Below these cells there is a basal cell which is small and has its wall cutinized.

Adjacent to these water-absorbing cells there are several layers of small, thin-walled cells which do not contain any chlorophyll.

Small vascular bundles end blindly in the small-celled tissue adjacent to the water-absorbing cells. The vascular bundles are numerous; both the xylem and the phloem contain parenchyma, and the bundle is surrounded by a sheath of thin-walled, colourless, parenchymatous cells.

On the upper surface, and especially above the midrib, there are a few excretory hairs which are covered with minute excrescences of calcium oxalate. These hairs are seen in surface view in fig. 9 and in transverse section in fig. 8.

Stem (fig. 10).—On the outside there is a bark formed of the dead epidermal and cortical cells. The cells of the cortex and of the epidermis have thickened walls, and the epidermal cells have their external walls cuticularized. A few of the

epidermal cells are produced into short, stiff hairs with thick walls and a thin cuticle.

Bounding the bark there is a single layer of large cells with thin suberized walls: this is the endodermis. Inside this there is a pericycle: this is composed of 1–3 layers of small cells with thickened, lignified walls.

The phloem forms a wide band; the sieve-tubes are of small diameter; with the phloem there is a fair amount of parenchyma.

The xylem forms a wide ring; it is composed of wood-fibres and a few narrow vessels which have thickened walls and are very regularly arranged in rows.

The medullary rays are not very close together; they are uniseriate, and are composed of small cells with thickened lignified walls.

The pith is also lignified; the cells are rounded or polygonal, and have thin walls.

29. *Wahlenbergia albomarginata* Hook.

Habit.—The plant is a small perennial herb, 2–4 in. high with a branched rootstock putting up a few short, erect stems. The leaves are rosulate or crowded on the short stems; they are $\frac{1}{4}$ — in. long, oblanceolate, obtuse, narrowed into a short petiole, entire, thick, and coriaceous; the margins are white and cartilaginous. The peduncles are leafless, one-flowered, and about 6 in. high.

Anatomy.

Leaf ([fig. 11](#)).—The upper epidermis consists of very large cells with thickened walls, especially the external ones. In addition there is a thin, rough cuticle. Some of the cells are produced into long, stiff hairs, the walls of which are very slightly cuticularized.

The lower epidermis is formed of small cells which have their external walls very much thickened. A cuticle is also present. Stomata are confined to the lower surface; the guard-cells are small, and are raised above the other epidermal cells. There are very small guard-cell ridges

The chlorenchyma is differentiated into palisade and spongy tissue. The palisade tissue consists of 3 rows of large, thin-walled cells which contain numerous fairly large chloroplasts. The two outer layers are closely packed, but there are small air-spaces between the cells in the third layer.

The spongy tissue is composed of large, irregular, thin-walled cells which contain numerous chloroplasts; there are moderately large air-spaces between the cells.

In the margins of the leaf the epidermal cells are smaller, and their walls are very much thickened, and some of them are produced into small papillae. Inside this layer there is a group of small cells which have very thick mucilaginous walls and very small cell-cavities.

The vascular bundles are small and contain only a small amount of lignified tissue. There is no stereome. The bundle is surrounded by a sheath of thin-walled colourless cells. Below the midrib there are some small, round, thin-walled cells which do not contain chlorophyll: they are for water-storage.

Peduncle.—The epidermis is composed of small cells which have all their walls, especially the lateral ones, very much thickened. The cavities are small. In addition there is a fairly thick rough cuticle. Stomata are of the same type as in the leaf.

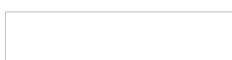


Fig. 11.—*Wahlenbergia albomarginata*. Transverse section of leaf ($\times 48$). *a*, unicellular hair; *b*, large cells of upper epidermis; *c*, cuticle; *d*, stereome in leaf-margin.

The cortex consists of 3–4 layers of oval cells with slightly thickened walls. These cells are closely arranged so that there are only very small air-spaces; the cells contain numerous chloroplasts. The endodermis is well marked, and consists of one layer of cells with thin suberized walls.

The phloem forms a narrow band. The sieve-tubes are of small diameter, and there is a good deal of parenchyma.

The amount of xylem is small. There are small groups of vessels surrounded by wood-fibres which have very thick walls and small cavities. The pith-cells are large and round; most of them are lignified, but there are a few cells in the centre which have unlignified walls.

Stem ([fig. 12](#)).—The epidermis is composed of somewhat larger cells than the epidermis of the peduncle; in transverse section the cells are squarish; their lateral walls are only slightly thickened, but the external

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and internal ones are much more so. There is a thick, rough cuticle. Some of the epidermal cells are produced into hairs like those on the leaf.

The cortex is a wider band than in the peduncle. The cells of the outermost layer have their walls slightly thickened, but the rest of the cortical cells have thin walls. There are only very small intercellular air-spaces. The cells contain a very few small chloroplasts in a peripheral layer of protoplasm. The cortex forms a water-storage tissue.

The endodermis and the phloem are the same as in the peduncle, except that the phloem is a wider zone of tissue. The cambium is easily seen.


Fig. 12.—*Wahlenbergia albomarginata*. Transverse section of stem ($\times 48$). *a*, unicellular hair; *b*, endodermis; *c*, phloem; *d*, cambium; *e*, xylem.

The xylem consists of vessels of small diameter; there is a large amount of xylem parenchyma. The pith is formed of large thin-walled cells which are closely packed together and are not lignified.

30. *Celmisia longifolia* Cass. var. *gracilenta* T. Kirk.

Habit.—This plant is a small, tufted, perennial herb. The leaves are all radical, simple, and erect; they are 3–7 in. long, $1\frac{1}{2}$ —1 in. broad, and the margins are revolute. The whole leaf is covered with silvery-white tomentum, and is produced into a broad sheathing base, which is also covered with tomentum. The sheathing leaf-bases are persistent, and are used to store water (*cf.* with “tunic” grasses—e.g.,

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Anatomy.

Leaf (figs. 13–17).—The general shape of the leaf in transverse section is shown in fig. 13. From this it will be seen that the midrib is very prominent, that the tomentum is thick, and that the leaves are revolute almost to the margin.

[Fig. 14](#) illustrates a *section passing through the midrib*. Both the lower and the upper epidermis consist of regular squarish cells which do not contain chlorophyll and which have their cell-walls very much thickened. There are no stomata in this region. From the epidermal layers very numerous fine hairs are produced, which form a silvery tomentum below the midrib and over the whole of the upper surface of the leaf. There is a thin cuticle on both surfaces of the leaf.

The vascular system in the midrib consists of one large bundle and two much smaller ones. The vessels of the xylem are arranged in very regular rows separated by xylem parenchyma. There is also a fairly large amount of parenchyma in the phloem. Above the phloem and below the xylem there is a mass of stereome, consisting of cells with very thick walls and small cavities. The cells above the xylem are larger than those below the phloem.

Fig. 13.—*Celmisia longifolia var. gracilenta*. Transverse section of leaf ($\times 36$). *a*, tomentum; *b*, vascular bundle.

Just above the lower epidermis there are 2 rows of chlorenchymatous cells. These cells are roundish, and have their walls slightly thickened, and contain numerous chloroplasts. Just below the main bundle these cells have their walls much thicker and contain a much smaller number of chloroplasts.

All the space between the upper epidermis and the chlorenchyma of the lower surface (except that occupied by the vascular bundles) is filled by a tissue consisting of very large cells with fairly thin walls. These cells are arranged very closely together, so that there are only minute intercellular air-spaces where three cells meet. All these cells form an aqueous tissue.

Section of the Leaf through the Lamina ([fig. 15](#)).—The upper epidermis consists of regular more or less squarish cells which are larger than the epidermal cells above the midrib. They have their walls considerably thickened, the external walls being thickened the most, and there is a

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rather thin, rough cuticle. From the upper surface there is produced a tomentum which is composed of very fine hairs. These hairs are 3–4 celled; the lowest cell has a cutinized wall.

Fig. 14.—*Celmisia longifolia var. gracilenta*. Transverse section of leaf passing through midrib ($\times 175$). *a*, upper epidermis; *b*, oil-drops; *c*, xylem; *d*, phloem; *e*, long multicellular hairs; *f*, shorter, more slender hairs; *g*, aqueous tissue.

The chlorenchyma is differentiated into palisade and spongy tissue. The palisade tissue consists of one layer of large, thin-walled cells, which contain numerous chloroplasts and also some large oil-globules. There are small intercellular air-spaces in this tissue.

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Fig. 15.—*Celmisia longifolia* var. *gracilenta*. Transverse section of lamina of leaf. *a*, upper epidermis; *b*, palisade parenchyma; *c*, oil-drops; *d*, spongy tissue; *e*, stoma; *f*, multicellular hair.

Fig. 16.—*Celmisia longifolia* var. *gracilenta*. Transverse section of sheathing leaf-base ($\times 36$). *a*, tomentum; *b*, vascular bundle.

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The spongy tissue is composed of about 6 rows of cells. In the upper part of the leaf these cells are about the same length as breadth, but just above the lower epidermis they are narrower and are elongated in a direction parallel with the surface of the leaf. These cells also have thin walls and contain oil, which is more abundant nearer the upper than near the lower surface of the leaf.

The lower epidermis consists of cells which are oval in transverse section. Many of them are produced into long, stout, several-celled hairs which have thin walls. The lowest cell has a thin cuticle. These hairs

Fig. 17.—*Celmisia longifolia* var. *gracilenta*. Transverse section of sheathing leaf-base ($\times 175$). *a*, upper epidermis; *b*, hypoderma; *c*, mesophyll; *d*, stereome; *e*, xylem; *f*, phloem; *g*, multicellular hair.

are much longer and thicker than those of the upper surface (and those beneath the midrib), and they do not form such a dense mass, so that their form can be seen more easily.

Stomata are confined to the lower surface of the leaf, where they are numerous. As is often the case with leaves which have a dense tomentum, the stomata are raised above the epidermal cells. The guard-cells have very thick walls, and there are guard-cell ridges.

Sheathing Leaf-base ([figs. 16](#) and [17](#)).—Fig. 16 gives a schematic view of this; fig. 17 shows the structure in detail.

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Both the upper and the lower epidermis consist of very regular cells, the walls of which are only slightly thickened. On both surfaces there is a thin cuticle, and on the lower (the outer) surface there are a number of hairs like those on the lower surface of the leaf.

Beneath the upper epidermis there is a hypoderma which is composed of a single layer of small sclerized cells in which the walls are very thick and the lumen very small.


Fig. 18.—*Celmisia longifolia* var. *gracilenta*. Transverse section of peduncle ($\times 230$). *a*, multicellular hairs; *b*, ridged cuticle; *c*, un lignified cortex; *d*, lignified cortex; *e*, xylem; *f*, phloem.

The vascular bundles are of the same type as that described for the leaves, but the stereome above the xylem and below the phloem is formed of much smaller cells than in the leaf. All the mesophyll consists of aqueous tissue, which is composed of thin-walled, colourless cells. Near the lower surface there are 2 rows of these cells, which are regularly

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arranged, the inner layer consisting of much larger cells than the outer. These cells are roundish or squarish in section, but the rest of the cells of the aqueous tissue are very irregular in outline. They lie close together, so that the intercellular air-spaces are minute.

Peduncle ([fig. 18](#)).—The epidermis consists of somewhat irregular cells which have very thick walls, especially the external ones. From some of the epidermal cells there are produced long multicellular hairs like those on the under-surface of the leaf. A thin cuticle is present; its surface presents numerous very fine ridges.

Below the epidermis there is a zone of dead cortex, consisting of very irregular, thick-walled cells with brown contents. The rest of the ground-tissue of the stem consists of lignified tissue. This can be divided into two regions—

(1.) An outer region where the vascular bundles are found. The cells in this region are rather small and have thick walls.

(2.) An inner pith in which the cells have thin but lignified walls. These cells are large and roundish. Small intercellular air-spaces are found in this tissue. The stem is hollow.

The vascular bundles are small and quite separate from one another. There is parenchyma in both the phloem and the xylem. The scleren-chymatous cells around the bundles are small.

31. *Olearia virgata* Hook. f.

Habit.—This plant is an erect, much-branched shrub, 2–5 ft. high. The branches are spreading, tetragonous when young, almost terete in the older parts. The

young branches are pubescent. The bark is dark red-brown. The leaves are opposite, obtuse, narrowed into a very short petiole, glabrous above and clothed with white tomentum beneath.

Anatomy.

Leaf ([fig. 19](#)).—The upper epidermis consists of medium-sized oblong cells; these have thin lateral and internal walls, but the external walls are thickened, and in addition there is a cuticle, which is, however, only a thin one. There are no stomata on the upper surface.

The lower epidermis is like the upper, but the external walls are not thickened, and many of the epidermal cells are produced into large T-shaped hairs, which are closely appressed to the surface.

The stomata are confined to the lower epidermis, and they are raised above the epidermal cells. The guard-cells are small and have thickened walls.

The chlorenchyma is differentiated. The palisade tissue consists of 2 rows of closely packed cells, the depth of which is only about one and a half times the breadth. The cells are thin-walled and contain numerous large chloroplasts.

The spongy tissue consists of 4 or 5 layers of irregular thin-walled cells with large air-spaces between them. These cells contain numerous chloroplasts, which are slightly smaller than those in the palisade tissue. The cells of the layer just above the lower epidermis are smaller and are more closely arranged.

The vascular bundle is small, and like that in *Celmisia longifolia* var. *gracilenta* except that there is no stereome. The vascular bundle is surrounded by a sheath of small, thin-walled, parenchymatous cells which contain a few chloroplasts arranged along their outside walls.

Fig. 19.—*Olearia virgata*. *a*, upper epidermis; *b*, palisade parenchyma; *c*, spongy parenchyma; *d*, xylem; *e*, phloem; *f*, T-shaped hairs.

Fig. 20.—*Olearia virgata*. Transverse section of stem ($\times 36$).

Fig. 21.—*Olearia virgata*. Transverse section of stem ($\times 175$). *a*, sclerenchyma; *b*, corky cells; *c*, chlorenchyma; *d*, pericycle fibres; *e*, phloem; *f*, xylem; *g*, lignified pith.

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Stem (figs. 20 and 21).—The general arrangement of the tissues is shown diagrammatically in fig., 20. From this it will be seen that the stem is tetragonal and that in each of the corners there is a small mass of sclerenchyma. The structure of the stem is shown in detail in fig. 21.

On the outside there are dead epidermal cells with a thin cuticle, and below this there are a few dead cortical cells. Beneath this layer there are 2–4 layers of large, squarish cells which have their cell-walls both suberized and lignified. The portion of the cell-wall adjacent to the cell-cavity is suberized, and nearer the middle lamella it is lignified.

Inside this corky layer there is a zone of cortex. The cells of this tissue are more or less oval in transverse section, and are closely packed together so that the intercellular air-spaces are very small. These cells contain a small number of chloroplasts. At intervals there are groups of pericycle fibres. These are of small diameter and have thick walls. In the four corners of the stem there is a mass of sclerenchyma, which is composed of slightly larger cells than the pericycle fibres.

The phloem forms a continuous band with its elements rather regularly arranged. The xylem is composed for the greater part of wood-fibres which have thickened walls.

The medullary rays are not numerous; they are multiseriate (3 cells wide), and their cells have thickened, lignified walls.

The pith is composed of large round or polygonal cells, which have lignified,

somewhat thickened, cell-walls.

32. *Helichrysum bellidoides* Hook. f.

Habit.—This plant is an herb. The stems are prostrate, slender, much branched, almost woody at the base, 6–12 in. long; the branches are numerous, erect, and leafy. The leaves are loosely imbricating, spreading, $\frac{1}{4}$ — $\frac{1}{2}$ in. long, obovate-spathulate, apiculate, flat, one-nerved, with the upper surface glabrous and the lower clothed with cottony tomentum.

Anatomy.

Leaf.—The upper epidermis consists of regular, large cells, which have their inner and lateral walls thin and the external ones slightly thickened. There is a thin cuticle. A few of the cells are produced into hairs.

The lower epidermis consists of cells that are smaller than those of the upper epidermis. Their walls are thin, and there is a very thin cuticle. Many of these cells are produced into fine 2- or 3-celled hairs, which form a dense tomentum on the under-surface.

The chlorenchyma is differentiated into palisade and spongy tissue. The palisade tissue consists of 2 rows of cells with thin walls and numerous large chloroplasts; there are air-spaces between the cells.

The spongy tissue is composed of large, irregular, thin-walled cells, which contain abundant large chloroplasts. These cells form a rather loose tissue with large intercellular air-spaces.

Stomata are confined to the lower epidermis, and the guard-cells are raised (as in *Celmisia longifolia* var. *gracilenta*, *Olearia virgata*, and *O. arborescens*). The guard-cells are small.

The vascular bundle is small, and is surrounded by a sheath of thin-walled cells which contain a very few chloroplasts. Just above the xylem there is a small group of 8 or 10 sclerized cells. The amount of lignified tissue in the xylem is small; both xylem and phloem contain parenchyma.

Between the bundle-sheath and the lower epidermis there are some thin-walled colourless cells which store water.

Stem.—The epidermis consists of squarish cells with their walls slightly thickened and with a thin cuticle. These cells contain tannin. Some of the epidermal cells are produced into hairs like those on the leaf.

The cortex consists of small regular cells; in the outer part of the cortex these cells have their walls lignified and also suberized. The inner layers of cortical tissue consist of thin-walled cells. All the cortical cells are closely packed together, so that there are only very small intercellular air-spaces. There is a well-marked endodermis, which consists of large cells with suberized walls.

The phloem forms a wide, continuous band; it contains a large amount of parenchyma.

The xylem forms a band about the same width as the phloem; it consists of vessels of rather small diameter and of wood-fibres.

The pith is solid, and consists of large, thin-walled polygonal cells which are closely arranged together. The pith-cells adjacent to the xylem are somewhat smaller and have their walls lignified.

33. *Cassinia Vauvilliersii* Hook. f. var. *rubra* Buch.

Habit.—This plant is an erect, closely branching shrub, 2–4 ft. high; the branches are stout, erect, and often glutinous. The leaves are numerous, close-set, erect or spreading, $\frac{1}{4}$ — in. long, linear-obovate, narrowed into a short broad petiole, very coriaceous, clothed with hairs on both surfaces; the margins are slightly recurved.

Anatomy.

Leaf.—The upper epidermis consists of rather small cells which have slightly thickened walls. These cells contain a few small chloroplasts. There is a thick cuticle. Some of the epidermal cells are produced into long 3- or 4-celled hairs—2 or 3 small hairs at the base and a long cell at the end. There are no stomata on the

upper surface.

The lower epidermal cells are smaller than the upper, and, like the latter, contain chloroplasts. Many of the cells are produced into hairs like those on the upper surface. The lower epidermal cells have slightly thickened walls, and there is also a thick cuticle.

The chlorenchyma is differentiated. The palisade tissue consists of 4 rows of large cells with slightly thickened walls and large chloroplasts. There are very small air-spaces between the cells.

The spongy parenchyma is composed of rather small, irregular cells which contain large chloroplasts. The walls are slightly thickened, and there are fairly large air-spaces between the cells.

Stomata are confined to the lower surface; they are of the same type as in *Celmisia longifolia* var. *gracilenta*.

The vascular bundles are small, and contain only a small amount of lignified tissue. They are surrounded by a sheath of thin-walled parenchymatous cells which contain only a small number of chloroplasts.

Stem.—The epidermis is composed of small cells which have thickened walls and also a fairly thick cuticle. Many of the cells are produced into hairs like those on the leaf.

Then there come some dead cortical cells; these have thick brown walls. Inside this layer there is suberized tissue, from 1 to 4 cells deep. The cells are large, thin-walled, and irregular.

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Below this tissue there are large groups of pericycle fibres; these have a small diameter, and their walls are thickened.

The phloem forms a wide band, with the sieve-tubes of small diameter; there is a fairly large amount of phloem parenchyma. The cambium is very easily seen.

The xylem contains vessels of fairly large diameter and wood-fibres which have very thick walls. There are no medullary rays.

The pith is solid; it consists of large roundish cells with thin walls.

34. *Senecio bellidoides* Hook. f.

Habit.—This is a small rosette plant. The leaves are all radical and spreading; the blades $\frac{3}{4}$ — $2\frac{1}{2}$ in. long, broadly oblong, obtuse, rounded or slightly cordate at the base, membranous, with entire margins; the upper surface is more or less covered with stiff glandular hairs, and the lower is sparingly covered with tomentum. The petioles are about $\frac{3}{4}$ in. long, and are covered with hairs. The scapes are 1–12 in. high, branched, and pubescent.

Anatomy.

Leaf ([figs. 22–26](#)).—Fig. 22 gives a diagrammatic view of the transverse section of the leaf. From this it will be seen that the number of vascular bundles is small; the relative frequency of the different types is also seen in this diagram. Fig. 24 shows the structure of the midrib, and fig. 23 of the blade of the leaf.

The upper epidermis consists of rather small cells, the outer walls of which are slightly thickened. There is a thin cuticle present. Stomata are found on both surfaces; the guard-cells are level with the surface, and have thickened walls and small guard-cell ridges. Some of the upper epidermal cells are produced into hairs of two kinds—

- (1.) Capitate glandular hairs: These are very long, and are multicellular, and have a rounded head.

- (2.) There are also other multicellular hairs formed of about 9 cells. At the base there are about 7 small rectangular cells which are closely packed together and have their outer walls slightly cuticularized. Above these cells there is a large, wide, and shallow cell which has a thick but uncutinized wall. Beyond this cell there is an elongated one, also with a thickened, uncutinized wall.

The lower epidermis also consists of cells which are more or less oval in transverse section. They have thin walls, except for the external ones, which are slightly thickened. There is a thin cuticle. Stomata are present on this surface also. The epidermal cells contain a few chloroplasts. Some of the epidermal cells give rise to

hairs of two kinds—

- (1.) There are a few glandular hairs as on the upper surface.
- (2.) Most of the hairs are like those on the upper surface, except that there are usually only 4 of the small cells and there are 2 long cells instead of 1.

The chlorenchyma is only slightly differentiated. The palisade tissue consists of 2 rows of cells, which have thin walls and contain numerous chloroplasts. These cells are wide and do not have the typical palisade form; they are fairly loosely arranged, so that there are large air-spaces between the cells.

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Fig. 22.—*Senecio bellidoides*. Transverse section of leaf ($\times 24$). *a*, glandular hair; *b*, multicellular hair; *c*, vascular bundle.

Fig. 23.—*Senecio bellidoides*. Transverse section of leaf ($\times 110$). *a*, glandular hair; *b*, multicellular hair; *c*, stoma; *d*, mesophyll.

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The spongy tissue consists of about 5 rows of large, irregular cells which have thin walls. There are fairly large air-spaces between the cells. The cells of the layer just above the lower epidermis are much smaller.

The Midrib.—There are three vascular bundles in the midrib. The lignified elements of the xylem are arranged regularly in rows which are



Fig. 24.—*Senecio bellidoides*. Transverse section through midrib of leaf. *a*, multicellular hair; *b*, aqueous tissue; *c*, xylem; *d*, phloem; *e*, canal lined by epithelial layer; *f*, chlorenchyma; *g*, glandular hair.

separated by xylem parenchyma. There is a good deal of parenchyma with the phloem. Beneath the phloem of each bundle there are 1 or 2 large canals, which are lined by epithelial cells.

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Under the upper epidermis there are a few cells which have thickened walls, and above the lower epidermis there are 2 rows of roundish cells which contain chloroplasts and which have their walls slightly thickened.



Fig. 25.—*Senecio bellidioides*. Upper epidermis of leaf ($\times 36$).

Fig. 26.—*Senecio bellidioides*. Lower epidermis of leaf ($\times 36$).

Fig. 27.—*Senecio bellidioides*. Transverse section of scape ($\times 36$)

The rest of the midrib is occupied by a mass of large, closely packed, thin-walled, more or less polygonal cells. These cells form a water-storage tissue.

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Figs. 25 and 26 show the surface view of the upper and lower faces of the leaf. From these it will be seen (1) that the glandular hairs are much more frequent on the upper surface, and (2) that most of the multicellular hairs of the lower epidermis are situated over the vascular bundles. This would suggest that they are for water-absorption.

Fig. 28.—*Senecio bellidioides*. Transverse section of scape ($\times 175$). *a*, multicellular hair; *b*, glandular hair; *c*, chlorenchyma; *d*, lignified tissue; *e*, vascular bundle; *f*, pith.

Scape ([figs. 27](#) and [28](#)).—The structure of the scape is shown schematically in fig. 27 and in detail in fig. 28.

The epidermis consists of fairly large cells which have thickened walls. A thin, ridged cuticle is present. Stomata are present, but they are not numerous. They are of the same type as those in the leaf. There are two kinds of hairs—(1) glandular; (2) hairs like those described for the upper epidermis, but the large cell at the base of the elongated cell is not present.

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The chlorenchyma consists of about 5 rows of large, roundish cells which have thin walls and numerous chloroplasts. There are moderately large air-spaces in this tissue.

Then there comes a band of smaller, roundish cells which have thickened, lignified walls. Below this there is the phloem, which is a narrow band of tissue. The xylem contains parenchymatous cells.

35. *Gahnia procera* Forst.

Habit.—This is a perennial tufted herb. The stems are about 2 ft. high, and are stout. The leaves are as long as or slightly longer than the stems, and are narrowed into long filiform points; the margins are involute, smooth above and scabrid below; the sheaths are dark brown or almost black.

Anatomy.

Leaf ([figs. 29–32](#)).—The transverse section of this is shown diagrammatically in fig. 29. This shows that the leaf is involute and furrowed, and that under each ridge there is a vascular bundle, accompanied by an extensive development of sclerenchyma. The margin of the leaf is occupied by a mass of sclerenchyma. Figs. 30–32 show the structure of the leaf in more detail.

Fig. 29.—*Gahnia procera*. Transverse section of leaf ($\times 36$). *a*, chlorenchyma; *b*, sclerenchyma; *c*, vascular bundles.

Fig. 33.—*Gahnia procera*. Transverse section of stem ($\times 24$). *a*, sclerenchyma; *b*, vascular bundles.

The upper epidermis consists of small cells, which taper slightly towards the outside of the leaf. The walls of these cells are thickened, especially the external walls, which produce small papillae. There is no cuticle.

The lower epidermis consists of very regular oval cells, which have their cell-walls,

especially the external ones, thickened. There is a thin cuticle on the lower surface.

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Fig. 30.—*Gahnia procera*. Transverse section of leaf ($\times 230$), *a*, upper epidermis; *b*, hypoderma; *c*, mesophyll; *d*, pulvinus; *e*, xylem; *f*, phloem; *g*, sclerenchyma.

Fig. 31.—*Gahnia procera*. Lower epidermis of leaf, at margin ($\times 230$) *a*, stiff, unicellular hair.

Fig. 32.—*Gahnia procera*. Transverse section of margin of leaf ($\times 230$) *a*, hair; *b*, sclerenchyma.

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Stomata are confined to the upper surface, where they are found only in the furrows. They are sunken below the level of the epidermal cells, and the guard-cells are small and have very thick cell-walls. The epidermal cells in the furrow are somewhat pear-shaped, and their walls are irregularly thickened, the result being a number of short papillae which serve to protect the stomata.

At the base of each furrow there are 3–5 large cells, which form a pulvinus. The cells of the pulvinus have a very thin cuticle, but the other epidermal cells are not

cuticularized.

The chlorenchyma is not differentiated into palisade and spongy tissue. The cells of this tissue are small, more or less polygonal, and very closely packed together. They contain a small number of fairly large chloroplasts: Some of the cells of this tissue contain tannin.

Below the upper epidermis, in the ridges, there is a hypoderma of very small lignified cells, in which the walls are very thick, so that the lumen is very small. In the middle of the ridge these sclerenchymatous cells are continued downwards, forming a band several cells wide, and then forming a sheath above the upper part of the vascular bundle.

The vascular bundle is surrounded by a sheath of oval lignified cells the inner cell-walls of which are thicker than the outer. The vascular bundle is of the usual monocotyledonous type, and has all the xylem parenchyma lignified.

Below the vascular bundle there is another zone of sclerenchyma, this being continued as a layer from 1 to 5 cells thick above the lower epidermis and below the chlorenchyma. These cells are small and have very small cell-cavities.

On the upper portion of the leaf there are small, stiff hairs on the lower surface and on the margins of the leaf. These are shown in figs. 31 and 32. They are very stiff, unicellular hairs with very thick stratified cell-walls, and are formed from the epidermal cells.

Peduncle.—This is shown diagrammatically in figure 33 (p. 301). The stem is hollow, and all the tissues except the epidermis and the phloem are lignified. This diagram shows the irregular arrangement of the vascular bundles, each of which is surrounded by-sclerenchyma.

Fig. 34 gives a more detailed view of part of the stem.

The epidermis consists of small pear-shaped cells with thickened cell-walls. A fairly thick cuticle is present.

Beneath the epidermis there is a more or less regular circle of vascular bundles, each of which is surrounded by a large mass of sclerenchyma, consisting of small cells with very thick cell-walls.

As we pass inwards the bundles become larger, and the amount of sclerenchyma around them is not so great. The cells of the sclerenchyma are somewhat larger and have larger cell-cavities.

The ground-tissue consists of fairly large, more or less regular cells, the walls of which are only slightly thickened and are lignified. These cells are closely arranged, so that there are only very small intercellular air-spaces. The cortical cells near the

middle of the stem are somewhat larger, and the cell-walls are thinner.

Bounding the ground-tissue there is a zone of cells which are very irregular both in shape and in size. These cells are empty and their walls are suberized.

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Fig. 34.—*Gahnia procera*. Transverse section of stem ($\times 150$). *a*, cuticle; *b*, sclerenchyma; *c*, xylem; *d*, phloem.

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36. *Astelia montana* (T. Kirk) Cockayne.

Habit.—This is a stout, densely tufted, perennial herb. The leaves are numerous, spreading, 1–2 ft. long and $\frac{1}{2}$ – $\frac{3}{4}$ in. broad, linear-lanceolate and acuminate. The leaves are very tough and leathery, and are many-veined; one nerve on each side is more prominent than the rest, and the margins and midrib are often coloured a yellow-red. Both the upper and the lower faces of the leaf are clothed with white tomentum. The base of the leaf is sheathing; and is densely covered with long silky hairs.

Anatomy.

Leaf.—Fig. 35 gives diagrammatically a view of a transverse section of half the leaf. From this it will be seen that there are two veins much more prominent than the others, and also more prominent than the midrib. Fig. 36 shows a transverse section through the midrib, and fig. 37 through one of the prominent veins.

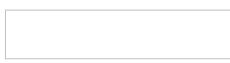


Fig. 35.—*Astelia montana*. Transverse section of leaf ($\times 9$). *a*, tomentum; *b*, aqueous tissue; *c*, stereome; *d*, vascular bundle; *e*, chlorenchyma.

Section through Midrib.—Both the upper and the lower epidermis consist of large cells somewhat elongated in a direction at right angles to the surface of the leaf. Above and below the veins the epidermal cells are more or less squarish. The epidermal cells have their walls, especially the external ones, thickened, and there is a cuticle present on both surfaces.

At intervals on both surfaces the epidermis is interrupted by groups of peculiarly modified cells forming a kind of scale. The scale consists of a short stalk of thin-walled cells, and above this the cells are larger and have thickened, cutinized walls. The cuticle of the uppermost tier of cells is frayed out into a kind of tomentum which more or less covers the surface of the leaf. The whole apparatus appears to be a modification for water-absorption.

Below the upper epidermis there is a zone of aqueous tissue, consisting of about 4 rows of very large, regularly arranged, closely packed, rectangular cells, which do not contain chloroplasts, and which have thickened, mucilaginous cell-walls.

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The chlorenchyma is not differentiated into spongy and palisade tissue. It consists of closely packed polygonal or roundish cells which contain numerous chloroplasts. There are no intercellular air-spaces.

Stomata are found on the lower surface only. The guard-cells are sunken below the surface of the epidermis, and the stomata are further protected by small guard-cell ridges over the opening. Subsidiary cells are present.

Fig. 36.—*Astelia montana*. Transverse section through midrib ($\times 175$). *a*, tomentum; *b*, upper epidermis; *c*, aqueous tissue; *d*, mesophyll; *e*, stoma; *f*, hair; *g*, stereome.

The vascular bundle is surrounded by a large mass of sclerenchyma: these cells are irregular and very closely packed, and have fairly thick cell-walls. The xylem and the phloem have the cell-walls of all the paren-chymatous cells lignified. The layer of mesophyll cells adjacent to the sclerenchyma is devoid of chloroplasts.

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Section through the Lamina in the Region of a Prominent Vein (fig. 37)—In these veins there is a large, more or less T-shaped mass of sclerenchyma surrounding the vascular bundle. As in the midrib, these cells are smaller on the under side than on the upper side, but here those on the upper surface are much larger than those above the midrib.

Fig. 37.—*Astelia montana*. Section through one of large veins ($\times 175$). *a*, tomentum; *b*, upper epidermis; *c*, aqueous tissue; *d*, mesophyll; *e*, stoma; *f*, hair; *g*, stereome.

Between the sclerenchyma and the upper epidermis there is a hypoderma of aqueous tissue consisting of more or less oval cells. Between the sclerenchyma and the lower epidermis this layer is only one cell thick.

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As we pass away from the midrib the aqueous tissue consists of rounded or polygonal cells which are not arranged in the definite rows found near the midrib.

37. *Dianella intermedia* Endl.

Habit.—This plant is a perennial herb, bearing numerous leaves, which are crowded at the base of the stem. The leaves are linear, 1–1½ ft. long, ½ in. wide, and are arranged in two vertical rows (distichous); the bases of the leaves are sheathing. The margins and the midrib are coloured orange-red.

Fig. 38.—*Dianella intermedia*. Transverse section of leaf ($\times 24$). *a*, cuticle; *b*, stereome; *c*, vascular bundle; *d*, aqueous tissue.

Fig. 39.—*Dianella intermedia*. Transverse section through midrib of leaf ($\times 175$). *a*, cuticle of upper surface; *b*, aqueous tissue; *c*, chlorenchyma; *d*, cuticle of lower surface; *e*, stoma; *f*, stereome; *g*, xylem; *h*, phloem.

Anatomy.

Leaf (figs. 38–43).—Fig. 38 shows the general arrangement of the tissues in a transverse section of the leaf. The vascular bundles are surrounded by a large band of sclerenchyma, which traverses the whole width of the leaf. Under the upper epidermis are some lignified cells, and in the centre of each mass of chlorenchyma there is some aqueous tissue. Fig. 39 shows in more detail the structure at the midrib.

The upper epidermis consists of rather irregular cells with thickened cell-walls. A thick cuticle is also present.

Below the epidermis there are 2 rows of large cells with thickened, somewhat mucilaginous cell-walls. These do not contain chloroplasts, and they form an aqueous tissue.

The chlorenchyma is not differentiated into palisade and spongy parenchyma. It consists of rounded or polygonal cells which contain numerous chloroplasts.

Fig. 40.—*Dianella intermedia*. Transverse section through lamina of leaf ($\times 175$). *a*, cuticle; *b*, hypoderma; *c*, stereome; *d*, lignified sheath; *e*, chlorenchyma; *f*, aqueous tissue; *g*, xylem; *h*, phloem.

The lower epidermis is formed of roundish or oval cells. There is a thick cuticle on this surface also.

The stomata are confined to the lower surface, and are found in the slight grooves. The guard-cells are small, and are deeply sunken below the surface, and the opening is protected by projections of the cuticle. All the epidermal cells in the grooves have curious peg-like cuticular projections, so that a surface view presents a peculiar appearance. These are shown in surface view in fig. 42, and in transverse section in fig. 43.

Fig. 40 gives a transverse section through the lamina, not passing through the midrib. The cuticle is much thicker than above the midrib. The upper epidermis consists of regular oblong cells, which are a little larger above the sclerenchyma.

Below this there is a hypoderma, from 1 to 4 cells deep, which consists of regular cells with lignified walls. Above the sclerenchyma bands this layer is only 1 cell thick, but above the chlorenchyma 2–3.



Fig. 41.—*Dianella intermedia*. Transverse section of margin of leaf ($\times 260$). *a*, cuticle; *b*, sclerenchyma.

Fig. 42.—*Dianella intermedia* Surface view of epidermis of lower surface ($\times 260$). *a*, opening above stomata.

Fig. 43.—*Dianella intermedia*. *a*, guard-cells; *b*, cuticle.

The sclerenchyma consists of irregular cells with small cavities. Near the upper surface of the leaf these cells are much larger than they are near the lower surface.

The band of lignified cells beneath the upper epidermis is continued down beside each band of sclerenchyma. Here it is 2 cells wide, and consists of oval cells.

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The chlorenchyma forms a compact mass, and in the centre of it there is some aqueous tissue which consists of very large roundish cells with very thin cell-walls.

Fig. 41 shows a transverse section of the margin of the leaf. The cuticle is very

thick. The cells of the upper epidermis are slightly elongated at right angles to the surface of the leaf, and have thickened walls, and the cells of the lower epidermis are smaller and are squarish. Beneath the epidermis there is a hypoderma composed of 1 or 2 layers of cells with thickened, lignified cell-walls. The rest of the margin is occupied by a large mass of sclerenchyma, the cells of which have their lumen almost obliterated.

38. *Libertia ixoides* Spreng.

Habit.—A perennial herb with a short creeping rhizome and long fibrous roots. The leaves are numerous, densely crowded, linear, flat, rigid, and arranged in two vertical series (distichous). The margins are cartilaginous and smooth.

Anatomy.

Leaf ([figs. 44–47](#)).—Fig. 44 shows diagrammatically a view of half the transverse section of the leaf. From this it will be seen that the vascular bundles are arranged in two series, one along each face of the leaf; that the bundles are opposite, and that each is surrounded by a mass of sclerenchyma.

Figs. 45 and 46 show in more detail the structure in transverse section.

The epidermis is composed of small, squarish cells, all the walls of which are thickened, and there is also a thick cuticle.

Stomata are found on both surfaces, and they are fairly frequent. The guard-cells are sunken right below the epidermis, and they have thickened cell-walls. The stoma is therefore at the bottom of a pit.

The chlorenchyma consists of large, roundish cells with somewhat thickened cell-walls and containing numerous chloroplasts. This tissue is fairly compact, so that there are only small intercellular air-spaces. Beneath each stoma, however, there is a fair-sized air-space.

The vascular bundles are of the usual monocotyledonous type, and all the xylem elements are lignified. Surrounding each vascular bundle there is a mass of sclerenchyma; this is composed of small roundish cells with thick cell-walls.

The central part of the leaf is occupied by a colourless tissue formed of large cells with slightly thickened cell-walls, and with small air-spaces between the cells. This tissue forms an aqueous tissue. In some parts the cells lying between the two opposite masses of sclerenchyma have lignified cell-walls.

Fig. 46 shows a transverse section through the margin of the leaf, which is thickened. The cuticle here is thicker, and the epidermal cells are somewhat larger, and their external cell-walls are thicker than near the centre of the leaf.

Under the epidermis there is a single layer of cells which contain a few chloroplasts. The rest of the space is occupied by a large mass of sclerenchyma, composed of cells with a very small lumen. In the centre of this mass there is a small vascular bundle.

Peduncle (fig. 48).—The epidermis is composed of small cells with all their walls, and especially the lateral walls, very much thickened. A cuticle is present, but it is not so thick as in the leaf.

Stomata are not frequent; the guard-cells have thickened cell-walls and are but slightly sunken, so that they are not at the bottom of a pit as in the leaf.

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Fig. 44.—*Libertia ixoides*. Transverse section of leaf ($\times 54$). *a*, sclerenchyma; *b*, chlorenchyma; *c*, vascular bundle; *d*, aqueous tissue.

Fig. 46.—*Libertia ixoides*. Transverse section of margin of leaf ($\times 230$). *a*, cuticle; *b*, sclerenchyma; *c*, vascular bundle.

Fig. 47.—*Libertia ixoides*. Surface view of epidermis ($\times 230$). *a*, opening above stoma.

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Beneath the epidermis there is some chlorenchyma—a band 2–4 cells deep, composed of spherical cells very closely arranged together, so that there are only minute air-spaces.

There are 4 more or less regular concentric rings of vascular bundles, the outer ones of which are composed of small bundles. The vascular bundles are of the usual monocotyledonous type, and each is surrounded by a small amount of sclerenchyma.

Fig. 45.—*Libertia ixiooides*. Transverse section of leaf ($\times 230$). *a*, cuticle; *b*, stoma; *c*, sclerenchyma; *d*, phloem; *e*, xylem; *f*, aqueous tissue; *g*, chlorenchyma.

All the cells of the ground-tissue except the chlorophyll-containing cells have pitted lignified walls. The cells nearest the chlorenchyma are small, have thick walls; and are closely arranged, so that there are no intercellular air-spaces. As we pass towards the centre of the stem the cells become larger and rounder, and their walls are thinner, and there are larger intercellular air-spaces.

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Fig. 48.—*Libertia ixiooides*. Transverse section of peduncle ($\times 230$). *a*, cuticle; *b*, stoma; *c*, chlorenchyma; *d*, sclerenchyma; *e*, phloem; *f*, xylem; *g*, pitted walls.

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Art. XXXII.—*Pteridophytes of Banks Peninsula (Eastern Portion).*

By W. Martin, B.Sc.

[Read before the Philosophical Institute of Canterbury, 3rd December, 1919; received by Editor, 31st December, 1919; issued separately, 30th June, 1920.]

Owing to its isolated geographical position, Banks Peninsula affords special opportunity for ecological investigation, yet few botanists have given it the attention it invites. Our present knowledge of the florula and of the distribution of the species has been admirably summed up in a recent paper by Laing (1919).

In his list of indigenous plants Laing refers to a large number of species of the former existence of which there can be little doubt, but whose presence is not now known with certainty. Such plants are recorded as "*species inquirendae*." Reference is also made to a number of species recorded by previous investigators, regarding the identification of which some doubt is expressed. Laing describes these as "*species excludendae*." It therefore seems desirable that an intensive study of the plants of this district should be conducted before further denudation of the primitive vegetation takes place.

Laing in his paper expresses the hope that "before the remnants of the primitive flora disappear every opportunity will be taken by local students to complete the work here outlined." The scope of the present paper is limited to an investigation of the past and present distribution of the pteridophytes of the Akaroa caldera and its immediate neighbourhood. The district examined consists of that portion of Banks Peninsula lying to the east of a line joining Peraki and Pigeon Bay. Practically every remnant of the ancient forest within the caldera itself has been visited since December, 1916, as well as the majority of similar areas that flank the outer walls. Most of the accessible cliffs within the harbour have also been examined, but the whole of the slopes facing the open sea require further and closer examination than I have been able to give to them.

The earliest existing records of distribution are contained in the writings of Raoul (1846), Armstrong (1880 and 1882), and Potts (1882); but for much additional information I am specially indebted to Mr. D. G. Riches, of Akaroa, who since

about 1880, while engaged on survey work that took him to every corner of the area under discussion, has been a close student of the ferns of Banks Peninsula and has made copious collections exclusively from this area. Many of the localities cited by Riches have been corroborated by Mr. Louis J. Vangioni, of Akaroa, and Mr. George Penlington, of Christchurch, to both of whom I am indebted for valuable information. In several instances I have been able, from information thus obtained, to locate ferns included by Laing in his list of doubtful inhabitants. Species recorded in this paper are represented by specimens from the localities named, and now in the possession of Mr. Riches or myself.

Probable Causes of Diminution or Extinction of Species.

Before the days of colonization the hills about Akaroa were clad with forest right to the water's edge, and it seems safe to assume that the atmosphere was more humid than it now is; but even if the annual

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rainfall had changed but little, there is to-day an almost entire lack of those taller and denser timber areas which were the home of the majority of the more delicate species of *Hymenophyllum* and *Trichomanes*, and I venture to suggest that the humidity within those areas that remain is also lower than it formerly was. For instance, in December, 1916, the stream that usually flowed through Le Bon's Bush, though never of large dimensions, had actually dried up, and the forest-floor could scarcely have been described as damp; yet there are evidences that this piece of forest was particularly rich both in wealth of fern-growth and in number of species.

To the wholesale destruction of the bush that accompanied the cutting-out of the timber and the conversion of these areas into pasture the disappearance or partial disappearance of many ferns is undoubtedly due, as, e.g., *Gleichenia Cunninghamii* and *Pteris tremula*, both of which appear to have been abundant. Then, again, where cattle have had access to the bush the undergrowth, with its wealth of terrestrial ferns, has disappeared save for a few hardy species that seem

able to accommodate themselves very rapidly to new and harsher conditions, as, e.g., *Asplenium bulbiferum*, *Pellaea rotundifolia*, *Polystichum Richardi*, *P. vestitum*, *Blechnum lanceolatum*, *B. fluviatile*, *B. discolor*.

Most of the larger Hymenophylla seem to have disappeared entirely, though the smaller species may still be found. The reason for this I am unable to state. It has to be remembered, however, that the favourite haunts for these ferns were the valleys between Le Bon's Bay and Damon's Bay, and that the bush has been practically cleared away from these areas. Further, it seems more than probable that these ferns cannot endure wind, which now blows freely through bush where formerly the air was perpetually still.

On the coastal rocks the following ferns are much less common than they apparently were formerly: viz., *Gymnogramme leptophylla*, *G. rutaefolia*, *Blechnum Banksii*, *Asplenium Richardi*. In fact, no trace of either *Gymnogramme* was seen by me. Other ferns commonly met with on banks and slopes immediately above high-water mark seem to hold their own against such aggressive exotics as *Dactylis glomerata*, *Agrostis stolonifera*, &c., while the pastures have been invaded by *Blechnum penna marinum*. This fern must, in the district under consideration, have descended from its former subalpine station right down to sea-level, where it is now common in places from which in the past it seems to have been absent. The two species of *Gymnogramme* formerly grew on steep banks of partially decomposed rock, where introduced grasses have now obtained a footing, and this may, wholly or partially, explain their disappearance.

Summary of the Results of the Investigation.

It will be seen from the following lists that at least seven (possibly eight) of the twenty *species inquirendae* mentioned by Laing are still growing in the district investigated, while Riches has shown that fourteen at least were former inhabitants. Of the sixteen *species excludendae* four were present—viz., *Hymenophyllum scabrum*, *Hymenophyllum ferrugineum*, *Trichomanes humile*, *Trichomanes Colensoi*.

Riches informs me that a considerable patch of a small-leaved umbrella-fern (*Gleichenia dicarpa*?) formerly grew near the summit of the hills at the head of O'Kain's, while he has specimens of *Lindsaya linearis* Swartz and *Lindsaya cuneata* Forst. var. *Lessonii* Hook. f. collected somewhere in

this neighbourhood and sent to him by a Mr. Craig about 1880. *Athyrium umbrosum* and *Asplenium Hookerianum* var. *Colensoi* were both collected by Riches and are now recorded for the first time.

In the accompanying list of existing species I give unrecorded habitats for at least thirty ferns and lycopods. There is ample evidence that some species now comparatively rare were once common—e.g., *Leptolepia novaezelandiae* and *Polystichum adiantiforme*. The former I have noted in nine separate localities, and the latter in four, though no other recent investigator has recorded them at all. *Adiantum affine* was once common over the whole area and is still widely distributed, but is plentiful only in a few localities, such as at Waterfall Gully on Mount Bossu, Nikau-palm Gully, and the cliffs near Mat. Wight's Bay. *Polystichum adiantiforme* has apparently not been recorded since Raoul first mentioned Akaroa as a habitat, though Mr. Louis J. Vangioni has it growing in his fernery on a fern-trunk from Grehan Valley, where I find it still fairly common. Laing regards Raoul's record as "probably an erroneous identification," but this species still exists in all the main Akaroa valleys, and near McDonald's, half-way up the Jubilee Road, at Wainui.

Referring to *Dicksonia fibrosa*, which he records from Wainui, Laing says, "As I have no specimens, I am somewhat doubtful of the identification." This fern is common in the Le Bon's Reserve, and has been obtained near the head of Barry's Bay by Mr. E. F. Stead. *Azolla rubra* is a new record on my own observation.

Abbreviations used in this Paper.

D. G. R. D. G. Riches.

R. M. L. R. M. Laing.

L. J. V. L. J. Vangioni.

G. P. George Penlington.

W. M. William Martin.

Existing Species not recorded since 1882.

Alsophila Colensoi Hook. f. Head of Stony Bay, * W. M.

Hypolepis distans Hook. Near Ferris's, Akaroa, W. M.

Pteris tremula R. Br. Little Tikao Bay, L. J. V. and W. M.

Blechnum vulcanicum Kuhn. Grehan Valley, D. G. R., G. P., W. M.

Polystichum adiantiforme (Forst.) J. Sm. Akaroa and Wainui, L. J. V. and W. M.

Dryopteris velutina O. Ktz. Neighbourhood of Akaroa, W. M.

Lycopodium scariosum Forst. Head of Long Bay and Stony Bay, W. M.

Lycopodium Billardieri Spring (?). Le Bon's Bay and Stony Bay, W. M.

Former Habitats of Species not recently noted on Banks Peninsula.

Hymenophyllum dilatatum Swartz. Hickory and Armstrong's Bush, D. G. R.

Hymenophyllum Malingii Mett. Long Bay and Stony Bay, D. G. R.

Hymenophyllum minimum A. Rich. Long Bay and Stony Bay, D. G. R.

Hymenophyllum tunbridgense Sm. Long Bay and Flea Bay, D. G. R.

Hymenophyllum multifidum Swartz. Long Bay and Stony Bay.

Hymenophyllum bivalve Swartz. Armstrong's Bush, D. G. R.

Hymenophyllum scabrum A. Rich. Long Bay and Hickory Bay, D. G. R.

[Footnote] * The Stony Bay referred to in this paper, unless otherwise stated, is the bay over the saddle from Balgueri Valley, Akaroa.

Hymenophyllum ferrugineum Colla (= *H. subtilissimum* Kunze). Stony Bay, D. G. R.

Trichomanes Colensoi Hook. f. Seaward side of Akaroa Ridge.

Trichomanes humile Forst. Seaward side of Akaroa Ridge, D. G. R.

Adiantum aethiopicum Linn. Akaroa, Raoul. Mr. Riches has a specimen of this maidenhair, but does not recollect where he obtained it.

Blechnum durum C. Chr. There is little doubt that this fern is correctly reported from Banks Peninsula by J. B. Armstrong. Riches has it from the foot of the beech bush, Stony Bay, where he says it was common. This was its northernmost limit. Apparently it grew close to, but not on, the actual coast-line.

Adiantum fulvum Raoul Grehan Valley, D. G. R.

Athyrium umbrosum Presl. A small clump formerly grew at Three Point Rock, Wainui, D. G. R. This is therefore the southernmost record for this species.

Dryopteris decomposita O. Kze. Children's Bay, Akaroa, D. G. R.

Polypodium dictyopteris C. Chr. Akaroa, Raoul; Stony Bay, D. G. R. I have not seen specimens of this fern.

Arthropteris tenella J. Sm Exact locality forgotten, D. G. R.

Gleichenia dicarpa R. Br. (?). Near head of O'Kain's, D. G. R.

Gleichenia Cunninghamii Hew. Five years ago Mr. G. Penlington and I came on this fern near a small stream near the head of Le Bon's (Martin, 1918), whence it has now totally disappeared. It was at one time very commonly distributed. Long Bay and Hickory, G. P. and D. G. R.; Flea Bay and Le Bon's, L. J. V.

Nothoclaena distans R. Br. Mat. Wight's Bay, on spurs of the hills, D. G. R.

Gymnogramme leptophylla Desv. Rocks near creek at lighthouse and on Adam's Point, D. G. R.

Gymnogramme rutaefolia Hook. & Grev. Adam's Point, D. G. R.

List of Species still growing in the Region investigated.

The species named in the following list are still growing in the localities recorded by Laing or myself. Records by Riches were made prior to 1900. Other records are not given unless the exact habitat is mentioned.

Hymenophyllum rarum R. Br. Waikerikikeri (Hickory), R. M. L.; Le Bon's, W. M., D. G. R. This species was once common, but is now difficult to find.

Hymenophyllum sanguinolentum Hook f. Le Bon's Reserve. This fern may most easily be found by following up the stream-bed till it reaches the waterfall, where it is growing on the rock and on neighbouring tree-trunks.

Hymenophyllum flabellatum Lab. Peraki Reserve, R. M. L., W. M. This fern is easily found on the caudices of *Dicksonia squarrosa*, at Wainui, Akaroa, Takamatua, and Le Bon's.

Hymenophyllum peltatum Bearne (= *H. unilaterale* Willd.). Long Bay, D. G. R. and R. M. L.

Trichomanes venosum R. Br. Extremely common on the stems of treeferns in almost every valley, W. M.; Balgueri Valley, R. M. L.

Cyathea dealbata Swartz. Everywhere common, but less so from year to year.

Cyathea medullaris Swartz. Mr. Hooker and others at Wainui inform me that some half-dozen specimens exist about a mile towards the Heads from Wainui, but I have not seen them.

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Hemitelia Smithii Hook. f. Akaroa and Wainui, R. M. L., W. M. Commonly met with all round the harbour.

Dicksonia squarrosa Swartz. Everywhere common.

Dicksonia fibrosa Col. Wainui, R. M. L.; Le Bon's, W. M.; Barry's Bay, E. F. Stead.

Alsophila Colensoi Hook. f. Common in bush above the Summit Road at the head of Stony Bay, near Akaroa. I have a doubtful record from Le Bon's.

Leptolepia novae-zelandiae (Col.) Kuhn. This and the last species do not appear to

have been collected in the last thirty years. I have noted this fern at Peraki Reserve, Wainui, Grehan Valley, French Farm, Le Bon's, and head of Robinson's Bay in the little tongue of bush that lies between the road and the summit, where it may easily be obtained.

Adiantum affine Willd. Nikau-palm Gully, R. M. L. All valleys round Mount Bossu. Wainui, French Farm, Rowe's Bush Waterfall, Akaroa, and especially on the coastal cliffs north of Mat. Wight's Bay. This fern must formerly have been widely distributed.

Hypolepis tenuifolia Bernh. Top of ridge, Akaroa to O'Kain's, W. M.

Hypolepis distans Hook. Neighbourhood of Akaroa, D. G. R., W. M.

Cheilanthes Sieberi Kunze. Spurs on Lucas Bay, D. G. R. Evidently less common than formerly.

Pellaea rotundifolia Hook. Everywhere abundant both in the bush and in the open.

Pteridium esculentum Cockayne. Common near the margin of the bush; covering many acres of valuable land on the spurs above Wainui and Akaroa, and increasing rapidly.

Paesia scaberula Kuhn. Mount Bossu, Wainui; R. M. L., W. M.; head of Balgueri Valley, W. M. and G. P.

Histiopteris incisa J. Sm. Stony Bay near O'Kain's, R. M. L.; Le Bon's, Stony Bay near Akaroa, and Long Bay, W. M.

Pteris tremula R. Br. Potts records this fern from "Tikao Bay," which is probably intended for Little Tikao Bay, where it is still growing, L. J. V., W. M.; foot of Peraki Reserve, W. M.; near top of range at Hickory and Stony Bay, D. G. R.

Blechnum Patersoni Mett. Peraki, Le Bon's, Balgueri and Grehan Valleys, Akaroa, Wainui; always at the higher levels and in damp bush.

Blechnum discolor Keys. Common in bush above 1,000 ft.

Blechnum lanceolatum Sturm. Common in bush.

Blechnum penna marinum Kuhn. To be met with at all levels from sea-level, as at Maori Kaik, to the summit. This is a most abundant fern on open hillsides; 300 ft. is given as the lowest level by Laing, but I have seen it almost on the sea-shore at Maori Kaik and at Wainui.

Blechnum Banksii Mett. Squally Bay and Stony Bay, D. G. R.; light-house, Akaroa, L. Cockayne; Stony Bay, W. M.

Blechnum capense Schlecht. Common, especially in bush above 1,000 ft. level.

Blechnum fluviatile Lowe. Common near bush-streams

Blechnum membranaceum Mett. Brough's Bay, D. G. R., G. P. I have not visited this locality, but have reason to believe it still exists there.

Blechnum vulcanicum Kuhn. This fern has eluded collectors and investigators for many years. It is growing freely on some rocks in a piece of bush bordering a small tributary of the main stream in Grehan Valley. Elsewhere on the peninsula it occurs in Kaituna Bush.

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Asplenium flabellifolium Cav. A cosmopolitan fern in the district examined.

Asplenium obtusatum Forst. f. On coastal cliffs. Within the harbour this fern presents all manner of intermediate gradations between *A. obtusatum* and *A. lucidum*. Wall (see Laing, 1919, p. 376) considers the coastal fern of Lyttelton Harbour to be a form of *A. lucidum* rather than of *A. obtusatum*. I hold the same view in respect to the *Asplenium* of Akaroa Harbour.

Asplenium lucidum Forst. f. Wainui, French Farm, Barry's Bay, Pigeon Bay, Akaroa, Little Tikao Bay. The typical form is met with flanking the streams for a few chains from their entry into the harbour wherever these are shaded by bush. Fronds 5 ft. 6 in. long were recently exhibited by me in Christchurch from Barry's Bay. On Adam's Point a gradual transition towards *A. obtusatum* may be noted, the pinnae becoming more and more oblique and erect, more coriaceous, and shorter, and the fronds more dwarf and compact. An examination of these localities leads me to think that the most potent factors in causing this transition are the degree of exposure and the degree of salinity at the roots. The degree of shade and moisture are also factors of importance.

Asplenium Lyallii (Moore) Cockayne. I obtained two specimens of this fern within a chain of typical *A. lucidum* and the fern here called *A. obtusatum* on Adam's

Asplenium Hookerianum Col. Three very distinct forms of this composite species exist in the locality. The typical form is abundant in Akaroa itself, at Maori Kaik, and at Wainui; it is well distributed generally. Superficially, a second form, found in Balgueri Valley, almost exactly matches the plate given by Field for *A. umbrosum* var. *parvifolium*. Var. *Colensoi* is found at Tikao Bay, D. G. R.

Asplenium bulbiferum Forst. f. The commonest bush-fern, but, like a number of others, it may often be seen growing in a crevice in a rock exposed to the full effects of sun and wind, in which situation it becomes extremely coriaceous.

Asplenium Richardi Hook f. Waikerikikeri, R. M. L.; coastal cliffs on the seaward side, D. G. R.

Asplenium flaccidum Forst. f. This fern is everywhere abundant.

Polystichum vestitum Presl. Very common in the upper regions of the bush—*i.e.*, above 1,000 ft. Where the bush has been cleared this fern often continues to thrive in the open.

Polystichum Richardi J. Sm. A very hardy cosmopolitan type, thriving equally well on the coastal cliffs, open pasture, and dense bush. It thrives at all levels. The *Aspidium oculatum* of the *Handbook* (Hooker) does not seem to be a fixed type, as considerable variation in the disc of the involucre and in the margin of the scales occurs sometimes in a single clump of *P. Richardi*.

Polystichum hispidum J. Sm. Maori Kaik, Newton's Valley, Balgueri Valley, Le Bon's, W. M. Nowhere common.

Polystichum adiantiforme (Forst.) J. Sm. Regarded by Laing as “probably an erroneous identification,” but undoubted specimens may easily be obtained on the caudices of *Dicksonia squarrosa* about a mile up Grehan Valley. I have obtained it in Newton's Valley, and also in the valley below the Jubilee Road, a quarter of a mile above McDonald's, at Wainui, where it was growing luxuriantly, though only two specimens were seen.

Dryopteris glabella C. Chr. Balgueri Valley, R. M. L., W. M.; Maori Kaik, Newton's Valley, Grehan Valley, and Rowe's Bush on Adam's Point, W. M.

Dryopteris punctata C. Cr. Common on the margins of the bush.

Dryopteris pennigera C. Chr. Common in shaded stream-beds below 1,000 ft.

Dryopteris velutina O. Ktz. This handsome fern still grows where it was discovered by Raoul. Akaroa, Rowe's Bush, Maori Kaik, W. M.

Polypodium Billardieri (Willd.) C. Chr. (= *P. australe* Mett.). Common on rocks and tree-trunks all round the summit.

Polypodium pustulatum Forst. f. Long Bay, D. G. R.; Stony Bay, W. M.

Polypodium grammitidis R. Br. Common on tree-trunks and on rock near the summit from Stony Bay to Wainui. Specimens from Le Bon's measured 12 in. in length.

Polypodium diversifolium Willd. Everywhere abundant.

Cyclophorus serpens C. Chr. Akaroa, Peraki, Island Bay, W. M.

Leptopteris hymenophylloides Presl. Abundant in the denser areas of bush, as at Peraki, Le Bon's, Stony Bay, &c. It also grows in the beech forest at the head of Balgueri Valley, facing full to the sun.

Ophioglossum coriaceum A. Cunn. Hills behind Wainui, ridge between Le Bon's and Hickory, R. M. L.

Botrychium australe R. Br. Grehan Valley. Mr. G. Penlington conducted me to a spot where it formerly grew abundantly, and we were fortunate enough to find a specimen about 400 ft. above sea-level. Brasenose (lower levels), G. P., D. G. R.

Lycopodium varium R. Br. Waikerikikeri, R. L. M.; head of Le Bon's and Barry's Bays, W. M. Specimens superficially resembling *L. Billardieri* Spring were obtained by me growing as epiphytes both at Stony Bay and at Le Bon's. At first I could find

no fertile fronds; and, referring to barren fronds sent to him, Dr. J. E. Holloway wrote me, "Almost certainly *L. Billardieri*." Writing later, after I had secured fertile fronds, he says, "I agree with you that the fertile plants you send are more of the form of *L. varium* than of *L. Billardieri*. These two species grade into one another so that it is quite possible to speak of an intermediate form as being a variation of the one as much as of the other. Seeing that they are recognized as two distinct species... and judging from the fertile specimens they deserve the name *L. varium*." The barren fronds were obtained from *Griselinia littoralis* and *Podocarpus totara*, while the fertile plants were epiphytic on *Dicksonia fibrosa*. All had a tendency to upward or erect growth, but the longer fronds drooped by reason of their weight.

Lycopodium Billardieri Spring (?). See preceeding note.

Lycopodium scariosum Forst Head of Long Bay and Stony Bay, D. G. R.; W. M.

Lycopodium volubile Forst. f. Wainui hilltops, above Le Bon's Bay, near Hilltop Hotel, R. M. L., W. M.

Tmesipteris tannensis Bernh. This pteridophyte grows plentifully in the stream-valleys at Akaroa, and more sparingly at Le Bon's and Peraki. Plants over 1 ft. in length are not uncommon on the tree-fern stems in Newton's Valley at Akaroa.

Azolla rubra R. Br. Pigeon Bay, W. M. This little floating water-fern frequents the surface of fairly stationary water, which is seldom provided in the Akaroa area, hence the probable reason for its not having been reported previously.

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Art. XXXIII.—*The Notocene Geology of the Middle Waipara and Weka Pass District, North Canterbury, New Zealand.*

By Dr. J. Allan Thomson, F.G.S., F.N.Z.Inst., Director of the Dominion Museum.

[*Read before the Wellington Philosophical Society, 22nd October, 1919; received by Editor, 31st December, 1919; issued separately, 16th July, 1920.*]

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Introduction.

The younger rocks of New Zealand, embracing all marine strata from Albian to Pliocene, consist in nearly all localities of accordant rock-series, and form, broadly speaking, a structural and physiographical unit. The rocks composing them—viz., conglomerates, sandstones, greensands, mudstones, and limestones—are much less indurated than the unconformably underlying greywackes, argillites, phyllites, schists, or granites, and physio-graphically form a weak cover to a resistant undermass. Unlike the latter,

they are rarely strongly folded, except in the neighbourhood of strong faults, and in general exhibit only a tilting or warping which they share equally with the undermass as a consequence of block-faulting. Owing to their softer nature they rarely occur far up the slopes of the tilted blocks, but are confined to the lower levels near the fault-angles.

The ages of the lower and upper members of these younger rocks vary greatly in different districts in New Zealand, and there is no locality where a complete series is found in superposition. Consequently it has seemed desirable to give them in their totality a descriptive name—viz., the Notocene—and to define it by diastrophic considerations as embracing all the beds deposited between the post-Hokonui and Kaikoura deformations (Thomson, 1917, p. 408).

The Notocene may be divided into the following divisions:—

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Table I.—Divisions of the Notocene.

Groups.	Stages	Probable Correlation
	Castlecliffian	Upper Pliocene.
Wanganuian	Waitotaran	Lower Pliocene.
	Awamoan	Upper Miocene.
	Hutchinsonian	
Oamaruian	Ototaran	Lower Miocene.
	Waiarekan	
	Ngaparan	Oligocene.
	Paparoan	
Kaitangatan		Danian to Eocene.
Piripauan		Senonian.
		Turonian Cenomanian.
Clarentian		Albian.

In 1919 I gave a description of the Notocene sequence in the Clarence Valley, Marlborough, which ranges from Clarentian to Awamoan, and possibly to Waitotaran. The North Canterbury Notocene sequence described in the present paper includes marine rocks ranging from the Piripauan to the Waitotaran, with an overlying terrestrial series of possibly Castlecliffian age. These rocks form a tilted strip running from the neighbourhood of Mount Grey north-east across the Waipara River in its middle reaches, and across its tributary the Weka Creek, occupying the whole of the Weka Pass, and thence continuing nearly east for eight miles or more a little to the south of the Waikare River. This strip is bounded on the north-western side by the pre-Notocene rocks of Mount Grey, the Doctor's Range, and the hills south of the Waikare River, except for a short distance near the township of Waikare, where its lower members abut against the recent alluvium of the Waikare River. On the south-east the upper members dip under the continuous gravel-plain of the Kowhai and Waipara Rivers and their tributaries. The area covered by these Notocene rocks may conveniently be known as the Middle Waipara and Weka Pass district, in distinction to the Upper Waipara district, near Heathstock, and the

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Lower Waipara district,^{*} between the township of Waipara and the sea, in both of which localities similar developments of Notocene rocks occur. These locality distinctions have already been made by McKay. The Middle Waipara and Weka Pass areas form a continuous district, but as they have separate access by road, and as there is no road traversing and connecting them, they are often treated of as separate districts. It should be noted that in the earlier literature the term "Waipara" was generally used for the Middle Waipara area alone, but that the term is now generally used colloquially by geologists for the whole of the Middle Waipara and Weka Pass district. In old reports the part of the Middle Waipara district between Boby's Creek and the Waipara River is sometimes termed "the Ram Paddock," a self-explanatory name referring to its use when part of the Glenmark Station.

In the history of Notocene geology the district of the Middle Waipara and Weka

Pass has attracted more attention than any other in New Zealand, and the Notocene sequence there displayed was made by Hector, Hutton, and von Haast the basis of their various schemes of classification of the Notocene; but, although the district is perhaps the most often quoted in our geological literature, no comprehensive account of the whole Notocene stratigraphy has been attempted since that of Park in 1888. Since that date many new observations have been made, a great deal more is known of the fossils from the various beds, and, moreover, new viewpoints have been found, so that a new account has become desirable. In attempting it I can lay no claim to exhaustive treatment, as there are many outcrops which I have not traversed, and every fresh visit to the district brings to light new fossil forms from the old localities, and new fossil-localities. There is abundant scope for further exploration, and the detailed survey of parts of the area may be suggested as useful theses for students. Still, the major outlines both of stratigraphy and of palaeontology can now be stated, and their bearing on the systems of classification of the younger rocks of New Zealand needs pointing out at the present time.

The map accompanying this paper ([fig. 1](#)) does not claim to be more than a sketch-map, and is in large part based on previous maps.

Although the attached bibliography includes a very large number of papers, a minority contain descriptive matter relating directly to the stratigraphy or palaeontology of the district, and the majority deal mainly with the correlation of the various beds and their place in general classifications of the younger rocks of New Zealand. These latter papers are concerned mainly with the validity or otherwise of the Cretaceo-Tertiary formation of Hector, a formation based, first, on the conformity of the Amuri limestone, Weka Pass stone, and "grey marls" within the district, and, secondly, on certain correlations believed to exist between the various rocks of the sequence and those of the Oamaru and West Coast areas. It will make for clearness if these matters are treated in separate sections of this paper.

Part I.—Descriptive Geology.

Geological Exploration of the District.

The subjoined table, showing the dates of the principal visits of geologists who have written on the district, will give some idea of the interest it has created amongst New Zealand geologists. The list does not include many other visits by those who have not published their observations

[Footnote] * Also known as "Double Corner."



Fig. 1.—Geological map of the Middle Waipara and Weka Pass district. Scale, $\frac{1}{2}$ in. to one mile. The sides of the map are N. 71° E. 1, Pre-Notocene. 2, Piripauan. 3, Amuri limestone and Weka Pass stone. 4, "Grey marls" and sands interbedded with 5, Mount Brown limestones. 6, Greta and Kowhai beds. 7, Notopleistocene (alluvial plains).

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[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Table II.—Dates of the Principal Visits of Geologists to the District.

Date of Visit.	Date of Publication (see Bibliography)
C. Forbes—1849	1855.
T. H. Cockburn Hood—1859	Owen, 1861.
1868	1870; Haast, 1870a.
Sir J. von Haast—1864, 1866, 1867 (three visits)	1869.
1869	1870; 1871.
1875	1879.

Sir J. Hector—1867 1873–74	1869. 1877a.
1886	1887a.
A. McKay—1872 (as collector for Canterbury Museum)	
1874	1877 a, b.
1876	1877c.
1886	1887a.
1891	1892.
F. W. Hutton—1873	1877.
?1884	1885b.
1886	1888.
J. Park—1887	1888.
1904	1905.
1912	1912.
P. Marshall, R. Speight, and C. A. Cotton—1910	1911; Cotton, 1912.
J. A. Thomson—1912	1912 a, b.
1913	1913.
1914, 1917, 1919	
P. G. Morgan—1915	1915; 1916 a, b, c; 1919.
R. Speight and L. J. Wild—1917	1918; 1919.
R. Speight—1918	1919.

The earliest notice of the district is that of C. Forbes (1855), who was assistant surgeon to H.M.S. "Acheron." He describes a journey up the bed of the Kowhai River to the foot of Mount Grey and a descent by the Karetu River, a tributary of the Okuku. The area he traversed thus probably lies just outside that treated in this paper, but he deals with the upper Notocene rocks of the same strip. He mentions the tilted gravels, since assigned by Speight (1919) to the Kowhai series, and a stratum of hard blue clay dipping south-east at an angle of 35° and containing an immense number of marine shells, the genera of which are specified. The blue clay underlies sandstone, and higher up the river similar beds are represented by dense, hard, blue limestone. These sandstones and blue clays belong doubtless to the Greta series (Waitotaran), and are obviously Tertiary, although Forbes expresses no opinion on this point.

In 1859 T. H. Cockburn Hood-discovered and collected saurian remains in the bed of the Waipara River and forwarded them to the British Museum. These fossils were described by R. Owen (1861), under the name of *Plesiosaurus australis*, and referred to the Jurassic period. This find stimulated great interest among geologists, although the early visits of von Haast and Hector were fruitless so far as further specimens were concerned. In his first visit, in 1864, von Haast apparently

mistook the cup-shaped Polyzoa from the lower Mount Brown beds for saurian vertebrae, and in consequence considered the saurians as survivors into the Tertiary. In 1870 he acknowledged his mistake and credited the discovery of the true position of the "saurian beds" to Hector. The next considerable collection of saurian remains was again made by Cockburn Hood, in 1868, but on their way to England the specimens were unfortunately lost through the wreck of the ship "Matoaka." Von Haast had fortunately made drawings and taken measurements of the more important bones, on which he published a note in 1870.

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Cockburn Hood in 1870 gave a description of the locality and the rocks from which he obtained his collection.

Following Cockburn Hood's successful search, Hector in 1868 sent R. L. Holmes to collect for the Colonial Museum, and he obtained a "fine series of specimens," principally from a tributary of Boby's Creek (*cf.* Hector, 1869, p. xi). Drawings of these, forwarded by Hector to Owen, enabled the latter in 1870 to add two further species to the fauna—viz., *Plesiosaurus crassicostatus* and *P. hoodii*. Hector in 1874 described other species from Holmes's collection, and mentions also a specimen collected at Boby's Creek. by W. T. L. Travers.

In 1872 von Haast employed A. McKay to collect for the Canterbury Museum, and it was his success in this task that later led to his employment in the Colonial Museum and Geological Survey. McKay subsequently collected further saurians for the Colonial Museum in 1874, but in 1877 he reported that all the more accessible specimens had been secured and further collections could only be made at considerable labour and expense. Nevertheless, in 1891 he was successful in recovering a specimen which he had first seen in 1874, but which had been for some years covered up by river-shingle. McKay's experience, as stated in 1892, was that "nearly all the boulders [concretions] that contain bones split in falling from the cliffs, or in being shifted along the river-bed, and it is never worth while to open a boulder so situated that does not show the presence of bones."

In 1876 or 1877 Hector exchanged "250 specimens, fossil Reptilia of New Zealand" with the Trustees of the British Museum, and descriptions of these were included by Lydekker in the *Catalogue of Fossil Reptilia and Amphibia* in 1888 and 1889. Hutton in 1894 described one of the specimens collected by McKay for the Canterbury Museum in 1872. Since 1892 no fresh collections of saurians from the district have been made, but the interest of geologists has been sustained for another reason—namely, the apparent conformity of the beds containing the saurians with others containing a purely Tertiary fauna.

The first general account of the geology was given by Hector in 1869, who noted that the saurian beds were intimately associated with, but probably underlay, blue and grey marly sandstone, sometimes passing into chalk, and were in turn underlain by white and brown sandstones containing coal-seams, and correlated with the Wealden. These three formations were covered unconformably by Miocene white and yellowish calcareous sandstone, in parts composed altogether of cup-shaped Polyzoa, and by reddish limestone, composed of comminuted shells. On these Miocene rocks rests Pliocene blue clay with beds of sand and gravel containing many existing species of marine shells. Hector gave no account of the structure, but stated his belief that the underlying "Triassic" rocks had been denuded into hills and valleys long prior to the Tertiary period. As Hutton pointed out in 1885, Hector did not distinguish between the "grey marl," the Weka Pass stone, and the Amuri limestone, but considered them all as a "blue-grey marly sandstone sometimes passing into chalk." The unconformity here postulated Hector always adhered to, the lower group becoming later his Cretaceo-Tertiary formation, and the middle (Miocene) his Mount Brown beds, or Upper Eocene.

The next account of the district, by von Haast (1871), was based on a detailed survey of the Middle Waipara part of the district, carried out under Hector's direction for the Colonial Geological Survey, and was accompanied by a map. Von Haast gave a detailed account of the beds in the Waipara River and in Boby's Creek, the most detailed account yet given so far as the beds below the Amuri limestone are concerned; but, like Hector, he

did not distinguish between the latter rock and the Weka Pass stone. The succeeding "grey marls" he considered as strongly unconformable to the underlying groups, and so showed them on his map; but, as Hutton pointed out in 1877, he failed to recognize the strong fault crossing Boby's Creek, which brings the middle Notocene against the older Notocene. Von Haast's map shows three inliers of the pre-Notocene within the Notocene of the Boby's Creek watershed, and these he considered as islands in a large pre-Notocene bay, along the shores and round the small islands of which the lower strata were first deposited in shallow water. His map also shows in approximately correct position a small detached outcrop of calcareous sands (Amuri limestone) in the upper part of Boby's Creek, which has escaped notice by all subsequent observers. In his next account of the district, in 1879, von Haast still adhered to an unconformity between the lower Waipara (Cretaceo-Tertiary) formation and the "grey marls" forming the base of the Oamaru (Upper Eocene.) formation.

Hutton in 1877 referred to the district in a general account of the geology of the north-east part of the South Island, and, as in his later writings, dealt summarily with the beds below the Amuri limestone, but emphasized the importance of the contact* between the Amuri limestone and Weka Pass stone, which in his opinion unconformably separated a lower—Waipara (Upper Cretaceous)—formation from an upper—Oamaru (Eocene)—formation. He first introduced the term "Amuri limestone, and considered that this rock was consolidated, jointed, and water-worn before the Weka Pass stone was deposited upon it. As already mentioned, Hutton correctly interpreted the fault in Boby's Creek, and described another in the upper part of the Weka Pass. Like Hector and von Haast, he considered that the Notocene rocks were deposited in valleys formed in the pre-Notocene ("Lower Cretaceous").

McKay in 1877 (1877a) was successful in finding a saurian in the green-sands between the "saurian beds" and the Amuri limestone. As regards the unconformities believed by Hutton and von Haast to exist, he stated that stratigraphically he could find no conclusive evidence of unconformity between the Weka Pass calcareous greensands (base of the Weka Pass stone) and the Amuri limestone; and "if the Weka Pass calcareous green-sands belong to the lower Waipara beds, no unconformity can be conceded as far as the uppermost beds of

the Mount Brown series." McKay at this date was therefore in substantial agreement with the position taken later by Park in 1888, and by Marshall, Speight, and Cotton in 1911.

In the same year (1877b) McKay gave a detailed account of the "reptilian" beds of Amuri Bluff and the Middle Waipara, and discussed the question of the pre-Notocene physiography. He concluded that it was improbable that the outlines of the present configuration of the area within which the Notocene remnants are found was determined in the pre-Notocene, or that the Notocene was deposited in a large bay, with inlets penetrating the mountain-ranges, but that the evidence pointed to the subsidence of a very wide area until deep-sea deposits were formed, and a subsequent upheaval of mountain-chains, between which, and in the folds of which, the younger rocks have been preserved to the present day. The views thus early put forward by McKay, though receiving little attention at the

[Footnote] * It is customary to term this contact the "junction" between these two rocks; but a junction is that which unites, whereas in the belief of many writers this surface of contact or touching is rather a surface of separation. The term "junction" has probably been adopted because there is practically a passage-zone and not a surface of separation, the zone consisting partly of Amuri limestone with intercalations of greensand and often with borings filled with greensand, and partly of greensand containing small pieces of Amuri limestone.

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time, were elaborated by him in later papers on other, districts, and, thanks mainly to the physiographical evidence in support brought forward in recent years by Cotton, are now generally accepted by New Zealand geologists.

In 1885 Hutton once more called attention to the contact between the Amuri limestone and the Weka Pass stone throughout North Canterbury, and its importance in respect to the classification and correlation of the Notocene sequence. Within the district he examined the contact at only one point—viz., in a small gorge of the Weka Pass Stream just above the railway-viaduct—and stated

that he believed this to be the only section in the neighbourhood where it could be studied. Although the contact is carefully described, the latter statement is quite incorrect, and is of interest as typifying Hutton's general neglect of detailed field-work. Not only may the contact be observed in numerous places within the Weka Pass, as McKay in 1887 pointed out, but it is exposed at short intervals throughout the whole length of the district. Hutton noted the common dip of the two rocks, but again stated his conviction that the water-worn surface of the Amuri limestone, and the presence of pebbles in the lower 6 ft. of the Weka Pass stone, were conclusive proof of unconformity. In addition, an overlap of the Weka Pass stone on to the slate rocks of Mount Alexander at Hurunui was adduced as further proof of unconformity. Hutton also gave lists of fossils from the Weka Pass stone and the "grey marls," showing that these two rocks, along with the Mount Brown beds, belonged to the Oamaru system, and pointed out that the Amuri limestone contained no characteristic fossils, but was always associated with underlying rocks containing remains of marine saurians and Cretaceous Mollusca. Consequently he claimed that the palaeontological break must be between the Amuri limestone and the Weka Pass stone, exactly where the strati-graphical evidence placed it. "If the line between the Waipara and Oamaru systems be taken immediately above the Amuri limestone, hardly any species of Mollusca, perhaps not a single one, will be found on both sides of it; whereas if it be drawn anywhere above the Weka Pass stone there must always be a large number of species found on both sides of it."

The attack thus made by Hutton on the classification adopted by Hector and the officers of the Geological Survey opened a period of very keen controversy, mainly between McKay and Hutton. McKay (1887a) reaffirmed the conformity of the Amuri limestone and Weka Pass stone on the grounds of the strict parallelism of the two rocks, and attempted to explain away the appearances of unconformity. The so-called shattering of the Amuri limestone he attributed to the effects of jointing combined with a downward working of the greensand into the joints, and he published analyses of the Amuri limestone and the supposed pebbles of the same rock in the green-sand to prove that the latter were concretionary phosphatic nodules. The Colonial Analyst called the insoluble residue from the Amuri limestone (42.74 per cent.) "almost pure sand (fine-grained)," and McKay suggested that, as the limestone was less than 50 ft. thick in the Weka Pass, "should the percentage of sand be much increased, the equivalent beds three or four miles distant might very well be mistaken for other than they are, or be absent," and hence overlap of the Weka Pass stone was no necessary proof of unconformity. He further cited a number of species of fossils from the Amuri limestone or lower beds which were also found in higher beds, the majority of his list, however, being from localities outside the "district. Hector (1887a), in commenting on McKay's paper, accepted the "definite chemical proof that the supposed fragmental layer at the base of the Weka Pass stone is truly concretionary," and published a map and section of the Weka Pass showing an unconformity between the "grey marls" and the overlying Mount Brown beds.

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In 1887 Hutton (1888) examined the sections made in the construction of the railway through Weka Pass, and distinguished five series of beds—viz., (1) the Amuri limestone and underlying greensandstones, (2) the Weka Pass stone and the overlying “grey marls” and sandstones, (3) the Mount Brown beds, (4) the Greta beds, (5) horizontal silts and gravels. Besides the unconformity between the Amuri limestone and Weka Pass stone, he admitted another between the Mount Brown beds and the “grey marls.” Lists of fossils of the Mount Brown and the Greta beds were given, the latter being placed in the Pareora system.

Park (1888) records a visit of nine days to the district, and gives an excellent general summary of the geology, accompanied by a map and section. His conclusion as to the presence of unconformities is stated as follows: “As a result of the examination of many of the magnificent sections between the Weka Pass and Waipara, I am strongly of the opinion that a complete sequence of beds exists from the base of the Cretaceo-Tertiary to the close of the Pareora formation, although the varying character of the deposits and their fossil remains show that the sea-bottom on which they were deposited was subject to frequent oscillations.” He accepted the concretionary nature of the pebbles at the base of the Weka Pass stone, but apparently admitted that the surface of the Amuri limestone was water-worn, due to “a sudden arrestment of the downward movement and a return to shallow-water conditions.” The “grey marls” were considered to pass insensibly into the Mount Brown beds: “indeed, it would be difficult to accurately fix or define their boundaries.”

Hector (1888) was obviously embarrassed by this conclusion of an officer of his survey as to the conformity between the “grey marls” and the Mount Brown beds, but contented himself with recording anew his belief in a marked discordance, with great denudation of the “grey marls.”

McKay (1892) re-examined sections in the Weka Creek, and more particularly in the Middle Waipara, paying particular attention to the “saurian beds.” Concerning the contact between the Amuri limestone and the Weka Pass stone,

he noted that in the Waipara limestone gorge the green-sand conglomerate and parting-beds of greensand with phosphatic nodules were absent, and that there was no sign of unconformity. He also recorded a stratigraphical unconformity between the "grey marls" and the Mount Brown beds near the mouth of Boby's Creek, evidently the same as that later recorded by Thomson in 1912 (1912b).

For a period of about twelve years no further examination of the district appears to have been made, and Hector and McKay on the one hand, and Hutton on the other, to the end adhered to the positions they had taken up. In 1905 Park abandoned the Cretaceo-Tertiary classification and accepted a modification of that of Hutton, in reality reverting practically to the position always taken by von Haast. He supposed that the Tertiary (Oamaruan) fossils reported from the Weka Pass stone were in reality obtained from tumbled masses of the Mount Brown limestones, and that the Weka Pass stone itself was unfossiliferous; consequently he included it in the Waipara (Upper Cretaceous) series. The "grey marls," he included with the Mount Brown beds in the Oamaru (Miocene) series, which rested unconformably on the Waipara system, "the Weka Pass stone and the Amuri limestone being thrown into folds in which the Tertiaries take no part whatever." The Tertiary beds were described in detail, and fresh lists of fossils were given, including a new fossil-locality for the Mount Brown beds near Mount Donald. Somewhat anomalously, Park rejected Hutton's name of "Greta beds" for the uppermost marine series, and accepted that of "Motunau beds" instead, although Greta is much nearer to the district than Motunau. These beds had latterly been accepted as

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belonging to the Pareora system (Upper Miocene), but Park suppressed that system throughout New Zealand, and correlated the Motunau beds with the Te Aute or Waitotara series, of older Pliocene age, thus returning to the original correlation of Hector (1869) and von Haast (1871). He described an unconformable contact between the Motunau beds and the underlying Mount Brown beds.

It is of interest to note that Park also accepted the earlier views of Hector, Hutton, and von Haast as to the pre-Notocene physiography. He considered that the main mountain features of New Zealand were already determined in the Eocene, and that the present intermont basins were old Tertiary fiords and inland basins which before the Miocene submergence were merely deep valleys of erosion.

The modern revival of interest in the district commenced with the paper on the younger rock-series of New Zealand by Marshall, Speight, and Cotton, in 1911. They restricted themselves to a critical examination of those localities where unconformities had been reported by earlier observers, and recorded their conviction that there was no unconformity in the Waipara and Weka Pass district. A map and block-diagrams of the Weka Pass were given to explain the erroneous view of Park that the Weka Pass stone and Amuri limestone were thrown into folds in which the Tertiaries take no part. The north-western part of the Notocene strip, from which the upper beds had been denuded, was thrown into folds whose pitch did not carry them beneath the south-eastern part, where the Upper Tertiaries are preserved. The peculiar characters of the contact between the Amuri limestone and Weka Pass stone are attributed to a change of conditions of deposition. "The change from pure (Amuri) to glauconitic (Weka Pass) limestone does not take place throughout the mass of the rock, but inter-laminations of glauconitic matter arise and separate pieces of limestone. As the conditions that control the depositions become more changed the inter-laminations of glauconitic matter become larger, and the pure limestone is reduced to nodules which appear like rolled pebbles." The contact relied on by Hutton for an unconformity between the "grey marls" and Mount Brown beds was considered a fault-contact within the Mount Brown beds. The section on which Park relied for an unconformity between the Mount Brown and Greta beds was described as showing complete conformity. The authors did not express clearly their views as to the pre-Notocene physiography, but apparently agreed with the view, accepted by all others than McKay, of a diversified surface admitting of considerable overlap within a very short distance.

A period of controversy between Park and Marshall then ensued as to the conformable or unconformable nature of the Lower Tertiaries and Upper Cretaceous of New Zealand. Park's first reply (1911) did not deal with the internal geology of the Weka Pass and Waipara district, but disputed the correlations made with rocks of the Oamaru district, and reaffirmed unconformity between Cretaceous and Tertiary on palaeontological grounds. Thomson (1912 A and B) recorded a fresh discovery of Oamaruan fossils in the Weka Pass stone, and noted an unconformity within the sandy beds between the Weka Pass stone and the lower calcareous horizon of the Mount Brown beds, in a cliff of the Waipara River gorge, just above the junction with Boby's Creek. "It appears, however, to be a purely local accident of bedding. With this exception, there is apparent conformity in section throughout the Waipara district." Marshall in 1912 quoted the fossils from the Weka Pass stone, which Park had admitted as conformable to the Amuri limestone, as proving Park's adhesion to the conformity of the Upper

Cretaceous and Lower Tertiary. Park (1912, 1913) inspected the new fossil-locality, accepted the Weka Pass stone as Oamaruan, but

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reaffirmed his belief in a necessary unconformity on palaeontological grounds, which he therefore placed, with Hutton, between the Amuri limestone and Weka Pass stone, and cited unconformities on the same horizon in other districts, and the controversy shifted to these.

Thomson (1913) described new fossil-localities in the Weka Pass stone at Onepunga and in the Mount Brown beds near the junction of the Weka Creek and the Weka Pass Stream. He expressed the opinion that "although a classic locality for the determination of the relationships of the Cretaceous and Tertiary beds, the Middle Waipara and Weka Pass district is not well suited, owing to its poverty in molluscs, to become the standard of reference for the Tertiaries of New Zealand."

Morgan (1915) described the section exposed in the gorge of the Weka Pass Stream near the railway-viaduct and in its upper valley, agreeing with the explanation of the structure put forward by Marshall, Speight, and Cotton, and devoted special attention to the contact of the Amuri limestone and the Weka Pass stone. The conclusion, stated to be tentative, was that the facts appeared to be clear proof of at least local unconformity. The same writer in 1916 (1916b) described the contact in the country between the Weka Creek and the Waipara River, recording the occurrence of small, extremely black, phosphatic pebbles in the glauconitic sandstone to a height of 4 ft. above the Amuri limestone surface, also one or two quartz pebbles and a pebble of flint, and also worm-borings now filled with glauconitic matter in the Amuri limestone. He noted that in the gorge of the Waipara River there was no sign of visible unconformity, but considered that it was still possible to accept the Amuri limestone and Weka Pass stone contact as representing a stratigraphical break. He cited a contact visible in a small gorge of Weka Creek as very satisfactory proof of the unconformity maintained by Hector and McKay as present between the "grey marls" and Mount

Brown beds. Sections were also given showing the Quaternary age of some of the faults of the district.

Speight in 1915 discussed the geology of the intermont basins of Canterbury with a view to arriving at a proper conclusion as to the pre-Notocene physiography, and whether or not the present Notocene beds were originally laid in discontinuous deposits or are the remains of a widely distributed cover which once masked the greater part of the surface of the country. He concluded in favour of the latter view, with the restriction that they did not form a complete veneer over the whole surface, but that elevations that survived the prior period of erosion projected like islands through the Tertiary sea, and may in some cases have been sufficiently high to form sanctuaries for the Antarctic element in the New Zealand flora.

Marshall in 1916 described the minute structure of the younger limestones of New Zealand, including specimens of the Amuri limestone and the Weka Pass stone from the Weka Pass. He found the Amuri limestone to consist mainly of very finely grained calcite, with fairly numerous, isolated chambers of *Globigerina*. Near the contact it contained a considerable number of grains of quartz sand and some glauconite, as well as some brown mica, together with different and larger species of Foraminifera, including *Cristellaria* and *Rotalia*. These characters, emphasized to a greater extent, were the features that distinguished the overlying Weka Pass stone from normal Amuri limestone. The microscopic structure and relations of these limestones served to indicate a strong resemblance between these stones near their contact, and such differences as there were would be a natural result of the shallowing of the water and of an increase in the velocity of the ocean currents. The depth of deposit of the Amuri limestone, a pure *Globigerina* ooze, was estimated at from 600 to 2,500 fathoms. Its age was considered to be Miocene.

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Thomson (1916) discussed the age and mode of origin of the Amuri limestone throughout North Canterbury and Marlborough, quoting fossils from it at Amuri

Bluff and the Trelissick Basin (discovered by Speight and Thomson) which proved the fossil-horizons to be Tertiary. As these occurred near the top of the limestone, which was always underlain by Cretaceous rocks, he concluded that it was in itself a Cretaceo-Tertiary rock—Cretaceous at the base and Tertiary at the top. He pointed out that the appearances of unconformity between the Amuri limestone and Weka Pass stone were not present where the base of the latter rock was not glauconitic, and concluded, therefore, that it was a purely local phenomenon, and not indicative of a non-sequence of any extent. He suggested that the Amuri limestone was in large part a chemical deposit, its silica content and its poverty in fossils becoming then easily explicable.

In 1917 Woods described the Cretaceous fossils of North Canterbury and east Marlborough in the collections of the Geological Survey. He found that rocks of two ages were represented, those of east Marlborough, north of Amuri Bluff, developed especially in the Clarence Valley (*cf.* Thomson, 1919) and the Awatere Valley, being of Lower Utatur (approximately Albian) age, and those of Amuri Bluff, Waipara and Weka Pass, and the Malvern Hills being Upper Senonian. In the Middle Waipara and Weka Pass district all the fossils came from the *Ostrea* bed and the "saurian beds," and in most cases were poorly preserved.

Thomson (1917) proposed the local terms "Clarentian" and "Piri-pauan" for the two groups of Cretaceous rocks correlated by Woods as "Albian" and "Upper Senonian" respectively, basing them on the rock-sequences below the Amuri limestone of the Clarence Valley and Amuri Bluff. He criticized the grouping of all the younger rocks of New Zealand by Marshall as a strictly conformable series deposited during a single cycle of depression and elevation, the period of maximum depression being everywhere contemporaneous, on the grounds that the Amuri and Oamaru limestones were of different ages and that unconformities are present in some districts. He rejected also Marshall's use of the name "Oamaru" for a system to include all the younger rocks, both on grounds of priority and because only a small part of them were developed at Oamaru, but admitted the necessity of an inclusive name for them in view of their diastrophic unity as more or less accordant rocks, deposited in a period of relative diastrophic inactivity between two periods of major diastrophic activity, and proposed the name "Notocene." The references to the Waipara and Weka Pass district were mostly to questions of correlation, but a summary of the succession from the coal-beds at the base to the Weka Pass stone was given with a view to showing the thinness of the beds between the highest known Piripauan and the base of the Amuri limestone. The tilted gravels unconformably overlying the marine succession in the Kowhai River were also briefly discussed.

Park (1917) suggested that not only was the tuff-bed recorded by Thomson and Speight in the Amuri limestone of the Trelissick Basin Oamaruan, but the whole of the Amuri limestone throughout New Zealand should be placed in the Tertiary, and an unconformity looked for below it, probably between the "saurian beds" and the overlying greensands, in which latter Haast had recorded a Recent brach-

opod in the Middle Waipara.

In 1917, also, Trechmann described Cretaceous Gasteropoda from New Zealand, mostly from the Selwyn Rapids, but one species from the *Ostrea* bed of the Waipara Gorge was included.

Speight and Wild (1918) gave a careful and very detailed description of the contact between the Amuri limestone and the Weka Pass stone, not

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only in the Middle Waipara and the Weka Pass, but also in numerous other localities in the region between Mount Grey and the Puhipuhi Valley. They distinguished between the two rocks a transitional layer, generally termed the "nodular" band or layer, which was uniformly about 1 ft. thick over an area of 100 miles by 15 miles, and was composed of phosphatic concretions and nodular masses of phosphatized Amuri limestone in a matrix of greensand or marl, with very occasionally some well-rounded pebbles of quartz and greywacke. The remarkable uniformity in the thickness of this layer over such an area was inconsistent with its being a shore-line deposit, and the character of the phosphatic pebbles pointed to their formation in a depth of over 100 fathoms. The upper surface of the Amuri limestone was not, they considered, an erosion surface, but one honeycombed by the borings and burrowings of marine organisms operating on the sea-floor at a considerable depth, with possibly some solution of calcareous matter by the solvent action of sea-water during a period of halt in the deposition. The borings were filled with the materials of the overlying bed and not by beach deposits. The rigorous parallelism of the Amuri limestone, the nodular layer, and the Weka Pass stone over such an area were inconsistent with a theory of unconformity by emergence and erosion. They therefore concluded that there was no unconformity, but that some alteration in depth or in the conditions of deposition no doubt occurred, which was of no greater amount than that which takes place when a bed of different lithological character is laid down in a perfectly conformable sequence. In describing the Middle Waipara occurrences the authors indicated the existence of a well-defined fault-

scarp along the east face of Mount Grey, limiting the extension of the Notocene beds in this direction. In 1919 the same authors discussed the nodular layer as a commercial source of phosphate.

Thomson (1919) discussed once more the age and origin of the Amuri limestone in Marlborough and Canterbury, arguing that it was in large part a chemical deposit on the outer slopes of the continental shelf. He accepted the view of Speight and Wild as to the conformity of the Amuri limestone and Weka Pass stone, and considered the contact as a plane of non-deposition, which he suggested might be due to a change of conditions putting a stop to chemical deposition, while the formation of purely organic ooze might be so slow as to allow time for the boring of the last-formed bed and the phosphatization of its upper surface before the deposition of the foreset greensand began. Dealing with Park's suggestion for an unconformity between the "saurian beds" and the Waipara greensands, he reaffirmed the Senonian age of the latter beds, rejecting Haast's determination of the brachiopod as Recent, and considered that if any disconformity existed it should be looked for above the Waipara greensands in the dark carbonaceous mudstone down into which the Amuri limestone passes.

Speight in 1919 gave a description of the tilted gravels of the Kowhai, Grey, and lower Waipara Rivers, and proposed for them the name of Kowhai^{*} series. He concluded that the age was most probably Pleistocene.

Morgan (1919) gave a general description of the limestones of the area, summarizing previous knowledge. He reaffirmed his belief that there is a true disconformity between the Amuri limestone and Weka Pass stone, and that it denotes a considerable time-interval.

[Footnote] * Speight spells the name "Kowai." The Lands Department maps give "Kowhai" for the river draining from Mount Grey and Mount Brown, and "Kowai" for the tributary of the Waimakariri River, and the distinction appears a convenient one. If Maori orthography is to be strictly followed, "Kowhai" should be used in both cases.

General Account of the Geology and Physiography.

As in all districts where any development of the Notocene is present, there are three main classes of rocks, viz.:—

Pre-Notocene: in this case greywackes and argillites, strongly folded,
(1.) indurated, and jointed, and truncated by an erosion surface, on which rests unconformably—

Notocene (as in Table III below): the rocks are only moderately indurated,
(2.) and then well jointed, but are not in all cases cemented they are for the most part strongly tilted, only locally folded, and are often faulted.

(3.) Notopleistocene: horizontal, for the most part unconsolidated, terrace and river silts and gravels.

The main subdivisions of the Notocene are shown in Table III.

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Table III—General Classification of the Notocene Rocks of the District.

Age.	Local Name.	Nature of Rocks.
Wanganuian	Kowhai beds	Terrestrial gravels.
	Greta (or Motunau) beds	Marine gravels, silts, and blue calcareous mudstones with gravelly shell-beds.
Oamaruan	Mount Brown beds	Rubbly impure limestones and calcareous sandstones, interbedded with sands.
	“Grey marls”	Grey calcareous and sandy mudstones, sandstones, and sands.

Kaitangatan	Weka Pass stone and Weka Pass greensand Amuri limestone	Limestone and calcareous sandstone, passing down into a calcareous greensand with phosphatic nodules. Chalky limestone, passing down into marls and glauconitic mudstones.
Piripauan	Waipara greensands	Glauconitic sands with hard, thin beds of greensandstone.
	“Saurian beds”	Purple glauconitic mudstones passing down into sands, both with yellow efflorescence.
	<i>Ostrea</i> bed	Sandstone cemented by poecilitic crystals of calcite, resting on a shell-bed mainly composed of oyster shells.
	Coal-measures	Carbonaceous shales, limonitic sandstones, and sands with thin seams of coal.

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Structure.

The general geological structure of that part of North Canterbury within which the district lies consists of elevated folded or tilted blocks with a general north-east and south-west trend, separating lowland areas which in the interior are intermont depressions. Broadly speaking, the elevated blocks may be regarded as anticlines and the depressions as synclines, though they are in many places bounded by faults on one or other side. The folding and faulting has been of geologically young age, after the close of the Notocene deposition, and is doubtless due to the same (Kaikoura) orogenic movements as caused the elevation of the Kaikoura Mountains. Since these movements erosion has largely stripped the Notocene cover from the higher parts of the anticlines-or tilted blocks, so that it is now found only on the lower slopes, and the resulting deposition has partially filled the synclines or fault-angles with horizontal Notopleistocene alluvium.

One such lowland area is the Amberley-Waipara Plain, which is a northern

continuation of the Canterbury Plain, from which it is nearly cut off by the Moeraki Downs, consisting of tilted late Notocene gravels. This plain, 135ft above sea-level at the township of Amberley, and 231ft. at the township of Waipara, slopes down south-east of the former place to low cliffs near the sea, but farther to the north-east it leaves the coast and enters an elliptical basin, crossing the Waipara River and extending some distance up the tributary Omihi Valley, being separated from the sea by the anticlinal elevation of Mount Cass. The lowland area extends farther to the north-east than the actual alluvial plain, and passes by way of the Greta Valley into the lower Hurunui Valley.

A second lowland area, farther inland and roughly parallel to the first, is the Hurunui-Waiau intermont basin, 567 ft. above sea-level at Culverden, which is drained by the Hurunui and Waiau Rivers. The south-western extension of this basin reaches the upper Waipara River near Heathstock, while a small lateral extension on the south-east side reaches the head-waters of the Waikare River near the township of Waikare, 733 ft. above sea-level.

The elevated belt separating these two lowland areas is divided by transverse depressions into three main blocks—viz., Mount Alexander (2,448 ft.) to the north-east, the Doctor's Range (2,568 ft.) in the middle, and Mount Grey (3,055 ft.) to the south-west. The north-easterly part is again divided obliquely by a nearly east-west fault, which runs from the neighbourhood of Waikare along the south side of the Waikare River, and separates a subsidiary low block, Moore's Hills, on the south from the higher Mount Alexander block to the north. The lowland area between these two blocks is occupied by the Waikare Valley, and is continuous at its head with the lateral extension of the Hurunui-Waiau intermont depression, forming the northerly of the two transverse depressions in the elevated belt. The southerly transverse depression is the fault-angle of a nearly north-south fault on the eastern side of Mount Grey, which lies on the upthrown side of this fault.

The Middle Waipara and Weka Pass district here described forms the lower south-easterly parts of this discontinuous elevated belt between the two main lowlands. The Notocene strip of which it is composed is bounded on its inland side by a fault near Mount Grey, rests unconformably on the pre-Notocene of the Doctor's Range, is thrown into a series of folds between the Weka Creek and Waikare, and at this point has not been completely stripped from the anticline of old rocks, and is again bounded by a fault

south of the Waikare River except for a few miles where it has again been stripped from the pre-Notocene on the summit of the Moore's Hills block. On its seaward side the Notocene strip everywhere dips under the Noto-pleistocene gravels of the Amberley-Waipara Plain. The Notocene beds are, with the exception of the Kowhai gravels, an accordant series, and behave as a structural unit in regard to folding and faulting. The general type of structure is shown diagrammatically in fig. 2.

Fig. 2.—A diagrammatic section from north-west to south-east across the district.

The disposition of the Notocene rocks as a simply tilted series with dips to the south-east is modified at various places both by faults and folds. The more important of these are the Mount Grey fault, bounding the Notocene to the south-west; the Boby's Creek fault, cutting the Notocene strip obliquely and separating the Mount Brown area from the remainder of the strip; and a series of folds transverse to the strip on the north-western side of the Weka Pass.

Fig. 3.—Section across the Boby's Creek fault.

The displacement along the Mount Grey fault is very great—probably over 2,000 ft.—but cannot be accurately estimated, as the Notocene rocks do not occur along the upthrown side. There must have been considerable drag accompanying the formation of this fault, for the limestones of the Notocene, which half a mile north-east of the fault-line strike north-east with a moderate dip to the south-east, become practically vertical near the fault-line and curve round to strike north-north-west.

The Boby's Creek fault runs west from the Waipara River north-east of Mount Brown, across the lower part and into the upper part of Boby's Creek, ending against the Mount Grey fault. The downthrow is on the north and east side, and amounts to about 1,300 ft. near the middle, where the "grey

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marks" have been brought opposite the coal-beds. On the south side of the fault some anticlinal folding is seen; the coal-measures occupy a middle position along the fault-line, and thence to the west a complete sequence up to the Amuri limestone may be traced, while to the east a similar sequence up to the Waipara greensands may be seen in Boby's Creek. On the north side of the fault, gentle anticlinal folding is shown by the "grey marls" in Boby's Creek below the road-bridge, and synclinal folding in the Main Mount Brown limestone both on the north bank of the Waipara River (see [Plate XXI, fig. 1](#)) and alongside the road in the angle between the fault, the Waipara River, and Boby's Creek.

Near Waikare, where there is a low transverse depression in the main elevated ridge separating the two lowland areas, the Notocene rocks have not been stripped from the pre-Notocene on the axis of the elevation, but continue across the saddle, and extend into the Hawarden area. There is thus anticlinal folding parallel to the elongation of the Notocene strip, but the structure is complicated by the presence south of Waikare of a syncline and anticline transverse, to the elongation of the strip. As these folds, exhibited only in the lower Notocene beds, do not continue to the southeastern side of the Weka Pass, where the upper Notocene beds outcrop, it was at one time considered that they were a proof of unconformity; but the structure was satisfactorily explained by Marshall, Speight, and Cotton (1911), whose diagrams are here reproduced ([fig. 4](#)). Without doubt the Mount Brown beds formerly extended north-west across the pass, and shared the same folding, but have since been removed by erosion.

Besides the above more important structural features there are a number of minor faults, with throws from a few inches to several feet, one of which, in the railway-cutting 43 $\frac{3}{4}$ miles from Christchurch, was mistaken by Hutton for an unconformity.

Physiography.

The main elements of the relief of the area under consideration and the

surrounding areas were doubtless determined by the Kaikoura orogenic movements, which caused the uplifts of the high-standing blocks—viz., Mount Grey, the Doctor's Range, Moore's Hills, and the Mount Alexander Range—and the (relative) downthrow of the intermont areas of the Heath-stock, the Waikare Valley, and the Omihi Valley. The drainage-pattern, however, was probably established in its major outlines during the earlier uplifts of which the Kowhai gravels serve as a record. The Waikare flats and the Heathstock lowland are stated by Speight (1915) to be part of the Hurunui-Waiau intermont depression, which is drained by the Waiau, Hurunui, Waikare, and Waipara Streams, each with its separate gorge through the seaward-lying enclosing ranges. The lowest gap in these ranges, the saddle of the Weka Pass, is not used by any stream, a proof that the above rivers occupied their present courses before the uplift of these ranges took place. They are, therefore, antecedent streams, or anteconsequents if the earlier uplifts are admitted as only earlier stages of the main uplift.

Following the main later uplifts fresh consequent streams would come into being, the chief of those which traverse our district being the Kowhai River in its main branches, the Weka Creek, and Omihi Creek. These streams, it will be noticed, are widely spaced.

In the period following the later uplifts an early mature topography developed. The presence of hard bands in the Notocene sequence—viz., the Amuri limestone and Weka Pass stone, the various Mount Brown limestones, and the harder sandstones of the Greta series—led to the development

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Fig. 4.

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of prominent cuestas, of which that of the main Mount Brown limestone (*cf. fig. 2*) is the highest and most persistent in the middle part of the strip, being breached only by the Waipara River and the Weka Creek. In the south-western part of the district the most prominent cuesta is that of the lower Mount Brown limestone, while east of Mount Donald the Weka Pass stone cuesta rises to equal prominence with that of the main Mount Brown limestone. Although subsequent depressions between the main cuestas were well developed, these were mostly occupied by small tributaries of various consequent or inconsequent streams, and there are few subsequent streams of any importance. The soft Piripauan beds and "grey marks" were for the most part reduced to low relief, and on them the Waipara River and Boby's Creek, and to a less extent the Weka Creek, developed broad flood-plains and meandering courses. The texture of dissection of the more porous Notocene was much coarser than that of the higher-standing pre-Notocene, which was characterized by numerous inequents with many rocky ledges.

North-east of Mount Donald the pre-Notocene rocks of Moore's Hills preserve fairly perfectly a fossil peneplain similar to those described by Cotton from Oamaru, Central Otago, the Gouland Downs, &c., including the presence on it of a small outlier of Weka Pass stone. No similar fossil peneplain appears to exist on the Doctor's Range, although the even slope from the height of the range to the saddle north of the Deans seems, when seen in profile, to suggest the presence of such a stripped surface. The reason for its absence near the Doctor's Gorge may possibly be the steepness to which the base of the Notocene has been tilted at this point, rendering it more liable to erosion; but, as the stratigraphy shows the existence of an overlap during the deposition of the Piripauan and Kaitangatan, it appears more probable that the surface on which the Piripauan rests was not peneplaned, though peneplanation had become practically perfect on the adjacent land before deposition of the Weka Pass stone.

The mature topography above described has been modified by a later revival of erosion due to regional uplift, which has allowed the Waipara River, the Weka Creek, and their main tributaries to incise themselves more than 100 ft. in the old flood-plains in narrow steep-walled gorges. The revival extends in the main streams right through the Notocene strip and into the adjacent parts of the pre-

Notocene rocks, but in the smaller, steep, and mostly dry tributaries draining the back of the cuestas of the Mount Brown and Greta beds has not passed, on the average, more than half their lengths, and the lower gorges through the Kowhai gravels and upper part of the Greta beds end abruptly in sand or gravel cliffs. Incised meanders are a marked feature of the rejuvenated topography, and are well displayed in the Waipara River both above and below the limestone gorge, and in Boby's Creek, while a beautiful example, superimposed on the pre-Notocene, is shown in the upper of the two inliers of those rocks in Bell's Creek. In the Waipara River the revived valley is graded right through the Notocene strip, but in Boby's Creek and Weka Creek the grading is not so perfect, and in the former the *Ostrea* beds cause a waterfall of about 20 ft.

The uplift which led to this revival is doubtless the same as caused the raised beaches of 150ft. and 250 ft., described by Speight (1912), near the mouth of the Waipara River. Its discontinuous nature is shown by a flight of terraces in the Waipara River above the limestone gorge, as figured by Cotton (1919) and shown in Plate XVI. Witness to its recent origin is also borne by numerous cut-off meanders at various heights in Boby's Creek.

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A still more recent revival of erosion is shown by the existence of small channels, a foot or two in breadth and depth, within the rejuvenated portions of the small streams draining from the back of the cuestas of the Mount Brown and Mount Donald beds. This revival, in the opinion of Cotton,^{*} may be due to the quicker run-off of storm-water owing to the eating-down of the original plant-covering by stock and rabbits, or to reduction of the plant-covering by slight desiccation of climate.

Caves and underground courses in the limestones are not a prominent feature of the area. Shelters caused by overhanging bluffs of Weka Pass stone are common, and are also developed in places in the Mount Brown limestones. The back slopes of the Weka Pass stone cuestas are marked by narrow fissures, generally parallel to the strike, which are mostly choked with clay and debris to a depth of 8–10 ft.

They are well displayed on the cuesta west of the Waipara River limestone gorge, and on the adjoining "grey marls" there are three large sink-holes occupied by lagoons. Sink-holes are also present in a similar position in the angle between the Weka Creek and the Weka Pass Stream. A persistent series of caves, said to be of considerable depth and extent, occurs at the foot of the Amuri limestone cuesta near Onepunga, just in front of the outcrop of the Weka Pass stone. The only underground course I have observed is in the Omihi Creek, northeast of Mount Donald, where the stream flows for a short distance underground in the Weka Pass stone. Springs and marshy areas are well displayed in many places and at various horizons where loose sands rest on more impervious rocks—e.g., on the hillside below Trounce's quarry, near Waikare, where sands below the Amuri limestone and glauconitic mudstone rest upon the Waipara greensands.

Detailed Stratigraphy.

Piripauan.

The Piripauan rocks of the district include all those Notocene rocks below the Amuri limestone and the marls, mudstones, or sandstones down into which it passes. All the fossils obtained from this group have been determined as Upper Senonian, including the Reptilia of the "saurian beds," and the presence of Reptilia in the overlying Waipara greensands justifies their inclusion also in the Piripauan. The rocks are nearly 800 ft. thick in the Middle Waipara district, but they are not more than 150 ft. a few miles east of the Weka Pass. The thinning-out is due to overlap, since in the eastern end of the district the sequence commences with the uppermost division, the Waipara greensands. Within the Piripauan no unconformity has been detected by any observer. The beds in most cases pass gradually into one another, and the divisions recognized are only for convenience of description.

Coal-measures and Ostrea Beds.

In the western part of the district, a bed formed mainly of black oyster-shells is very persistent, but as coal-seams lie sometimes above and sometimes below it it is conveniently included with the coal-measures. The clearest sections are those of the Doctor's Gorge, Waipara River, and in the various tributaries of Boby's Creek.

[Footnote] * Personal communication.

Doctor's Gorge, Waipara River.—According to von Haast's account (1871), the coal-beds are 150 ft. thick, and consist of rusty-coloured loose sands, with some harder bands of limonitic sandstone, followed by white quartz sands, and enclosing several seams of very inferior lignite and shales, the former from 9 in. to 2½ ft. thick. These in turn are followed by angular, loose, quartzose sands, covered frequently with an efflorescence of sulphur, and not showing any stratification. They strike north and south, with an easterly dip of 33°, and rest on pre-Notocene rocks, which dip about 70° north-north-east. It appears that von Haast must have based the above description on beds some distance each side of the gorge, for on the river-banks the total thickness under the *Ostrea* bed does not exceed 40 ft. Park's account (1888) closely follows von Haast's, but in addition he records the presence of distinct plant-impressions from the shales—viz., *Fagus Ninnisiana*, *Phyllites eucalyptoides*, *Griselinia myrtifolium*, and a fragment of *Coriaria (Cinnamomum?)*.

The succeeding *Ostrea* bed is about 20 ft. thick, and really consists of two or three shell-beds with sandy layers between. In places it consists chiefly of shells of *Ostrea*, in others of *Pugnellus*, and in others again of both of these, while there are a lesser number of other species of pelecypod. The upper part of the upper shell-bed is locally cemented by a calcareous cement in the shape of large poecilitic plates of calcite, and contains a few grains of glauconite and feldspar, in addition to the quartz of which it mainly consists. This is presumably the rock referred to by McKay (1877b) as "glance sandstone." The mollusca collected at this locality by McKay (1891) were determined by Woods (1917) as *Trigonia hanetiana* d'Orbigny, *Ostrea* sp. cf. *dichotoma* Bayle, and *Pecten (Camptonectes) hectori* Woods. In addition a species of *Cardium* is common, but does not appear to have been forwarded to Mr. Woods. Trechmann (1917) collected and described *Pugnellus waiparensis*.

Boby's Creek.—In Boby's Creek and its tributaries there are numerous sections of these beds, as they wrap round several inliers of the pre-Notocene rocks. I have not explored the area fully, and remain undecided whether or not there are two *Ostrea* beds represented. Where first seen, on going up Boby's Creek, the *Ostrea* bed is only about 2 ft. thick, and dips down-stream. It rapidly thickens, as it rises on the sides of the cliffs up-stream, to about 6 ft., and is underlain by grey sands

with a few carbonaceous streaks and many ironstone partings, and with occasional yellow efflorescence. After about 100 ft. these sands pass down into a lignitic series of interbedded carbonaceous shales and grey sands, also of considerable thickness. The section then becomes obscure for some distance. An *Ostrea* bed again reappears at the waterfall, but the beds below it have not been studied. In Bell's Creek, between the two gorges of pre-Notocene rocks, there is a lignite seam which has been worked by former occupants of Onepunga Farm.

Von Haast (1871) describes the beds in Boby's Creek as rusty-coloured loose sands, similar to those in the Waipara River, followed by several seams of lignite and shale, about 10 ft. in thickness, some of them of better quality than those of the Waipara River. These in turn are followed by angular white quartzose sands, succeeded by the *Ostrea* bed. At the water-fall this consists mostly of complete specimens of the large *Ostrea*, but in other places the shells are more fragmentary, and in places the bed is replaced by calcareous sands.

The fossils determined by Woods from the *Ostrea* bed of Boby's Creek were "*Area hectori*" Woods, *Trigonia hanetiana* d'Orb., and *Ostrea* sp. cf. *dichotoma* Bayle. In addition I obtained *Cucullaea* sp., *Cardium* sp., and *Pugnellus waiparensis* Trechmann (?).

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A peculiar feature of the *Ostrea* beds, perhaps most marked in Boby's Creek, is the strong smell of petroleum given out when the oyster-shells are freshly broken. I submitted specimens to the Dominion Analyst, but he reported that only a trace of petroleum could be determined analytically. The black colour of the oyster-shells and the odour of petroleum appear in New Zealand to be practically confined to the Piripauan *Ostrea* beds of North Canterbury.

McKay's Creek.—McKay collected in 1874 from the *Ostrea* beds of McKay's Creek, which is presumably one of the creeks entering the Waipara River from the north, above the limestone gorge, but he gave no detailed account of the beds in this locality. Woods determined from his collections the following species: *Nemodon*

sp. and *Pecten* (*Camptonectes*) *hectori* Woods.

Birch Hollow ([Plate XVII, fig. 1](#)).—The beds below the *Ostrea* bed are much thicker to the north of the Waipara River, and are well exposed in Birch Hollow, at the upper end of the high terraces, where they form two large bluffs. They consist of a lower series of rotted conglomerates, 50 ft. thick; a middle lignite series of grey sands and carbonaceous shales, in places passing into lignite-seams, together about 100 ft. thick; and a higher series of yellow sands with ironstone partings, about 150 ft. thick. The *Ostrea* beds consist of a lower oyster-bed, 15-ft. thick, separated from a high similar bed, 1 ft. thick, by 20 ft. of sandstone. They contain *Ostrea* sp. cf. *dichotoma* Bayle and *Pecten hectori* Woods. The beds here are flatter than in the Waipara River, and strike north-north-east, with a dip of 15° east-south-east.

Weka Creek.—The *Ostrea* beds are well displayed in the Weka Creek, where they are about 40 ft. thick. At this locality I collected the specimens of *Ostrea* sp. cf. *dichotoma* Bayle figured by Woods, and he determined also *Pecten* (*Camptonectes*) *hectori* Woods from McKay's earlier collection. There are few other molluscs, but a fragment of a rhynchonellid was observed. The underlying rocks consist of loose white sands, 40 ft. thick, resting on 5 ft. of coal-shale, which here lies hard on the rotted argillite, and laterally dovetails into the sands.

The *Ostrea* bed is again seen as a thin band in the northern tributary of Weka Creek rising near Waikare, and may extend some distance to the north-west in the Waikare-Hawarden district. East of the Weka Pass these lower beds have not been observed, and they are certainly absent at the eastern end of the district.

“Saurian Beds” and Waipara Greensands.

Waipara River.—An almost complete section of the beds between the *Ostrea* bed and the base of the Amuri limestone is exposed in the banks of the Waipara River between the Doctor's Gorge and the limestone gorge ([Plate XVI](#)). They consist of sands, mudstones, and greensands, and may be conveniently termed the “sulphur sands” and “sulphur mudstones,” together constituting the “saurian beds,” and the “Waipara greensands.” The sulphur sands and mudstones are so termed from the presence of a yellow efflorescence on the rocks, formed of sulphur compounds, combined with a distinct smell of sulphurous gases in the near vicinity of the cliffs and talus, particularly where these rocks are cut through by narrow gorges. The yellow efflorescence has not been chemically examined in the Waipara district, but a similar efflorescence on Clarentian mudstones in the Nidd Valley, near Coverham, has been reported on by the Dominion Analyst, who states,

“The encrustation contains a small quantity of free sulphur. The water extract showed the presence of ferrous sulphate and small quantities of calcium and magnesium salts.” The efflorescence or encrustation is presumably due to the oxidation of sulphide of iron, present mostly in a state of fine division in the rocks, but partly in well-defined small nodular concretions. The name of “saurian beds” is given because of the presence of large concretions containing saurian bones in the upper part of the sulphur sands and the lower part of the sulphur mudstones. This is the horizon from which most of the Piripauan saurians have been obtained both in this district and at Amuri Bluff; but it should be noted that specimens have also been obtained both in the underlying coal-measures and in the overlying Waipara greensands. The latter rocks have usually been termed the concretionary greensands; but this name is unsatisfactory—first, because the concretionary beds compose only the lower part of the greensands, and, second, because there is a higher greensand horizon with true concretions to which the name might equally refer.

The *Ostrea* bed in the Waipara River is followed by clean white sands, containing a few carbonaceous shaly partings near their base. After about 100 ft. they become much more argillaceous, and pass finally into streaky rocks, forming grey cliffs, and consist, when freshly broken, of a dark mudstone matrix containing lighter-coloured streaks of glauconite and quartz sand in a calcareous base. At about 300 ft. above the *Ostrea* bed there is a thin band, about 6 ft. thick, consisting mainly of quartz sand and glauconite. This is succeeded by purple micaceous mudstones with a shaly parting, which are perhaps 200 ft. thick. The sulphur efflorescence commences after the first 50 ft. of sands, and continues in greater or less intensity throughout. Well-defined, nearly circular concretions, mostly from 4 ft. to 9 ft. in diameter, commence about 100 ft. above the *Ostrea* bed, and continue along certain planes for about 200 ft. ([Plate XVII, fig. 2](#)). Further similar concretions reappear in the middle and upper part of the purple mudstones. The concretions are formed of hard calcareous sandstone, and consist of grains of quartz with subordinate feldspar, glauconite, magnetite, and muscovite, set in a calcareous cement which is occasionally poecilitic, the individual calcite crystals being sometimes as much as an inch in diameter.

Fossils are not common in these concretions, but, owing to the keen search that

has been made for saurian bones, a large number has been collected. McKay (1892) noted that out of a total of some 250 "boulders" examined only six or eight proved shell-bearing, and three were rich in shells. Usually in the shell-bearing concretion there is a mixture of monocotyledonous and dicotyledonous plant-remains. The pelecypods collected by McKay from this locality were determined by Woods (1917) as follows: *Malletia (Neilo) cymbula* Woods, *Trigonia waiparensis* Woods, and *Thracia* sp. In addition imperfect specimens of *Belemnites* were included, and gasteropods, which were sent to Professor Wilckens, of Jena, before the war, and have not yet been described. The Reptilia collected from the "saurian beds" in this vicinity by Hood, Holmes, von Haast, and McKay, as determined by Owen, von Haast, Hector, and Lydekker, were: *Leiodon haumuriensis* Hector, *Cimoliosaurus australis* (Owen), *C. hoodi* (Owen), *C. holmesi* (Hector), and *C. haasti* (Hector). Hood collected other specimens, which were lost in the s.s. "Matoaka," including bones which he judged to belong to *Teleosaurus*, but Hector (1874) considered it probable that the specimens should be referred to *Leiodon*.

[View Image](#)

View looking down the Waipara River towards the limestone gorge, with the Deans Range in the background 1, pre-Notocene rocks of the Doctor's Range, 2 upper part of "saurian beds", 3, lower (concretionary) Waipara greensands; 4, upper Waipara greensands; 5, glauconitic mudstones underlying Amuri limestone, 6, lower (marly) part of Amuri limestone; 7, upper (chalky) part of Amuri limestone; 8, Weka Pass stone; 9, lower Mount Brown limestone (C); 10, upper Mount Brown limestone (D); 11, slip composed mainly of Amuri limestone.

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Fig. 1.—Looking down Birch Hollow, Middle Waipara. The lower cliff on the left shows the lignitic series, and the upper cliff the yellow sands of the Piripauan below the *Ostrea* bed. Fig. 2—Grey muddy sandstones with saurian concretions, Waipara River.

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Fig. 1—Cliff of lower (concretionary) Waipara greensands, Waipara River. Fig. 2.—View of the upper part of the Weka Pass. *a*, pre-Notocene rocks of the Moore's Hills block; *b*, Waipara greensands; *c*, Weka Pass stone surmounting Amuri limestone, *d*, Mount Brown beds in Mount Donald.

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Fig. 1.—Cliff of Weka Pass stone overhanging Amuri limestone, Waipara River, near limestone gorge. Fig. 2.—“Fucoids” in the Weka Pass greensand, cliffs overlooking Waipara River above limestone gorge.

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The question was raised by Holmes (*cf.* Hector, 1869) whether the saurian “boulders” were not derived, or at least “deposited in the bed as rolled masses,” since in some of them the saurian bones reach to the exterior, and appear there to be water-worn. Von Haast (1871) confirmed this observation, but concluded that the concretions were *in situ*. McKay (1892, p. 99) was therefore led to describe the boulders in great detail to explain this phenomenon: “They are often encased in 5 in. to 6 in. of impure cone-in-cone limestone, or by an envelope of similar thickness composed of sandy calcareous matter, preserving fucoid stems so abundantly that these must have formed a perfect envelope round the nucleus and greater mass of the concretion. Interior to this cone-in-cone or fucoidal covering the concretion is a hard greyish-blue limestone rock, and the remains of various species of saurians when present for the most part appear near the centre; but in cases in which considerable and connected portions of a saurian skeleton occur the bones are sometimes found through the whole diameter of the concretion proper, and into the cone-in-cone limestone or fucoidal envelope that surrounds the harder central portion. From the high cliff on the left bank of the

river below the junction of Pirau Burn, concretions often fall into the channel of the river at its base, and in several cases, as at present can be seen, they leave embedded in the marly greensands one-half or less of the cone-in-cone, more rarely of the fucoidal, envelope; also boulders may be seen *in situ* from which one-half of the cone-in-cone envelope has been loosened and fallen off, leaving the concretion beneath perfectly round and smooth. When the calcareous matter accreting to form the boulder has from any cause been insufficient to include the whole of the remains within the concretion proper, some of the bones are fractured or jointed along the line joining the boulder and its envelope, and the bones thus appearing at the surface are polished as though the boulder had been formed mechanically, and transported to the position it now or lately occupied by the action of running water."

In the creek called by McKay the Pirau Burn the sands immediately above the *Ostrea* bed are well bedded by the interposition of numerous carbonaceous shaly partings, and present a great similarity to the sands under the *Ostrea* bed farther to the north east.

The sulphur mudstones forming the upper part of the "saurian beds" are followed by the Waipara greensand, which may here be divided into a lower and an upper group. The lower group consists of 75 ft. of alternating hard and soft greensandstones, the hard bands being 1 ft. to 2 ft. in thickness and an average of 7 ft. apart. The hard parts are not continuous, but have a concretionary appearance ([Plate XVIII, fig. 1](#)). They have generally been described as calcareous, but show little effervescence with acid, and in thin section are found to consist of rounded grains of quartz and glauconite, accompanied by small pyritized fragments of organisms (probably radiolarian), set in a fine-grained granular matrix which is not birefringent. In hand-specimens the rock is mottled green and purplegrey. The upper group, 110 ft. thick, consists of softer, very dark greensands with a good deal of argillaceous matter and frequently with a shaly parting. In the cliff on the south side at the upper end of the large river-meander these pass quite gradually into the succeeding glauconitic mudstones, but in the cliff on the north side at the junction with Birch Hollow there are a few bands of hard greensandstone at the top, similar to those of the lower series. These upper greensands contain many pyrite concretions and have a marked yellow efflorescence.

Fossils are very scarce in the Waipara greensands, the most common being an obscure form from the lower group which has defied recognition. They consist of calcareous tubes, $\frac{1}{2}$ in. to 1 in. in diameter and a few inches in length, the interior being filled with matrix. Von Haast (1871b) recorded the presence of "some shells which appear to be allied to *Radiolites*," and the specimens he collected are preserved in the Geological Survey collections. They resemble the calcareous tubes collected by me, but are distinguished by the presence of nodal-like marks at intervals, giving the specimens an external resemblance to an equisetite stem. Dr. Marie Stopes, who kindly examined the series of specimens, writes that they are certainly not Equisetinean or structures of any higher plant, and that Professor Garwood, who also carefully examined them, concluded that they were not algal; she showed them also to specialists working on lowly animals, but none of them would claim them, and the consensus of opinion was that they were inorganic. Von Haast (1871a) recorded also from the lower group "*Waldheimia lenticularis*" and some pieces of a *Pecten* too small for recognition," and from the upper group two small Pectens, *Waldheimia lenticularis* and *Scalaria browni* (?). Park (1888) recorded a *Waldheimia* and a *Pecten* from the lower group. Unfortunately, none of the above fossils are preserved in the Geological Survey collections. McKay (1877a) collected bones of *Cimoliosaurus australis* in a detached mass of greensand near the junction of Birch Hollow with the Waipara River, and in 1913 I obtained part of a saurian jaw with teeth in a hard band near the top of the upper group at the same locality. These two saurian occurrences serve to unite the Waipara greensands with the saurian beds in the Piripauan. There is every appearance of conformity, however, with the succeeding group.

Birch Hollow.—The sequence of the "saurian beds" and Waipara greensands in Birch Hollow is essentially similar to that in the Waipara River, but owing to the flatter dips, and the slipping of the sides of the narrow gorge, the thickness of the beds cannot be easily estimated. The creek is nearly choked below the *Ostrea* bed by the abundance of saurian concretions coming from the grey sandy mudstones. Many of these show saurian bones and a few are crowded with gasteropods, but are too hard to break with an ordinary hammer. A good collection of saurian remains could be made from this gorge if the difficulties of transport could be solved, but they are very considerable, as the sides form sandy cliffs nearly 200 ft. in height, while the bottom is choked for over a mile with fallen beech-trees and

large boulders. The greensand bed separating the grey, streaky, sandy, concretionary mudstones below from the purple sulphur mudstones above is about 6 ft. thick, and is characterized by an abundance of small quartz pebbles of about in. diameter. The purple micaceous mudstones are well exposed in the main northerly tributary, which I did not explore, and appear to be upwards of 200 ft. thick. They do not appear here to bear any saurian concretions, and I noticed only one small concretion, of 4 in. diameter. The banded concretionary greensands do not appear to be more than 50 ft. thick, while the succeeding upper greensands at the mouth of the creek are perhaps thicker than in the Waipara River, and contain an abundance of pyrite nodules up to 3 in. or 4 in. in diameter. They are very dark, richly glauconitic, soft sandstones, with occasionally a tendency to assume a shaly parting, and in places have a very strongly marked sulphur efflorescence. From them I obtained a minute shark's tooth, considered by Mr. P. G. Morgan to be *Odontaspis* sp.; and similar to *O. attenuata* (Davis).

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Boby's Creek.—The “saurian beds” and Waipara greensands of the Boby's Creek watershed closely resemble those in the Waipara River. The *Ostrea* bed is followed down-stream by sandstones forming grey to light-yellow cliffs, and becoming more argillaceous when traced upwards, finally passing into grey sandy mudstones with marked yellow efflorescence. Saurian concretions commence a very short distance above the oyster-bed, but rarely exceed 4 ft. in diameter. Near the top these grey mudstones are notably streaky and inclining to be purple, and they are succeeded by a bed of loose sand about 20 ft. thick, which in turn is followed by similar streaky mudstones rapidly passing up into purple micaceous mudstones, which here abut against the fault. The higher beds appear on the high terrace on the south bank and up the most easterly tributary on this side, and consist of the concretionary greensands, the still higher beds not being exposed. The thicknesses of the above beds cannot be accurately estimated, as the bedding-planes are not well expressed, and the creek runs obliquely to the strike. In the upper part of Bell's Creek, besides the above rocks a small exposure of the upper Waipara greensands occurs. The whole series should be exposed in Boby's Creek above the waterfall, but I have not studied it there.

The following species of saurians, collected by Holmes, Travers, McKay, and von Haast, have been determined from the "saurian beds" of Boby's Creek: *Cimoliosaurus australis* (Owen), *C. haasti* (Hector), and *C. caudalis* Hutt. From Hector's collection of 1867, Chapman (1918) identified the following fish-remains: Teeth of *Scapanorhynchus subulatus* (Ag.) and of *Odontaspis incurva* (Davis), and vertebrae of *Lamna* (?). Presumably these are from the "saurian beds."

Weka Creek.—The *Ostrea* beds are followed by loose sands of considerable thickness, which become more sulphurous and argillaceous in their upper part. The succeeding mudstones are harder than in the Waipara River, and in places are almost flinty and contain impure flint nodules a few inches, in diameter. They are slightly micaceous, and are pale lilac on weathered surfaces, with rusty joint-planes and an occasional yellow efflorescence. These flinty mudstones present a great resemblance to Clarentian flinty mudstones in the Kekerangu and Benmore areas both in texture and colour. In their upper part they become less hard, and greyer in colour. No saurian concretions are seen either *in situ* or in the stream-gravels lower down, and are probably absent in this locality. The succeeding beds (Waipara greensands) are not here exposed, owing to a slip of Amuri limestone covering them.

In the northern tributary of Weka Creek rising near Waikare the hard bands of the Waipara greensands crop out at a number of points or form shoadings on the lower hills below the high cuesta of Amuri limestone and Weka Pass stone, and cross over into the Waikare watershed at the western end of Waikare Township. Thence the Waipara greensands extend as a narrow strip to the east between the township and the hills, but are partly covered by surface deposits of soft limestone and sands. Loose greensands are exposed in the excavations for the Waikare hospital site.

Weka Pass—Waikare Saddle.—Between the Waikare flats and the upper part of the Weka Pass the upper Piripauan beds are disposed in a flatly-dipping anticline around the western end of the ridge of pre-Notocene rocks which lies to the south of the Waikare Stream, and are exposed in the railway-cutting on the saddle near the 47-mile peg from Christchurch. The sides of this cutting are now considerably slipped and heavily grassed. Hutton (1885), who had an opportunity of examining this section soon after

the cutting was made, describes the beds, from below upwards, as bright-green argillaceous sands, calcareous green sandstone with shark's teeth, dark-grey micaceous sandy clay, and dark greensands. The dark-grey sandy clay passes in places into hard pale-lilac flinty mudstones similar to those observed in the Weka Creek.

East Side of Weka Pass.—In the valley entering the Weka Pass Stream from the east a little above the viaduct the hard bands of the Waipara greensands form a well-marked cuesta in the upper half of the valley, which continues over the saddle down to the upper part of Chasm Creek. The hard bands appear to be about 100 ft. above the pre-Notocene rocks, and about 300 ft. below the Amuri limestone and Weka Pass stone contact.

Chasm Creek and Omihi Valley.—In the lower part of Chasm Creek and the more easterly tributaries of the Omihi Valley the Waipara greensands are not exposed, owing to an overlap first of the Amuri limestone and underlying sands, and finally of the Weka Pass stone on to the pre-Notocene.

Waikare Valley.—About eight miles east of Waikare, Notocene rocks appear on the south side of the Waikare Valley and extend for some miles to the eastward. A continuous section of the beds below the Weka Pass stone is not exposed, but I observed in a small road entering the hills near what was Mr. Davy's farm that hard banded greensandstones, exactly similar to the lower group of the Waipara greensands, here form the base of the sequence, and rest directly on the pre-Notocene rocks. Higher up some loose sands were observed, but no typical Amuri limestone was seen, and the total thickness of the beds below the Weka Pass stone does not appear to exceed 100 ft.

Kaitangatan.

Amuri Limestone.

The upper part of the Amuri limestone throughout the district is a glistening-white, hard, very fine-grained limestone, which is generally at the surface closely jointed into small cuboidal blocks. The lower part is more argillaceous and greyer

in colour, and has a much coarser fracture. It passes down by imperceptible stages into a grey mudstone, and this in turn becomes a glauconitic mudstone with nests of glauconite distributed in an apparently capricious manner. This latter rock in the Waipara River rests with apparent conformity on the Waipara greensands, and much resembles the uppermost saurian mudstone immediately underlying the concretionary greensands. In the eastern end of the district, however, the glauconitic mudstones under the Amuri limestone rest on loose sands, which appear to be interposed between them and the Waipara greensands. For this reason, and because no distinctively Piripauan fossils have been found in them, they have been included with the Amuri limestone.

The microscopical characters of the Amuri limestone of Weka Pass have been briefly described by Marshall (1916a), who describes it as a pure *Globigerina* ooze: "The chambers of *Globigerina*, which are generally isolated, are fairly numerous. By far the greater part of the rock consists of very finely grained calcite." Near the contact of the Weka Pass green-sand it "contains a considerable number of grains of quartz sand and some glauconite, as well as some brown mica."

A number of analyses of Amuri limestone from the Weka Pass have been published with a view to the comparison of its composition with that of pebbles in the Weka Pass greensand, or with that of the Weka Pass stone. These are collected in the following table, along with analyses of the latter rocks, and have been in part recalculated.

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[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Table IV.—Analyses of Amuri Limestone and Weka Pass Sto

—	1	2	3	4	5	6	7	8	9	10	11	12
SiO ₂		7.25	14.45	11.12	7.52	6.74						
Al ₂ O ₃		0.66	1.03	1.78	1.64	1.50						

Fe ₂ O ₃	32.07	0.54	0.77	46.55	49.33	49.75	47.72	44.32	48.86	37.73	48.65	42.20
CaO		0.21	0.29	0.22	0.22	0.67						
CO ₂	25.19	39.24	36.21	36.41	38.49	38.76	36.85	33.32	38.19	29.30		
P ₂ O ₅				0.28	0.19	0.12	0.52	1.21	0.16	0.27	0.16	0.45
H ₂ O and organic		2.06	1.58	1.74	1.05	1.20						
Insol.							11.75	16.97	9.30	28.20	12.08	11.95
Alk. and undet.	42.74	0.40		1.90	1.56	1.26						
Sum	100.00	100.00	100.00	100.00	100.00	100.00						
CaCO ₃	57.26	88.64	81.56	82.34	87.47	88.09	83.75	75.73	86.80	66.60	86.43	74.09
MgCO ₃		0.45	0.61	0.46	0.46	1.41						
Ca ₃ (PO ₄) ₂				0.72	0.49	0.31	1.34	3.12	0.41	0.70	0.41	1.16

1 to 13, Amuri limestone; 14, Weka Pass greensand; 15, Weka Pass stone; 16, phosphatic concretion.

1. Right bank of Weka Pass Creek, near the railway-viaduct. McKay, 1887a.
2. Average sample from thickness of 40 ft. Park, 1905.
3. 2 ft. below Weka Pass greensand, Park, 1905.
4. At contact with glauconitic calcareous sandstone, in gorge of Weka Pass Stream above railway-viaduct, Morgan, 1915.
5. Uppermost layer in same locality as 4. Morgan, 1915.
6. Hard Amuri limestone, about 35 ft. below upper surface, in same locality as 4 and 5. Morgan, 1915.
7. Pebbles of Amuri limestone in glauconitic calcareous sandstone, same locality as 4,5, and 6. Morgan, 1915.

8. Amuri limestone, near upper surface, same distance up valley of Weka Pass Stream above railway-viaduct, Morgan, 1915.
9. Amuri limestone, 30 ft. below upper surface, in same locality as 8. Morgan, 1915.
10. Amuri limestone, 50 ft. to 80 ft. below upper surface, in same locality as 8, Morgan, 1915.
11. Sample 2 ft from present surface of Amuri limestone. Speight and Wild, 1918.
12. Sample from upper 6 in, of honeycombed portion of Amuri limestone. Speight and Wild, 1918.

Detached nodules of Amuri limestone lying in the Weka Pass stone a few inches above the present surface of the Amuri limestone. Speight and Wild, 1918.
14. Weka Pass greensand, 2 ft. above Amuri limestone, Park, 1905.
15. Average sample of Weka Pass stone broken from the whole thickness, Weka Pass. Park, 1905.
16. Phosphatic nodule from Weka Pass greensand, McKay, 1887.

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It will be seen that the hard white limestone at the top consists of 80 to 88 per cent. of carbonate of lime and 14 to 6 per cent. of silica. The grey limestone 50 ft. to 80 ft. below the upper surface contains only 66 per cent. of carbonate of lime.

The Amuri limestone contains few microscopic fossils either within the district or elsewhere. In the small gorge above the viaduct in the Weka Pass I observed a small fragment of a *Pecten* about 25 ft. below the upper surface. Foraminifera constitute a fair proportion of the rock, and from a collection which I made from the uppermost 3 ft. in the above locality Mr. F. Chapman determined the following forms: *Guembelina globulosa* (Ehr.), *Bulimina obtusa* d'Orb., *Bulimina*, sp. nov., *Globigerina cretacea* d'Orb., *Anomalina ammonoides* (Reuss), and *Pulvinulina elegans* (d'Orb.). From the same locality, 25 ft. to 30 ft. below the upper surface, he determined *Nodosaria annulata* Reuss, *Globigerina bulloides* d'Orb., *Anomalina ammonoides* (Reuss), and *Pulvinulina elegans* (d'Orb.). These forms, he considers, establish the Danian age of the rock.

The underlying glauconitic mudstones yield Foraminifera, Ostracoda, fish-scales and vertebrae, and fragments of molluscs and brachiopods. The fossiliferous nature of this horizon has only recently been established, and the specimens, excepting the brachiopods, have not been examined by specialists. The brachiopods include a species of *Aetheia* hardly distinguishable from the Oamaruan *A. gaulteri*. The remainder bear no resemblance to Oamaruan species, and include a new genus of Terebratellid. I hope to describe these and other Cretaceous brachiopods in the near future.

Waipara River.—The best section through the Amuri limestone is that afforded by the banks of the Waipara River at the Limestone Gorge and on the south bank for some distance above it. The following beds are exposed:—

	Feet.
Hard, white (chalky), closely-jointed limestone, including a few marly bands near the base	100
Softer, grey, argillaceous (marly) limestone with coarser bedding and jointing	60
Grey mudstone, passing down into dark blue-grey streaky mudstone, with nests and streaks of glauconite	300

The upper white limestone is thin-bedded and closely jointed in all directions. It forms nearly vertical cliffs, passing below into grassy talus-slopes. The grey limestone is thicker-bedded and less jointed, and has a spheroidal weathering like a mudstone. It is sometimes known as the "fucoidal limestone," from the presence of a peculiar fossil (?) known as the Amuri "fucoid," shown in fig. 5. This consists of rudely conical masses of limestone, with the apex of the cone directed upwards, the diameter of the base ranging from a few inches up to 3 ft. From the apex of the cone coarse flutings radiate to the exterior, the flutings being rounded on the bottom, and the intervening ridges rounded or angular according to the

shape of the flutings. The surfaces on which the latter are developed are not strictly conical, but sometimes almost spiral, as in the figure. Occasionally the flutings bifurcate. The "fucoids" occur chiefly in the main mass of the grey marly limestone, but are best displayed in a marly band, about 18 in. thick, 10 ft above the base of the white limestone. Besides the "fucoids" the grey limestone contains numerous Foraminifera and many small chitinous flakes. It was to a small fragment of the Amuri "fucoid," labelled "Culverden," but more probably from the Waipara or Amuri Bluff, that Hutton gave the name of *Pinna plicata*.

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The mudstones down into which the grey limestone passes are variable rocks, being in places ordinary dark-grey mudstones, in others very glauconitic mudstones, but for the most part consisting of a mudstone matrix, blue when freshly broken, white when weathered, containing small and large nests of glauconite in large grains. They thus resemble considerably the saurian sandy mudstones, but are more argillaceous and glauconitic. There appear to be about 300 ft. of these beds above the large river-meander on the south bank, and probably a greater thickness between the mouth of Birch Hollow and the limestone gorge on the south side. Foraminifera are abundant throughout, but are mostly rotted. Shell-fragments are present in a few places, while fish-scales and vertebrae and obscure plant-remains are fairly frequent. In the cliffs on the north bank of the river below Birch Hollow crushed tubes of *Teredo* are not infrequent, but no other shells were obtained. From a cliff on the east side of the small creek on the right bank I obtained a number of fragments of brachiopods. It is eminently desirable that as complete a collection as possible should be made from this horizon.

Fig. 5.—The Amuri "fucoid."

Bell's Creek, Boby's Creek. In the upper part of Bell's Creek, and in a small tributary which has cut a gorge through the Amuri limestone, the lower, grey limestone and

the underlying glauconitic mudstones are exposed in a number of small cliffs, not furnishing a connected section. The glauconitic mudstones resemble those in the Waipara River, and contain large and small Foraminifera, fish-scales, and various spines and spicules, but no shells were obtained except a single fragment of a brachiopod. Near the base these rocks contain numerous rounded white and green quartz pebbles up to in. diameter, and small rounded pieces of retinite up to in. diameter.

Weka Creek.—The Waipara greensands are not exposed in the main branch of Weka Creek, owing to a slip of limestone overlying them, and the succeeding glauconitic mudstones are also mostly obscured. The upper 12 ft. of the latter bed is exposed in the cliffs of a small creek entering from the west just above the limestone gorge, and consist of dark mudstones with nests of glauconite similar to that below the Amuri limestone in the Waipara River. They are directly succeeded by the marly limestone, of which about 30 ft. is exposed. The same mudstones occur in the bed of the Weka Creek at the junction of this tributary, and yield fish scales and vertebrae and Foraminifera.

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Weka Pass.—The exposures of the lower part of the Amuri limestone are not very good in the Weka Pass. Morgan (1915) has noted the following sequence:—

- (1.) Amuri limestone, fairly pure, 40 ft. or less in thickness. This is much jointed and even shattered in places.
- (2.) Amuri limestone, argillaceous, about 40 ft. thick. This rock where exposed to weathering breaks into small cuboidal or irregularly-shaped fragments.
- (3.) Calcareous light-grey claystone, probably between 40 ft. and 50 ft. thick. Exposed surfaces break into very small fragments.

(4.) Uncemented sand; with lumps of clay.

Waikare.—An important exposure has recently been made by the excavation for soft (surface) limestone in Trounce's pit, a mile west of Waikare. This pit lies on the grassy slopes below the outcrop of the outlier of Amuri limestone, and has passed through the surface deposit of soft limestone into a tough glauconitic mudstone, which exactly resembles those below the Amuri limestone at Weka Creek and the Waipara River. Mr. B. C. Aston has determined the carbonate of lime as 10 per cent. It contains numerous Foramanifera and rare sharks' teeth and brachiopods, including *Aetheia* sp. cf. *gaulteri*.

From borings made in the grassy slopes below the pit, and from the presence of springs farther down, it appears that the above mudstone rests on glauconitic sands, which in turn rest on some impermeable bed, along the top of which a series of springs appears.

Omihi Creek.—North-north-east of Mount Donald the Amuri limestone and underlying rocks are exposed in a small dry gorge tributary to the main tributary of the Omihi Creek. The lowest beds exposed are about 60 ft. of yellow sands, mostly fine-grained but with a fair proportion of large well-rounded quartz grains and much white mica. These become glauconitic and harder 3 ft. from the top, and are succeeded by 15 ft. of glauconitic mudstone, which passes up into 5 ft. of fucoidal argillaceous limestone with a good deal of glauconite. This is succeeded by the concretionary band of the Weka Pass stone, here about 6 ft. thick, which in turn is followed by 40 ft. to 50 ft. of typical Weka Pass stone.

The sands at the base are well exposed farther up the main tributary of the Omihi Creek, and rest upon the Waipara greensands.

Farther east, although there are no clear exposures, the beds between the Weka Pass stone and the pre-Notocene rocks greatly diminish in thickness, and it is probable that no Amuri limestone exists. East of Moore's Hill South the beds below the Weka Pass stone again increase in thickness, and near Davy's farm sands similar to those described above are seen between the Waipara greensands and the Weka Pass stone.

Oamaruian.

Weka Pass Greensand and Weka Pass Stone.

The "Weka Pass stone" is an old quarryman's name for the building-stone of the Weka Pass, and was introduced into geological literature by Hutton (1877), who included under it not only the limestone, formerly used as a building-stone, but also the calcareous greensandstone down into which the limestone passes. McKay

referred to the latter rock as the "greensand conglomerate," while Speight and Wild termed it the "nodular

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band" or "layer." Since it is not always nodular within the district, but is always more glauconitic than the overlying limestone, it is admissible to name it the "Weka Pass greensand," and to confine the name of "Weka Pass stone" to the overlying limestone. There are thus two greensand horizons both in the Weka Pass and the Middle Waipara—viz., the Waipara greensand below the Amuri limestone, and the Weka Pass greensand resting on the Amuri limestone. There is a third greensand horizon in the Waipara River—viz., a facies of the "grey marls" resting on the Weka Pass stone.

The Weka Pass stone is an arenaceous, slightly glauconitic limestone, 50 ft. to 100 ft. thick, the calcareous part of which is composed of the tests of Foraminifera and a fine-grained base similar to that of the Amuri limestone. In some parts, where the terrigenous elements are feebly developed, the rock becomes almost indistinguishable from the Amuri limestone, and, like it, is then thin-bedded and closely jointed, but for the most part it is coarser in texture, is cream-coloured instead of white, and is thick-bedded and not closely jointed. Consequently it presents, as Morgan (1915) pointed out, a more massive appearance in natural exposures than the Amuri limestone. Its chemical composition is shown in Table IV, consisting mainly of 67 per cent. of carbonate of lime and 22 per cent. of silica, whereas the Weka Pass greensand contains only 47 per cent. of carbonate of lime and 35 per cent. of silica. The Weka Pass greensand, being a softer rock than the two limestones it separates, is generally hollowed out, and the Weka Pass stone overhangs the hollow in a massive rounded ledge ([Plate XIX, fig. 1](#)). Where the Amuri limestone below is also clifffed the hollow of the greensand makes a marked break in the cliff, which is often occupied by a sheep-walk. Along certain parts of the outcrop the Weka Pass stone is apparently weaker towards erosion than the Amuri limestone, and instead of overhanging it in a cliff, as is usually the case, forms a small cuesta at the foot of the dip-slope of the more prominent Amuri limestone cuesta. This is the case between Onepunga Farm (to the south of

Boby's Creek) and Mount Grey, and for a short distance north-east of the North Dean. At Onepunga the Weka Pass stone is rather more glauconitic, than usual, and Speight and Wild have suggested that this and the greater abundance of phosphatic nodules are evidence that the old shore-line is being approached. More direct evidence would be an increase in the percentage and grain-size of the terrigenous material; and, as this is wanting, the suggestion lacks weight, more especially as the confirmatory evidence of overlap of the lower beds is absent in this locality.

The Weka Pass greensand presents two facies. In a few localities it is a simple slightly glauconitic calcareous sandstone presenting no peculiarities. This is particularly the case in the middle part of the limestone cliffs south of the Waipara River, between the road leading down from the Ram Paddock to the river and the limestone gorge. Lenticular masses of glauconitic material appear in the upper part of the Amuri limestone, and these gradually increase in number and size until the whole mass becomes glauconitic, and after a few feet passes insensibly into the Weka pass stone. At this locality "fucoids" are abundant in the upper part of the greensand ([Plate XIX, fig. 2](#)), including a peculiar type with curved transverse divisions like the septa of an *Orthoceras*, but unsymmetrical.

Elsewhere the Weka Pass greensand presents a very peculiar contact towards the Amuri limestone, a contact which has been repeatedly claimed as unconformable and with which a very considerable proportion of the literature on the district has been concerned. Little can be added to the

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detailed descriptions by Morgan (1915, 1916) and the exhaustive discussion by Speight and Wild (1918). The upper beds of the Amuri limestone are not compact, but consist of small separated blocks of white limestone, a few inches in diameter, in the interstices of which there occurs a filling of calcareous greensand of the same nature as the overlying bed of greensand. The upper 1 ft. or 2 ft. are most affected, but the penetration of the limestone by the greensand occasionally reaches a depth of 6 ft. The blocks of limestone are mostly irregular in outline, and

similar in shape to the cuboidal blocks isolated by jointing throughout the limestone. Morgan describes the fissures between the blocks as irregular cavities, following joint-planes to a great extent, but evidently enlarged by chemical erosion or solution, and mentions the existence of small peninsulas of limestone, some of which are joined only by a narrow neck to the main mass, extending several inches upward into the glauconitic sandstone. Speight and Wild describe the Amuri limestone as "jointed into flaky quadrangular blocks, the upper 2 ft. or more being bored by marine worms and the casts filled with glauconitic sandstone. The amount of boring increases progressively upwards until what may be called the transitional layer is reached." When I first examined the contact, in 1912, I noted occasional borings with round sections in the limestone, filled with glauconitic calcareous sandstone, but I formed the impression that the greater part of the penetration of the limestone by the greensand had taken place along joint-planes enlarged by solution, and after re-examining the contact with Speight and Wild's explanation in mind I am still of the same opinion, and agree with Morgan. I noted also in the gorge of the Weka Pass Stream above the viaduct that 5 ft. below the contact, where the limestone is practically undisturbed, there are occasionally bedded lenticular masses of glauconitic calcareous sandstone within the limestone. Speight and Wild observed a similar phenomenon in the Weka Creek, where they describe the limestone as breaking into quadrangular blocks, with interstitial calcareous greensand in layers parallel to the bedding in its upper portions, very occasional burrows extending to 6 ft. below the actual junction.

The uppermost part of the Amuri limestone, termed by Speight and Wild the "transitional layer," they describe as follows: "This consists in its lower part of Amuri limestone material thoroughly bored, with the interstices filled with glauconitic limestone. The result of the boring increases progressively, and the quantity of glauconitic material increases *pari passu*. The upper 6 in. is completely bored, so that peninsulas of Amuri limestone project at times into the overlying glauconitic layer, and at times become detached and resemble subangular pebbles in appearance. They are more phosphatic than the underlying limestones, and the included glauconitic limestone is more phosphatic than the overlying glauconitic layer. Included in this band are small angular nodules, green or black in colour, which are strongly phosphatic. Very occasionally small well-rounded pebbles of quartz, about $\frac{1}{4}$ in. in diameter, are met with."

The lowest layer of the greensand, described in the last part of the above extract, is termed by Speight and Wild the "nodular layer." The great majority of the inclusions are subangular pieces of Amuri limestone, slightly phosphatized, and the true phosphatic concretions are relatively scarce and quite small. The limestone inclusions are most abundant in the lower 12 in. of the greensand, but occur sporadically up to 2 ft. from the base, and are then, according to Morgan, mostly rounded. In addition to the quartz pebbles noted in the Weka Pass, Speight and Wild record a well-rounded

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pebble of greywacke near Boby's Creek, while Morgan records one or two very small pebbles of greywacke, together with a small rounded phosphatic lump, probably a fragment of bone. I have obtained from various localities rounded quartz pebbles up to $\frac{1}{2}$ in. diameter, a subangular pebble of quartzschist 1 in. long, and flattened pebbles of schistose greywacke over 1 in. in diameter. The upper part of the greensand passes by an increase of its calcareous content quite gradually into the Weka Pass stone.

The Weka Pass stone and greensand contain fossils only sparingly, the chief horizon being at the transition bed of the two rocks, on the underside of the overhanging bluffs so commonly developed. The richest locality for fossils is at Onepunga.

Cetacean bones occur fairly commonly, but are rarely perfect. I obtained an ear-bone of a whale from Onepunga. Sharks' teeth are fairly widespread, and I collected the following: From Onepunga, *Isurus desori* and *Lamna apiculata*; north-west of Mount Brown, *Odontaspis elegans*; cliffs overlooking Waipara River, *Isurus retroplexus*, *I. desori* (identified by Mr. P. G. Morgan). In addition Chapman identified the following species, believed to come from the Weka Pass stone, though the exact locality is uncertain: *Odontaspis incurva*, *Odontaspis* sp., *Isurus desori*, *Carcharodon megalodon*, and *Scombroclupea* cf. *macrophthalmia* (Heckel). The specimen of *Carcharodon megalodon* was labelled "Boby's Creek," and Chapman states that he examined the matrix, and had no hesitation in stating that it came from the Weka Pass stone. There is, however, no outcrop of this rock in the main branches of Boby's Creek, though the specimen may have come from the slopes of Mount Brown.

Of molluscs, *Pecten huttoni* and *Epitonium lyratum* are the most abundant, and occur in the cliffs overlooking the Waipara River, north-west of Mount Brown, at Onepunga, in the Weka Pass, and in the upper part of the Weka Pass Stream. At Onepunga I obtained in addition *Struthiolaria spinosa*, *Euthria media* (Hutt.)?, *Voluta* sp. cf. *protorhysa* Tate, *Turris altus*, *Dentalium solidum*, *Limopsis aurita*, *Teredo heaphyi*, and indeterminable species of *Aturia*, *Polinices*, *Architectonica*,

Pleurotomaria, *Trochus*, and *Ostrea*. From the cuesta between the Deans and the Waipawa River I obtained the holotype of *Lima imitata* Sut., and on the opposite side of the river observed casts of ribbed Pectens on the back slope of the cuesta.

Of brachiopods, *Aetheia gaulteri* is most widespread, being found at Onepunga, between the Deans and the Weka Creek, and in the upper part of the Weka Pass Stream. *Pachymagas cottoni* n. sp. has been obtained from Onepunga and the cliffs overlooking the Waipara River. *P. huttoni* has been collected at Onepunga.

Foraminifera are fairly abundant as isolated large examples at many localities, while smaller species occur throughout the rock. From a collection made in the small gorge above the viaduct in the Weka Pass Mr. F. Chapman has identified (*inter alia*) *Clavulina antipodum* Stache, *Polymorphina lingulata* Stache, and *Truncatulina thiasa* (Stache). From an examination of these and other Foraminifera and the sharks' teeth he considers that the rock is probably Eocene.

Echinoid fragments and spines are common at many localities, and *Graphularia* sp. and casts of other corals are found at Onepunga.

Hutton (1885 b, c) recorded a large number of fossils from the Weka Pass stone, including many of those mentioned above. The additional species (in modern nomenclature) are: *Scaphella elongata*, *Voluta attenuata* (cf. *V. sp. cf. protorhysa*, above), *Epitonium rotundum*, *Galeodea senex*, *Pleurotomaria*

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tertiaria, *Aturia ziczac* var. *australis*, *Lima laevigata*, *Pecten williamsoni*, *P. fischeri*, *P. beethami* var. B; beside brachiopods, echinoids, corals, and sharks' teeth, in which Hutton's identifications cannot be so safely accepted. Unfortunately, many of the older collections in the Canterbury Museum are labelled simply "Weka Pass," without reference to the exact horizon. It is possible that the species he identified as *Lima laevigata* should be *L. vmitata*, which resembles it in size.

The Weka Pass stone presents little variation in composition and thickness throughout the district. Morgan estimates it at 100 ft. thick in the Weka Pass

Stream. Usually it is not so thick, the average being perhaps 60 ft. It succeeds the Amuri limestone everywhere this is developed, but in the tributaries of the Omihi Creek east of Mount Donald it overlaps the Amuri limestone and rests directly on the greywackes of the Moore's Hills block. No actual exposure of the junction can be seen, but there is a small, flat-lying outlier lying off the second V outcrop uphill east of Mount Donald, and near the top of a road leading from the Waikare Valley, which approaches within 20 yards of an outcrop of greywackes, with only a few feet difference in level, so that not more than 20 ft. of beds can separate the two rocks. The neighbouring greywacke surface has all the characters of a recently stripped fossil peneplain. The Weka Pass stone in this neighbourhood is more glauconitic than usual, with fairly numerous dark phosphatic concretions, and has a peculiar pencil-like or thumb-like fracture.

The “Grey Marls” and Mount Brown Beds.

The beds following the Weka Pass stone have long been known as the “grey marls” and the Mount Brown beds, and the conformity or unconformity of these two sets of beds has been much canvassed, but there has been no close definition of what is to be included in these two series. “Grey marls” by common consent include any mudstone between the Weka Pass stone and the overlying limestones, which also by common consent are included in the Mount Brown beds; but between these two limits there is also a considerable thickness of sands and sandstones; and, moreover the upper limit—viz., the lowest limestone of the Mount Brown series—is not a persistent lithological horizon in the district. It will therefore be convenient to describe these two “series” together.

Five limestones must be distinguished in the Mount Brown series, and may be conveniently indicated by the letters A, B, C, D, and E. The lowest, A, forms a cuesta on the Ram Paddock, and also on the watershed between Boby's Creek and the Kowhai River, towards Mount Grey. It is a white polyzoan impure limestone containing in places an abundance of large cup-shaped Polyzoa, and is the “white and yellowish calcareous sandstone” of Hector (1869), and the “Bryozoa beds” of Haast (1871). The succeeding limestones, except the last, are mostly reddish-brown rubbly arenaceous limestones, the calcareous matter being largely comminuted shells of various marine organisms. Polyzoa, barnacles, or brachiopods in places constitute the greater part of the limestones, and there are also molluscan shell-beds. The second, B, forms the lower of the two limestone cuestas on the south-east side of the Weka Pass, and contains few fossils except small cup-shaped Polyzoa and barnacles. It may possibly be the same as the third, C, which forms the lower band on the cliffs overlooking the Waipara River below the limestone gorge, and is characterized by the presence of the brachiopod *Magadina waiparensis* Thomson. The fourth, D, is the main band throughout the district, occupying the

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top of the ridge overlooking the Weka Pass, the greater part of the skyline between the Weka Creek and the Waipara River, and the summit of Mount Brown. It contains a rich brachiopod fauna, the commonest species being *Magadina browni* Thomson, *Pachymagas parki* (Hutton), and species of *Rhizothyris*. The uppermost limestone, E, forms the cuesta southeast of the main band, D, at the approach to the Weka Pass, and is characterized by the brachiopods *Neothyris novara* (von Ihering) and *Stethothyris sufflata* (Tate).

Middle Waipara, South of Boby's Creek-Fault.—Starting at the western end of the district, in the tributary of Boby's Creek rising near Mount Grey, the Weka Pass stone passes up gradually into grey mudstones, the typical "grey marls," which are here apparently 200 ft. to 300 ft. thick. They yielded *Verconella costata*, *Malletia australis*, *Limopsis aurita*, *Pecten huttoni*, and *Diplodon zelandica* (Gray)? Above these the section is not clear, but there are sands containing *Turritella* and *Malletia*. The watershed between Boby's Creek and the Kowhai River is here occupied by a cuesta of the lowest Mount Brown limestone, A, which is a white polyzoan limestone, about 50 ft. thick. It yielded *Pecten huttoni*, fragments of a ribbed *Pecten*, and *Pachymagas clarkei* n. sp. The higher Mount Brown limestones were not here studied.

In Mount Brown two bands of reddish-brown limestone may be distinguished. The lower, B, is not richly fossiliferous, but has yielded *Anomia trigonopsis* and *Pecten palmipes*. Bed C has not been identified, but the upper band, D, forming the summit, is thicker than usual. Fossils are scarce near the summit on either side, but in the cliffs overlooking the Waipara River, where over 100 ft. of limestone is exposed, there is a very persistent band, formed mainly of *Magadina browni*, near the top. From some holes at the base of the cliff I obtained an abundance of *Bouchardia minima* Thomson, besides *Magadina browni*, *Pachymagas McKayi* n. sp., *Anomia trigonopsis*, *Pecten williamsoni* Zittel (?), *P. zelandiae*, and *Lima colorata*.

Middle Waipara, North and North-east of Boby's Creek Fault.—On the northern side of the Boby's Creek fault, in the north branch of Boby's Creek, the Weka Pass

stone passes up gradually into grey mudstones, about 60 ft. thick. These are followed by a considerable thickness of soft sandstones, separated into upper and lower divisions by a thin bed of mudstone containing *Mopsea* sp. and Foraminifera. The upper sands are cut off by the fault.

The most complete section is that afforded by the banks of the Waipara River below the limestone gorge, and partially repeated in the lower part of Boby's Creek owing to folding. The section is continued in the higher slopes to the east up to the horizon of the main Mount Brown limestone, and includes the following beds:

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

	Feet.
Main Mount Brown limestone (D)	60
Loose yellow-brown sands	80
Third Mount Brown limestone (C)	30
Bluish muddy sandstones with concretions, passing down into polyzoan shelly beds and a grit at the base	200
Mudstones with thin sandstone intercalations	200
Whitish sandstones with thin mudstone intercalations	200
Glauconitic mudstone	25
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The Weka Pass stone becomes glauconitic at its top, and passes quite gradually into glauconitic mudstones. The succeeding sandstones are in beds of 4 ft. to 10 ft., separated by mudstones 6 in. to 2 ft. thick. Some of the sandstones contain small rounded pebbles of foraminiferal calcareous sandstone, suggesting derivation by erosion from the Weka Pass stone. In the higher beds the sandstones are in thinner layers and the mud-stones thicker. Fossils are scarce

throughout, and so tender as to be very difficult of collection. *Epitonium zelebori* was obtained low down in the sandstones. Two shelly beds were noted on the right bank of the river, below the grit, both containing *Pecten huttoni*, the higher being similar to the polyzoan beds above the grit. The latter rock contains small pebbles of greywacke. It is succeeded by alternations of thin polyzoan limestones and bluish sandstones, and the latter beds continue to the base of the third Mount Brown limestone (C), and contain poorly defined concretions with shells and plant-remains (Plate XX). Just above the polyzoan beds I obtained *Paphia curta* and a fine specimen of *Pecten beethami* var. B Hutt.

Part of the above sequence is repeated in the lower part of Boby's Creek, north-east of the fault, and in the banks of the Waipara River above and below the junction of Boby's Creek. The cuesta of the lowest Mount Brown limestone (A) on the Ram Paddock is composed of a whitish polyzoan calcareous sandstone, consisting chiefly of larger cup-shaped and smaller Polyzoa, and yielding fairly numerous but poor specimens of *Pachymagas clarkei* n. sp., with rare pectens and echinoids. The limestone thins out rapidly along its strike in both directions, and obviously formed a polyzoan reef or shoal in the Oamaruan sea. To the west-south-west it crosses the Natural Bridge Creek, greatly diminished in thickness, just above the natural bridge, but does not continue to the east-north-east as far as the banks of the Waipara River. It apparently thins out also in the direction of its dip (south-south-east), but is presumably represented by the polyzoan beds near the bottom of Boby's Creek and those above described in the Waipara River.

In the Natural Bridge Creek, and in Boby's Creek below it, there is some gentle folding, so that a continuous section is difficult to trace. The polyzoan beds appear to be the lowest horizon exposed, and are succeeded by bluish muddy sandstones yielding *Anomia trigonopsis*, *Pecten beethami*, *Pecten huttoni*, and *Nucula sagittata* Sut., the latter species being first described from this locality. These are succeeded by current-bedded sands, on which a cream-coloured sandstone rests unconformably.

At the time of my first visit, in 1912, a recent slip had exposed a very clear unconformity on the side of the bluff facing the Waipara River at the upper corner of the junction between Boby's Creek and the river ([fig. 6](#)). The rocks below and above the surface of the contact were of similar nature—viz., bluish muddy sandstone—but those below were not so clearly bedded. The upper beds contained pebbles and boulders of the same nature, and also of grey mudstones and of greywacke, as well as broken shells. This section had become obscure at the time of my visit in 1913. A short distance up the Waipara River, on the same bank, I observed some shell-beds, which must lie above the unconformity, containing casts of *Cucullaea*, ribbed Pectens, a large *Dentalium*, and many gasteropods.

The lower part of the “grey marls” is exposed on the back of the cuesta of Weka Pass stone between the limestone gorge of the Waipara River and the saddle north-west of the North Dean. Here 50 ft. of grey mud-stone follows the Weka Pass

stone with every appearance of complete

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View across Waipara River below limestone gorge. 1, bluish-grey sandstones; 2, lower Mount Brown limestone (C); 3, yellow-brown sands; 4, main Mount Brown limestone (D)

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Fig. 1.—Syncline in the main Mount Brown limestone (D), Waipara River, north-east side below Boby's Creek. Fig. 2.—Cliff in Weka Pass Stream, below railway-cutting, 43½ miles from Christchurch. A fault with downthrow to the left intersects the cliff. 1, grey sandstone (top of "grey mails"); 2, hard calcareous conglomerate with shells 3. lower Mount Brown limestone (B).

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conformity. Fossils are fairly plentiful, including corals and Foraminifera, but the molluscs are mostly in the condition of casts. They include *Turritella carlottae* Watson and *Corbula canaliculata* Hutt. The succeeding beds are not exposed, but higher up the slope loose sands are seen.

The Middle and North Dean are composed of a yellow calcareous sandstone with many comminuted shells in certain bands, and frequent inclusions of a yellow-brown sandstone, which also forms separate bands. This is probably the second Mount Brown limestone (B). The main band (D) does not here form the crest of the range, but appears in rounded hills about half a mile to the south-east. Between B and D there are sands and further yellowish-white calcareous sandstones containing "fucoids," barnacles, Polyzoa, and echinoids.

The third Mount Brown limestone (C) is a yellow calcareous sandstone, about 30 ft. thick, containing in places an abundance of *Magadina waiparensis*. It may be traced from near the South Dean to the cliffs opposite the meander in the Waipara River below the gorge, but appears to pass into a sandstone before the river is reached.

Fig. 6.—Unconformity at junction of Boby's Creek and the Waipara River.

The Main Mount Brown limestone (D) forms the crest of the cuesta on the cliffs near the Waipara River, but higher up the hill, towards the Deans, it falls back behind the crest. It is divided into two parts by a persistent band of sand, 5 ft. thick, which contains occasional specimens of *Ostrea*, *Anomia*, and barnacles. The lower part is harder and not so rubbly as the upper, and contains few fossils but barnacles. The base of the upper part consists of a persistent shell-bed, 2 ft. thick, containing *Pecten beethami*, *P. burnetti*, *Lima colorata*, *Anomia trigonopsis*, and casts of many other-species, including *Turritella*. The remainder is the usual red-brown rubbly impure limestone, containing an abundance of *Magadina browni*. The main band is bent into a syncline where it reaches the Waipara River ([Plate XXI, fig. 1](#)); the lower part consists of alternating sands and calcareous sandstone, containing *Pecten huttoni*, while the underlying sands contain *Placun anomia* sp. and *Pachymagas* not sufficiently well preserved for specific identification.

On the opposite side of the river the Main Mount Brown limestone (D) is exposed in a small syncline, truncated by the Boby's Creek fault. It is of the usual rubbly character, and yielded *Pecten burnetti*, *Ostrea* sp., *Magadina browni*, *Rhizothyris rhizoida*, and *Pachymagas* of the *parki* series. Cup-shaped Polyzoa are fairly abundant.

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Weka Creek.—In the Weka Creek the contact of the Weka Pass stone and “grey marls” is well exposed. Speight and Wild (1918) have noted that the agreement in dip is absolute, and the contact does not show any signs of unconformity, but the Weka Pass stone exhibits on its upper surface a narrow bored zone similar to that on the upper surface of the Amuri limestone. “This is succeeded by 1 ft. of slightly glauconitic sandy marl, then by 12 ft. of slightly glauconitic sandstone, passing up into sandy marl and becoming more argillaceous higher up but still preserving something of its arenaceous nature.”

The thickness of the sandy mudstones is difficult to estimate, as the creek here runs obliquely to the strike, but is about 70 ft. Near the top *Amusium zitteli* is fairly common, and there are also casts of other bivalves and gasteropods, at least two species of coral, fish-scales, and Foraminifera. Such shells as exist are mostly too fragile to collect. The mudstone is succeeded by a sandstone, and then there are alternations of sandstone and mudstone up to the horizon of the second Mount Brown limestone (B).

Weka Pass.—In the middle part of the Weka Pass Stream from the road-bridge over the stream downwards, and in the railway-cuttings opposite, there are several isolated exposures of the “grey marls,” but no continuous section. The lowest beds, at the bridge, are typical sandy mudstones resting directly on the Weka Pass stone. The actual junction cannot be observed, but only about 3 ft. of beds is not exposed, and each rock appears to be approaching the other in composition. From these sandy mudstones, which appear to be about 50 ft. thick, I collected casts of *Verconella*, *Crassatellites*, *Loripes*, *Nucula*, and *Nuculana*.

Lower down the stream there are two large cliffs of well-bedded soft grey sandstone, and similar beds are exposed in the railway-cuttings above. The thickness of these sandstones does not probably exceed 200 ft. They are again succeeded by a sandy mudstone of unknown thickness, exposed at the first bend of the stream above the cliff of the lower Mount Brown limestone described below. These are succeeded by loose sands, passing into a grey muddy sandstone, together about 50 ft. thick.

In the upper part of the Weka Pass Stream only the lower part of the "grey marls" is exposed, as a typical sandy mudstone near the viaduct. From this rock I collected *Limopsis aurita* Brocchi (?) and Foraminifera, and McKay's earlier collection included *Ampullina miocaenica* Suter. A selection of the Foraminifera supplied by Mr. F. Chapman was as follows: *Clavulina communis* d'Orb., *Bulimina inflata* Seguenza, *Ehrenbergina serrata* Reuss, *Nodosaria vertebralis* Reuss, *N. prismatica* Reuss, *N. consobrina* d'Orb., *N. longiscata* d'Orb., *Lingulina costata* d'Orb., *Cristellaria vortex* d'Orb., *C. gyroscalprum*, Stache, *Globigerina triloba* Reuss, *Truncatulina thiara* (Stache), *Anomalina ammonoides* (Reuss), *Pulvinulina karsteni* Reuss, and *Rotalia soldanii* d'Orb. These indicate, according to Mr. Chapman, that the horizon is probably Eocene.

There are two prominent calcareous horizons in the Mount Brown beds on the south-east side of the Weka Pass, lying about 400 ft. and 800 ft. respectively above the Weka Pass stone. The upper horizon (D) forms an escarpment on the crest of the ridge, and the lower (B) presents a less prominent escarpment as a salient half-way down the slope, but in the angle between the Weka Pass Stream and the Weka Creek it forms a separate lower cuesta in front of the cuesta of the main band (D), and it assumes the same physiographic prominence between the Weka Creek and the North Dean, where, as already noted, it forms the summit of the range.

about 35 ft. of sands. Both bands consist of hard brown arenaceous limestone, with sandstone intercalations, forming cavernous cliffs owing to the weathering-out of included fragments of derived sand-stone. This phenomenon is well displayed in the cuesta between the Weka Creek and the Weka Pass Stream, where the derived fragments often show clear bedding oblique to that of the enclosing rock. Fossils are scarce and consist chiefly of small cup-shaped Polyzoa and barnacles, but *Anomia* sp. and partial valves of *Magadina* were observed. The lower bands are exposed on a cliff below the railway-cutting, between it and the Weka Pass Stream, where they are intersected by a small fault with downthrow to the north ([Plate XXI, fig. 2](#)). The base of the limestone on the northern (downthrown) side consists of a lenticular hard calcareous conglomerate enclosing specimens of *Cucullaea*, *Struthiolaria tuberculata* and many other gasteropods, and numerous barnacle (*Balanus*) fragments. Unfortunately the matrix is too hard to enable satisfactory specimens to be collected. The conglomerate rests upon soft grey sandstones, of which the few feet exposed show no bedding, so that the presence of an unconformity cannot be definitely asserted, but the presence of the derived fragments of sandstone in the overlying limestone makes it probable.

In the Weka Creek the lower limestone (B) flattens out just before reaching the creek-banks and is not exposed on the banks. It seems probable that it is cut off by a fault with downthrow to the south-east.

The third Mount Brown limestone (C) does not appear to be developed in the lower part of the Weka Pass or in the Weka Creek, but is again found not far below the main band (D) on the north-west face of Mount Donald, and for some distance to the south-west, where in a col in the cuesta it reaches the summit. It forms at the last point about 40 ft. of hard calcareous sandstone, in bands of 1 ft. to 3 ft. thick separated by shelly sands containing *Magadina waiparensis*, *Anomia trigonopsis*, and *Pecten burnetti*. A little nearer Mount Donald the bands coalesce to form a shelly limestone containing an exceptionally large number of derived sandstone inclusions, which weather out and give it a very cavernous appearance. It contains Polyzoa, barnacles, and shelly fragments, including *Magadina waiparensis* and *Anomia trigonopsis*. On the north-western face of Mount Donald the base contains a shell-bed with many casts of large gasteropods. It is here underlain by sands containing concretions.

The main Mount Brown limestone (D) forms, as already mentioned, the crest of the watershed south-east of the Weka Pass. It is divided by a persistent bed of sand, which outcrops just below the crest on the Weka Pass side, and yielded *Pachymagas cottoni* n. sp. and *Waiparia abnormis*. This limestone crosses the railway-line in the cutting 43 miles 21 chains from Christchurch. At the northern end of the cutting there is about 35 ft. of sands exposed below the lowest bed of limestone. These sands contain occasional shells, including *Ancilla pseudaustralis*, *Pecten huttoni*, and very fragile shells of *Crepidula* sp. Immediately below the lowest limestone bed is a thin bed of broken shells, including *Anomia trigonopsis*.

and *Glycymeris* sp. The lowest limestone bed is 5 ft. thick. It is succeeded unconformably by 25 ft. of sands, containing many small derived pieces of sandstone, and yielding *Anomia trigonopsis*. Then follows 3 ft. of limestone, succeeded by another 25 ft. of sands. These are succeeded by the

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main mass of the limestone, 25 ft. thick, containing at the top a shelly band with *Pecten huttoni*, *P. beethami*, *P. burnetti*, and *Lima colorata*. The limestone also contains many brachiopods, including species of *Rhizothyris* and *Pachymagas*, *Magadina browni*, and *Terebratulina suessi*. It is followed by 6 ft. of sands, and a further 16 ft. of nodular limestone, which contains *Bouchardia minima*, *Magadina browni*, and *Pachymagas* sp. This is followed by 3 ft. of creamy calcareous sandstone, which, as will be seen later, is best regarded as forming the base of the next horizon.

Fossils are abundant in places on the dip-slopes of the main band (D), especially near the top of the small valley entering the Weka Pass Stream between the 43 m. 21 ch. and 43 m. 3 ch. cuttings, and over the saddle at the head of this valley down to the first valley trending to the Omihi Creek. Here the uppermost rubbly band seen in the railway-cutting is well exposed near the foot of the main dip-slope, and yields a rich brachio-pod fauna, besides *Pecten burnetti*, *P. beethami*, *Pecten* sp. nov., *Lima colorata*, *L. paucisulcata*, *L. lima*, *Ostrea angasi*, *O. gudexi* Suter (?), *Anomia huttoni*, *A. furcata*, *Isurus desori* (Ag.), *I. hastalis* (Ag.), small echinoids and fragments of larger species, and numerous cup-shaped and bottle-shaped Polyzoa. The brachiopods identified are *Terebratulina suessi*, *Bouchardia minima*, *Magadina browni*, *Rhizothyris scutum* n. sp., *R. rhizoida*, *R. elongata* n. sp., *R. curta* n. sp., *R. crassa* n. sp., *R. elliptica* n. sp., *R. fortis* n. sp., *R. obesa* n. sp., *R. pirum* n. sp., *R. ovata* n. sp., *R. amygdala* n. sp., *Pachymagas bartrumi* n. sp., *P. speighti* n. sp., *P. haasti* n. sp., *P. hectori* n. sp., *P. parki*, *P. McKayi* n. sp., *P. morgani* n. sp., and *P. coxi* n. sp.

The uppermost Mount Brown limestone (E) forms a prominent cuesta behind the dip-slope of the main band, and thence crosses the railway in the cutting 43 miles

2–3 chains from Christchurch, and descends into the Weka Pass Stream and Weka Creek a few yards above their junctions. The succession from the main band upwards may be followed without a break in the Weka Pass Stream and the Weka Creek, while parts of the beds are exposed on the escarpment of the cuesta to the east. The total thickness is about 100 ft., the last 35 ft. being formed by the uppermost limestone, which in the railway-cutting is a reddish-brown to yellow arenaceous limestone with numerous small pockets containing small pebbles, up to $\frac{1}{4}$ in. in diameter, of greywackes and jaspers. It contains many polyzoan and echinoid fragments.

Immediately succeeding the main limestone (D) is a creamy calcareous sandstone a few feet thick, well exposed just above the foot of the dip-slope of the main band, where it yields *Stethothyris sufflata* and *Neothyris anceps* n. sp. When followed over the first saddle into the most easterly tributary of the Omihi Stream it forms a sharp V down-stream, and on the far side is 3 ft. thick and yields *Pachymagas andrewi* n. sp. It is here followed by a hard band 2 ft. thick in turn succeeded by more soft creamy limestone, 3 ft. thick, yielding *Lima colorata* and *Pachymagas cottoni* n. sp. This is again followed by another hard band 1 ft. 6 in. thick, and the exposed section here ends with soft calcareous sandstone containing *Lima colorata* and *Cucullaea alta* var. B. The above limestone bands are included with the uppermost limestone (E) because of the occurrence in them of *Stethothyris sufflata*.

In the gorge of the Weka Pass Stream the above calcareous sands are succeeded by blue muddy sands, about 50 ft. thick, which contain fossils sparingly throughout, and include two shell-beds. The lower 20 ft. contains *Cucullaea alta* var. B. and *Lima colorata* fairly commonly, and also yielded

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Turritella concava, *Natica australis*, *Ampullina suturalis*, *Verconella costata*, *Ancilla pseudaustralis*, *Surcula fusiformis*, *Limopsis zitteli*, *Pecten william-soni*, *P. huttoni*, *Tellina eugonia*, and *Dosinia greyi*. The lower shell-bed lies about 30 ft. below the limestone, and is exposed in the Weka Pass Stream at and below the

suspension bridge, and also in the Weka Creek. It yielded *Magadina browni*, *Neothyris novara*, *Rhizothyris curiosa*, *Crepidula monoxyla*, *C. gregaria*, *C. striata*, *Polinices gibbosus*, *Galeodea sulcata*, *Sigapatella novae-zelandiae*, *Latirus brevirostris*, *Verconella costata*, *V. dilatata*, *Voluta arabica*, *Voluta* sp. cf. *protorhysa* Tate, *Ancilla novae-zelandiae*, *Dentalium solidum*, *Placunamonia incisura*, *Limopsis zitteli*, *Pecten crawfordi*, *P. burnetti*, *P. huttoni*, *Crassatellites attenuatus* (fragments), *Venericardia purpurata*, *Cytherea sulcata*, *Protocardia alata*, and *Thracia* n. sp. The upper, or *Hinnites*, shell-bed occurs at or near the base of the limestone, and is exposed in the railway-cutting, in the Weka Pass Stream and its tributary crossing the railway-line above the cutting, and in the Weka Creek. It yielded *Neothyris novara*, *Stethothyris sufflata*, *Hemithyris nigricans* mut., *Dentalium solidum*, *Pecten crawfordi*, *P. burnetti*, *Hinnites trailli*, *Lima paucisulcata*, *Ostrea angasi*, *Cytherea sulcata*, *Chione stutchburyi*, *Cochlodesma angasi*, and *Protocardia alata*.

The limestone (E) closing the sequence of the Mount Brown beds contains a fair number of brachiopods and a few molluscs in the Weka Creek, the railway-cutting, and the cuesta leading to the Omihi watershed, and yielded the following species from these localities: *Crepidula gregaria*, *Galeodea senex*, *Ancilla pseudaustralis*, *Anomia trigonopsis*, *Antigona sulcata*, *Pecten burnetti*, *P. beethami*, *P. triphooki* Zitt. (?), *P. hochstetteri*, *Lima paleata*, *Terebratulina* sp. cf. *cancellata* Koch, *Stethothyris sufflata*, *Neothyris novara*, *N. iheringi* n. sp., *Rhizothyris curiosa*, *R. media* n. sp., *R. scutum* n. sp., *R. curta* n. sp., *R. elliptica* n. sp., *R. fortis* n. sp., *R. obesa* n. sp., and *Pachymagas hectori* n. sp.

As the limestone cuesta is traced from the Weka Creek past the first tributary of the Omihi Creek towards the second it exhibits no longer the characteristic brachiopods and becomes more of a hard shell-bed, the shells being mostly casts at the outcrop. It appears to be continuous past the back of Mount Donald towards the Waikare Valley, but has not been examined in this direction.

The summit of Mount Donald forms an outlier of beds resting on the main limestone band (D). These appear to be the lower beds of the *Stethothyris sufflata* zone. Park (1905) stated that some mile and a half north of the pass, near the highest part of Mount Donald, the beds were richly fossiliferous, and gave a list of forty-eight species of cetacea, fish, molluscs, brachiopods, cirripedes, and echinoids. I have been unable to rediscover this locality.

Behind the cuesta of the main limestone (D), running from the Weka Creek towards the Deans, the first cuesta is that of a shelly calcareous sandstone containing fine pebbles, which lies about 120 ft. above the main band (D). This is presumably the uppermost band (E). It has not been recognized in the Waipara end of the district.

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Greta Beds.

The Greta, or Motunau, beds of the district are a variable series of littoral beds, consisting largely of gravels and gravelly shell-beds, oyster-beds, coarse sands, and blue calcareous or sandy mudstones, with rare lignite-seams.

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The constituents of the gravels consist predominatingly of the harder elements of the pre-Notocene of the North Canterbury mountains—viz., greywackes, grits, quartzites, and jaspers; but there are also pebbles of basalts and lamprophyre-like igneous rocks. No pebbles of the underlying Notocene beds have been observed, nor has any clear unconformity with the Mount Brown beds been detected, but the faunal break is such that one may well be suspected, and it is more than probable that outside the area an overlap of these beds on to the pre-Notocene will be discovered.

Those bands with a harder cement, mostly calcareous, stand up as cuestas on the back slopes of Mount Brown, the Deans, and the hills near Glenmark, but they are not well exposed in the small creeks draining these slopes, and the best sections are those of the Kowhai River in its main branches, the Waipara River, and the Weka Creek. An intermittent section is also yielded by the railway-cuttings between Waipara and the Weka Pass.

Kowhai River and Mount Brown.—Only a part of the north branch of the Kowhai River was explored, and a discontinuous section of the Motunau beds observed in the creeks draining from Mount Brown. In a cliff facing Mount Brown, the base of which is about 200 ft. above the top of the main limestone (D), there is an oyster-conglomerate about 50 ft. thick, yielding *Ostrea arenicola*, succeeded by 50 ft. of hard calcareous conglomerate, and resting on sands with a bed of fragile shells.

In a tributary notching the cuesta of the Mount Brown beds, west of Mount Brown, lower beds are exposed. Above the main limestone (D), with *Magadina browni*, there is a gap of about 20 ft. in the succession, and then there is a further

10 ft. of brown calcareous polyzoan sandstone with much quartz, perhaps still in the Mount Brown series. This is followed by brownish-green sands and 1 ft. of calcareous sandstone. The succeeding beds are 40 ft. sands, 10 ft. fine conglomerate with pebbles of jaspers, grey-wackes, and dark porphyritic rocks, 50 ft. brown sands, and 10 ft. fine conglomerate oyster-beds with 8 in. boulders of a white calcareous sandstone containing friable fossils at the base, the same horizon being represented 100 yards down-stream by four separate oyster-beds separated by sands. After a gap of 50 ft. some 15 ft. of coarse conglomerate is exposed. The oyster-beds yielded *Anomia huttoni*, *Ostrea angasi*, and *O. nelsoniana*.

On the road from Onepunga to the Kowhai Valley the first beds exposed are oyster-beds and hard coarse conglomerates, lying about 200 ft. above the main Mount Brown limestone (D). In the first large cliff in the north branch of the Kowhai River below there are fine conglomerates and sands, with many oyster-beds. The next prominent bed upwards in the sequence is again an oyster-conglomerate with a hard white calcareous cement. About a quarter of a mile down-stream the first mudstone is exposed, and is a very green rock without fossils. It lies about 300 ft. above the main Mount Brown limestone (D).

The upper part of the Greta beds is exposed in the lower part of the north branch of the Kowhai River and its numerous tributaries. The rocks are fine conglomerates, gravelly shell-beds, oyster-beds, sandstones and loose sands, blue mudstones and sandy mudstones, and thin lignite seams. Continuous exposures are not found, and, judging from neighbouring cliffs, the conglomerates and sandstones are lenticular and not persistent. Fossils are fairly abundant, but are in many cases very fragile. The oysters belong to the species *Ostrea angasi*, *O. arenicola*, and *O. corrugata*. An exhaustive collection of the other species was not made, but the following were noted: *Chione meridionalis*, *Gari lineolata*, *Modiolus australis*, *Protocardia pulchella*, and *Sigapatella novae-zelandiae*.

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The beds are covered unconformably by the Kowhai gravels, the junction being

clearly seen in a tributary draining from Mount Brown. Mr. R. Speight informs me that a very good fossil-locality for the Greta beds has been discovered recently in the north branch of the Kowhai River.

The first cuesta behind that of the main Mount Brown limestone (D) on the Mount Brown road consists of a fine conglomerate containing sparse pebbles of quartz, greywacke, and jaspers in a white calcareous cement, and lies about 100 ft. above the main limestone. Whether this represents the uppermost Mount Brown limestone (E), or, as seems more probable, the base of the Greta series, remains uncertain. A series of alternating sands and shelly gravels capped by a hard coarse conglomerate forms the next cuesta, lying at least 100 ft. above the former. The shells represented are chiefly *Glycymeris laticostata*, *Crepidula gregaria*, and *C. monoxyla*; but I collected also *Antigona zelandica*, *Chione stutchburyi*, *Dentalium solidum*, *Dosinia greyi*, *D. subrosea*, *Ostrea nelsoniana*, *Spisula aequilateralis*, and *Verconella mandarina*.

Waipara River—For some distance below the outcrop of the main Mount Brown limestone no Notocene beds are exposed on the north bank of the Waipara River, and the base of the Greta series does not outcrop at this point. The lowest beds seen lie on the south bank, at the bend of the river opposite the end of the cuesta running down from Mount Brown (but on the opposite side of the Boby's Creek fault), and consist of sandstones with concretions, followed by mudstone, on which rests 20 ft. of fine gravelly and sandy shell-beds containing *Cerithidea bicarinata*, *Tellina deltoidalis*, *Verconella dilatata*, *Venericardia difficilis*, and other species too fragile to collect. This is followed by soft greenish mudstones yielding *Ancilla mucronata*, *Cerithidea bicarinata*, *Chione yatei*, *Cominella adspersa*, *C. quoyana*, *Crepidula gregaria*, *Mactra discors* (?), *Ostrea angasi*, *Struthiolaria papulosa*, and *Tellina deltoidalis*. Above this occur shelly conglomerates 6 ft. thick, containing *Ancilla australis*, *A. pyramidalis*, *Barnea similis*, *Sigapatella novae-zelandiae*, *Cerithidea bicarinata*, *Chione chiloensis*, *C. yatei*, *Ischnochiton maorianus*, *Cominella quoyana*, *C. adspersa*, *Crepidula costata*, *C. striata*, *C. monoxyla*, *Diplodon zelandica*, *Dosinia greyi*, *Lapparia corrugata* (?), *Lutraria solida*, *Mangilia sinclairi*, *Modiolus australis*, *Musculus impactus*, *Ostrea angasi*, *Rissoina vana*, *Seila chathamensis* var., *Verconella dilatata*, *V. mandarina*, *Terebra tristis*, *Trochus tiaratus*, *Trophon corticatus*, *Venericardia purpurata*, *Voluta arabica*, *Volutospina huttoni pseudorari-spina* (?). To these about 20 ft. of mudstone succeed, containing fossils similar to the lower mudstones; then a further 10 ft. of sandy and gravelly shell-beds (mostly *Ostrea* and *Venericardia* with *Anomia huttoni*), about 25 ft. of mudstone, another *Ostrea* and *Venericardia* shell-bed, 12 ft. of muddy sands, 10 ft. of yellow sands, and 10 ft. of gravels, after which the section ends.

About a quarter of a mile down-stream on the north bank there is an exposure of mudstones with fossil wood resting on sandstones and shelly conglomerates. The mudstones yielded *Arcopagia disculus*, *Cerithidea bicarinata*, *Chione chiloensis*, *Crepidula monoxyla*, *Dosinia greyi*, *D. subrosea*, *Modiolus australis*, *Ostrea angasi*,

and *Tellina deltoidalis*. These are succeeded by a muddy sandstone. After a gap in the succession further sandstones and shelly conglomerates appear.

A boulder obtained from the river-bed farther down by a settler con-contained *Ostrea ingens*. The matrix was a pebbly calcareous sandstone, quite similar to some of the hard bands of the Greta beds forming small cuestas on the slopes towards the Deans.

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Weka Creek.—The lowest beds of the Motunau series appearing in the Weka Creek are shelly conglomerates, which are followed on the right bank by greenish mudstones, 20 ft. thick, crowded with *Chione stutchburyi*. The next beds to outcrop are a series of shell-beds yielding *Ancilla novae-zelandiae*, *Anomia huttoni*, *Barnea tiara* Tate, *Calyptarea maculata*, *C. tenuis*, *Gari lineolata*, *Glycymeris laticostata*, *Mactra dubia*, *Mytilus canaliculus*, *Ostrea tatei*, *Spisula aequeilateralis*, *Trochus conicus*, and *Verconella dilatata*. Farther down-stream, in a high cliff near the road, there is a hard oyster-bed about 6 ft. thick, from which *Ostrea arenicola* was identified.

In the railway-cutting 43 miles 2–3 chains from Christchurch the uppermost Mount Brown limestone (E) is followed, apparently quite conformably, by a thin bed of white sand, showing on the south-west (creek) side of the cutting, succeeded by about 12 ft of shelly conglomerate. This is followed by a yellow-brown polyzoan calcareous sandstone, greatly resembling the underlying limestone (E), of which 12 ft. is exposed. On the north-east side of the cutting, where the section is clearer, the shell-bed is divided in two by a mudstone intercalation, and there are loose brown sands, making a total of about 35 ft. of beds before the calcareous sandstone is reached. Park (1905) interpreted the upper calcareous sandstone as a portion of the Mount Brown beds, and considered that it was covered unconformably by the shell-beds which really underlie it. The constituents of the conglomerates are mostly coarse, hard greywackes and jaspers, but basalts and rotted lamprophyre-like igneous rocks are represented. The majority of the pebbles are 1 in. to 2 in. long, but a few up to 8 in. were observed,

all well rounded. The shells collected were *Amphidesma australe*, *Ancilla novae-zelandiae*, *A. hebera*, *A. mucronata*, *Anomia huttoni*, *Cerithiella* n. sp., *Chione chiloensis*, *Crepidula gregaria*, *Dentalium solidum*, *Dosinia subrosea*, *D. greyi*, *Glycymeris globosa*, *G. laticostata*, *Ostrea angasi*, *O. manu-briata*, *O. tatei*, *Polinices ovatus*, *Sigapatella novae-zelandiae*, and *Spisula aequilateralis*.

Kowhai Series.

The Kowhai series consists of tilted terrestrial gravels, resting unconformably on the Greta series, and containing boulders of all the underlying Notocene beds as well as the greywackes of which they are mainly composed. The beds form the lower hills adjoining the Amberley Waipara Plain, and have a larger development in the Moeraki Downs to the southwest of the district, and in the hills between Amberley and the lower gorge of the Waipara River. The best exposures are in the Kowhai River, but the beds are also seen in the creeks draining from the Deans and in the tributaries of the Omihi Creek.

Kowhai River.—In the high cliffs of the north branch of the Kowhai River north-east of Tobin's Road there are from 100 ft. to 200 ft. of brownish gravels dipping at a low angle to the north-east. The gravels are poorly sorted and poorly stratified, and consist mainly of greywackes, grits, and jaspers from the pre-Notocene rocks, with rare basalts. The boulders and pebbles vary from 1 ft. in diameter down to the smallest quartz grains, and there is a good deal of clay in the cement. In general shape they are angular, but the edges are always rounded. These gravels rest on a clay-bed about 18 in. thick, dipping 12° south-east, which has a sharp surface towards the gravels above, but passes down quite gradually to a series of grey gravels. These consist mostly of pebbles of the pre-Notocene, but contain also pieces of greensand, Amuri limestone, Mount Brown limestone with *Magadina browni*, and red and white sandstones.

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In a tributary draining from Mount Brown unconformable contacts of these gravels with the underlying Greta beds are clearly exposed. In some cases the

lowest bed of the Kowhai series rests on a surface obliquely truncating several beds of the Greta series. In other cases the surface of contact is with a single bed, but shows clear evidence of erosion in its irregular contours.

Part II.—Descriptive Palaeontology.

Considerable collections of fossils were made by McKay and other members of the Geological Survey, but came chiefly from the Piripauan. In 1912 and 1913 I spent several weeks in the district supplementing these collections, especially from Tertiary horizons, as a result of which I announced in 1913 that "although a classic locality for the determination of the relationships of the Cretaceous and Tertiary beds, the Middle Waipara and Weka Pass district is not well suited, owing to its poverty in molluscs, to become the standard of reference for the Tertiaries of New Zealand."

The description of the saurians by Owen, Haast, Hector, Lydekker, and Hutton has already been mentioned in the account of the exploration of the district. The Piripauan Pelecypoda were described in a palaeonto-logical bulletin by Woods (1917), while the Gasteropoda were forwarded before the war to Professor Wilckens, of Jena, now of Bonn, and their description has been delayed. The Tertiary Mollusca were determined by Mr. H. Suter, who described the new species in 1917. The fish-remains, both Cretaceous and Tertiary, were described by Chapman in 1918. More recent collections, in 1915 and 1919, have been determined by Mr. P. G. Morgan. The Foraminifera were also forwarded to Mr. Chapman, and he is preparing a palaeontological bulletin on this group. A few of the Brachiopoda have been noticed in my earlier papers on this group, and to render this account more complete a reference to these is given below, together with descriptions of the new species. The echinoids, cirripedes, and Polyzoa have not yet been determined, but there is little good material in these groups.

Tertiary Mollusca.

An attempt has been made to use the most recent nomenclature, and many of the names employed by Suter have been rejected on account of the criticisms by Iredale, Smith, and Hedley. From a geological point of view these frequent changes in the names of common species are deplorable, but are a sign of the renewed activity in the study of the group. From a scientific standpoint there is no justification for neglecting any proposed change which bears on the face of it evidence of its correctness, and one can only hope that finality will soon be attained. In such a case as the species of the Volutidae, where the changes of generic appellation have been numerous, and authorities still differ, I have deemed it best to retain the original name *Voluta*. A few notes on individual species are appended.

Seila chathamensis Sut. var.

A specimen was obtained from the Greta beds of the Waipara River on which Mr. Suter remarked in 1913 that it was more cylindrical than Recent examples. He added that this was the first record of this species fossil.

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Anomia furcata Sut.

This finely radially costate Recent species occurs abundantly in dredge-spoils from Wellington Harbour, where it shows considerable variety of form and outline. A single specimen was obtained in 1919 from the main Mount Brown limestone (D), near the Weka Pass, and can be almost exactly matched, both as regards form and ornament, with a Recent specimen. This is the first record of this species fossil.

Anomia trigonopsis Hutt.

All the specimens recorded under this name were determined by Mr. Suter in 1913 as *A. walteri* Hector. On seeing four specimens from the White Rock River, in South Canterbury, which I collected in 1917, Mr. Suter then expressed his conviction that *Anomia walteri* was a synonym of *A. trigonopsis* Hutt., and that the latter name should be used for the Recent species.

Ostrea angasi Sow.

Concerning specimens from the oyster-beds in the tributary of the Kowhai River notching the cuesta of the Mount Brown beds west of Mount Brown, Mr. Suter remarked that the left valve is strongly ribbed, but nevertheless they are not *O. corrugata* Hutt.

Musculus impactus (Herrman).

This Recent species is *Modiolaria impacta* of the *Manual*. Mr. Suter remarked on a specimen from the Greta beds of the Waipara River that it is a much elongated form, but not *M. elongata* (Hutt.).

Mactra dubia (Hutt.).

- 1873. *Corbula dubia* Hutt., *Cat. Tert. Moll.*, p. 18.
- 1911. *Mactra chrydaea* Sut., *Trans. N.Z. Inst.*, vol. 43, p. 596.
- 1914. *Mactra chrydaea* Sut., *Pal. Bull. N.Z. Geol. Surv. No. 2*, p. 49.

When Suter discovered, on revising the type of Hutton's *Corbula dubia*, that it corresponded exactly with his own *Mactra chrydaea*, he rejected the earlier name on the ground that it was not figured by Hutton. This is against the International Rules, and Hutton's name must stand, unless it has been preoccupied under *Mactra*, which is, of course, quite possible.

Brachiopoda.

Rhynchonellidae.

Very few specimens of rhynchonellids have been obtained, and the absence of species of this family and of the Terebratulidae, although they are so common in correlative rocks in the Treliwick Basin and at Oamaru, makes the group, unfortunately, less valuable than it otherwise might be for purposes of correlation. The species represented are as follows:—

Aetheia gaulteri (Morris).

Cf. Thomson, *Geol. Mag.*, dec. 6, vol. 2, 1915, p. 389, fig. 1, *a*, *b*. A few specimens have been obtained from the Weka Pass greensand' from various localities, and are of the broad type described as *Terebratella sinuata* by Hutton.

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Fig. 1.—*Rhizothyris elliptica* n. sp.
Fig. 2.—*Rhizothyris amygdala* n. sp.

Fig. 3.—*Rhizothyris curiosa* Thomson.

Fig. 4.—*Rhizothyris media* n. sp.

Fig. 5.—*Rhizothyris curta* n. sp.

Fig. 6.—*Rhizothyris rhizoida* (Hutt.).

Fig. 7.—*Rhizothyris orata* n. sp.

Fig. 8.—*Rhizothyris lateralis* n. sp.

Fig. 9.—*Rhizothyris pirum* n. sp.

Fig. 10.—*Rhizothyris scutum* n. sp.

Fig. 11.—*Rhizothyris elongata* n. sp.

(All slightly reduced)

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Figs. 1, 2.—*Rhizothyris fortis* n. sp.

Fig. 3.—*Rhizothyris elliptica* n. sp.

Fig. 4.—*Rhizothyris amygdala* n. sp.

Fig. 5.—*Rhizothyris pirum* n. sp.

Fig. 6.—*Rhizothyris obesa* n. sp.

Fig. 7.—*Rhizothyris rhizoida* (Hutt.).

Figs. 8, 9.—*Rhizothyris crassa* n. sp.

Fig. 10.—*Rhizothyris obesa* n. sp.

Fig. 11.—*Rhizothyris elongata* n. sp.

(All slightly reduced)

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[Figure 1-6] (All slightly reduced)

Fig. 1.—*Rhizothyris curta* n. sp.
Fig. 2.—*Rhizothyris scutum* n. sp.
Fig. 3.—*Rhizothyris media* n. sp.
Fig. 4.—*Rhizothyris lateralis* n. sp.
Fig. 5.—*Rhizothyris curiosa* Thomson.
Fig. 6.—*Rhizothyris ovata* n. sp.
Figs. 7, 8, 9.—*Pachymagas bartrumi* n. sp.
Figs. 10, 11, 12, 13.—*Pachymagas hectori* n. sp.
Figs. 14, 15.—*Terebratulina* cf. *cancellata* Koch.

(All slightly reduced)

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[Figure 1-14] (All slightly reduced.)

Figs. 1, 2, 3.—*Neothyris iheringi* n. sp
Figs. 4, 5, 6, 7.—*Pachymagas haast*, n. sp.
Figs. 8, 9, 10, 11.—*Pachymagas parki* (Hutt.).
Figs. 12, 13, 14.—*Pachymagas speighti* n. sp

(All slightly reduced.)

Hemithyris nigricans (Sow.).

A mutation of this well-known Recent species is found in the uppermost Mount Brown limestone (E). It differs from Recent specimens only in its slightly smaller size and slightly more imbricated growth-lines. A similar mutation is found in Park's upper Hutchinsonian of Target Gully, Oamaru district, the lowest horizon from which any specimens referable to this species have been found.

Terebratulidae.

Terebratulina suessi (Hutt.).

Three specimens only of this species have been found, in the top of the main Mount Brown limestone (D). They agree well with the type from the Curiosity Shop.

Terebratulina sp. cf. *cancellata* Koch. (Plate XXIV, figs. 14, 15.)

A single, not very well preserved specimen from the uppermost Mount Brown limestone (E) seems referable to the Terebratulidae from its epiphyrid beak characters and labiate foramen, while a fine dichotomous striation suggests *Terebratulina*. These characters are combined only in the Recent Australian species *Terebratulina cancellata* Koch, which, however, on account of its beak characters, will doubtless be made the type of a new genus. The specimen under consideration is larger than the average specimen of *T. cancellata*, but does not show the dorsal biplication characteristic of adults of that species. Its dimensions are Length, 38 mm.; breadth, 30 mm.; thickness, 21 mm.

No terebratulids other than the above have been obtained and the absence of *Liothyrella* is worthy of remark.

Terebratellidae.

Bouchardia minima Thomson.

This species occurs locally in abundance in the main Mount Brown limestone (D).

Magadina browni Thomson

Magadina waiparensis Thomson.

Trans. N.Z. Inst., vol. 47, 1915, pp. 399, 400, 402, 403, figs. 7, *a*–*d*, 8, *a*, *b*.

M. waiparensis has been found only in the third Mount Brown limestone (C) in the cliffs overlooking the Waipara River, and near Mount lo Donald. *M. browni* is extraordinarily abundant in places in the main limestone (D), and can be found in most exposures. It occurs rarely in the sandstones under the uppermost limestone (E). It is strange that *Magadina* should be so abundant in the Waipara district and be absent or very rare from the Oamaru district. There are two specimens in the Geological Survey collection from locality 308, Oamaru formation, Oamaru, Hector, 1876. One is a specimen of *M. browni*, and the other a new species of *Magadina*. The locality record gives little information, and must be accepted with caution in view of the absence of similar specimens in the extensive collections made by Uttley, Park, and myself.

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Genus *Rhizothyris* Thomson.

Trans. N.Z. Inst., vol. 47, 1915, p. 399, figs. 5, *a*–*d*, 6, *a*, *b*.

Specimens of *Rhizothyris* are extremely abundant in the main Mount Brown limestone (D), and less so in the uppermost limestone (E). They present a great variety of form, the extremes being so different that it is impossible to imagine that they had not been differentiated into separate true-breeding races, although there are so many intermediates that it is obvious that the evolution either had taken place only a short time previously or was still in progress. Similar polymorphism is displayed by the specimens from Hutchinson's Quarry, Oamaru,

the Maerewhenua green-sands, and the Curiosity Shop. As the forms are not exactly the same in these localities, and as a stratigraphical value may be found to attach itself to certain forms, it is desirable to create species for all the distinctive types. To show the interrelationships of these it will be necessary to describe here a few shells from the other districts. The bearing of the results on correlation is discussed in Part III of this paper.

The ancestral type from which all the species appear to have developed has not yet been found adult, but is represented by the half-grown shell of *R. curiosa* Thomson. This is shown by the growth-lines to have been a suborbicular shell with a broad, uncurved hinge-line, and without any folding. From its development in outline appears to have proceeded along three main lines.

The first series is characterized by a retention of the broad, uncurved hinge-line, but there is an increasing elongation of the shell, combined with an increasing narrowing of the front. To this series belong *R. curiosa* Thomson, *R. media* n. sp., *R. scutum* n. sp., *R. rhizoida* Hutt., and *R. elongata* n. sp.

The second series is also characterized by the retention of a broad, little-curved hinge-line, and by increasing elongation, but this is not accompanied by a tapering of the front, and the shells retain an elliptical shape. Here belong *R. curta* n. sp. and *R. elliptica* n. sp.

The third series is characterized by an increasing narrowing and curvature of the hinge-line, and elongation is accompanied by a narrowing of the front, so that the shape passes from subcircular through broadly ovate, ovate, to narrowly ovate. Here belong *R. lateralis* n. sp., *R. pirum* n. sp., *R. ovata* n. sp., and *R. amygdala* n. sp.

There has also been development in the amount of folding, and at each stage in the development in outline folding may take place preventing further development of outline in quite the same manner as would be possible to an unfolded shell. The folding is in all cases simple ventral uniplication (sulcate or concavi-convex of Buckman). In general the effect of folding on outline is to produce a sudden truncation of the front. The folded shells are also generally more convex than the unfolded. Where necessary, species have been set up for the reception of the strongly folded and convex forms—viz., *R. crassa* n. sp., *R. obesa* n. sp., and *R. fortis* n. sp.

Mr. S. S. Buckman has also pointed out to me that a further discrimination may be made according to the stage of foraminal development. All the species are permesothyrid, and almost epithyrid, but in some there has been remigration of the foramen with the production of pseudotela. I am not yet clear as to the specific value of this criterion, and have not applied it in the present analysis.

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Rhizothyris curiosa Thomson. ([Plate XXII, fig. 3](#); Plate XXIV, fig. 5.)

Trans. N.Z. Inst., vol. 47, 1915, p. 399, fig. 6, *a, b*.

Three specimens referable to this primitive species have been found in the uppermost limestone (E). It occurs also in the Curiosity Shop green-sand, the Ngapara limestone, and the Clarendon limestone.

Rhizothyris media n. sp. ([Plate XXII, fig. 4](#); Plate XXIV, fig. 3.)

Similar to *R. curiosa* in shape and size, but slightly more elongate. The growth-lines repeat the outline of *R. curiosa* at about three-quarters the length of the dorsal valve, and the subsequent development is in the direction of a narrowing front, making the outline shield-shaped instead of suborbicular. The sides curve outwards only very slightly from the broad, nearly straight hinge-line. The convexity, folding, and beak characters are essentially similar to those of *R. curiosa*. Length of holotype, 38.5 mm.; breadth, 35 mm.; thickness, 18 mm.

Type locality: Curiosity Shop, Rakaia River, Canterbury. Besides the type locality, this species occurs in the limestone of Fossil Point, Ashburton River (Haast coll.). One specimen from the lower shell-bed of the Weka Pass Stream and several from the uppermost Mount Brown limestone (E) are referable here.

Rhizothyris scutum n. sp. ([Plate XXII, fig. 10](#); Plate XXIV, fig. 2.)

Shell in outline resembling a long heraldic shield. The hinge-line is nearly the breadth of the shell, and only slightly curved. The growth-lines repeat the outline of *R. scutum* at about three-quarters the length of the dorsal valve. The shell is very little folded, and both valves are rather depressed, -as in *R. curiosa* and *R. scutum*. Length of holotype, 43 mm.; breadth, 34 mm.; thickness, 19.5 mm.

Type locality: Greensands, Hutchinson's Quarry, Oamaru. Besides the type locality, this species occurs also in limestone near Clifden, Waiau, Southland (G. M. Thomson coll.), in the Curiosity Shop greensands, Rakaia River, and in the

main Mount Brown limestone (D) and the uppermost limestone (E) of the Weka Pass.

Rhizothyris rhizoida (Hutt.). ([Plate XXII, fig. 6](#); Plate XXIII, fig. 7.)

- 1905. *Bouchardia rhizoida* Hutt., *Trans. N.Z. Inst.*, vol. 37, p. 480, pl. xlvi, fig. 7.
- 1907. *Magellania rhizoida* Iher., *Ann. Mus. Nac. Buenos Aires*, ser. 3, tom. 7, p. 473.
- 1915. *Rhizothyris rhizoida* Thomson, *Trans. N.Z. Inst.*, vol. 47, pp. 397–99, fig. 5, a.

The holotype, which comes from the Weka Pass, is a shell with worn beak, which led Buckman from an examination of the figure to state that the foramen was mesothyrid, but it is really permesothyrid. Shells exactly matching the holotype in shape are not common, but the species may be allowed to include those shells intermediate in elongation between *R. scutum* and *R. elongata* which are moderately elongate, with a slightly curved hinge-line nearly the breadth of the shell, and a marked taper. These shells are moderately to strongly convex, and always show some folding.

The species is common in the main Mount Brown limestone (D), from which the holotype was doubtless derived, but does not appear to extend into the uppermost limestone. It is also common at Hutchinson's Quarry.

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Rhizothyris elongata n. sp. ([Plate XXII, fig. 11](#); Plate XXIII, fig. 11.)

- 1905. *Bouchardia elongata* Park, *Trans. N.Z. Inst.*, vol. 37, p. 541 (*nomen nudum*, ascribed to Hutton).

Three specimens only, of extremely elongate tapering form, have been collected—two by McKay from Hutchinson's Quarry, and one by myself from the dip-slope of

the main Mount Brown limestone, Weka Pass. All three are imperfect, and I have selected the least-damaged specimen from Hutchinson's Quarry as the holotype. The hinge-line is broad and little curved, and is nearly the breadth of the shell. The sides taper gradually to a narrow front. The convexity and folding is moderate in all three specimens, and the beak little incurved.

Dimensions in Millimetres.

	Length.	Breadth.	Thickness.
Holotype	55	37	27
Paratype, Hutchinson's Quarry 34+		23.5	10
Paratype, Weka Pass	47	30	19+

Rhizothyris curta n. sp. ([Plate XXII, fig. 5](#); Plate XXIV, fig. 1.)

Shell broadly elliptical, with a broad, little-curved hinge-line almost as broad as the shell; sides gently convex and regularly rounded, meeting the nearly straight front in obtuse angles. Valves moderately and nearly equally convex; anterior commissure nearly straight, with only a very slight, broad, rounded ventral sinuation. Length of holotype, 37 mm.; breadth, 33 mm.; thickness 20 mm.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. The species occurs rarely in the type locality and in the uppermost Mount Brown limestone, and one specimen has been obtained from the concretionary bed, Deborah Cutting, Oamaru. It also occurs in a dwarfed form, up to 26 mm. long, in the Maerewhenua greensands.

Rhizothyris crassa n. sp. (Plate XXIII, figs. 8, 9.)

Shell in outline resembling *R. curta*, Valves strongly convex, anterior commissure with a broad, fairly deep, ventral sinuation. Beak erect. Length of holotype, 41 mm.; breadth, 37.5 mm.; thickness, 27 mm.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. The species in common in the type locality.

Rhizothyris elliptica n. sp. ([Plate XXII, fig. 1](#); Plate XXIII, fig. 3.)

- 1915. *Rhizothyris rhizoida* (Hutt.) Thomson, *Trans. N.Z. Inst.*, vol. 47, p.398, fig. 5, d (not of Hutton).

Shell elongate-elliptical, hinge-line broad and little curved, sides lightly convex and regularly rounded, front rounded. Valves moderately convex, anterior commissure with a slight rounded ventral sinuation. Length of holotype, 47 mm.; breadth, 36 mm.; thickness, 22 mm.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. The

species is rare both in the type locality and in the uppermost Mount Brown limestone, and is also found in the Hutchinson's Quarry greensands. Dwarfed forms from 25 mm. to 32 mm. in length are common in the Maerewhenua greensands.

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Rhizothyris fortis n. sp. (Plate XXIII, figs. 1, 2.)

Shell elongate-elliptical, hinge-line fairly broad and little curved, sides lightly convex, rounded, front narrowly truncate and nearly straight. Valves strongly convex, anterior commissure with a broad ventral sinuation. Beak nearly erect. Length of holotype, 60mm.; breadth, 44.5 mm.; thickness, 36 mm.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. Two specimens only referable to this species have been found in the type locality, and two in the uppermost Mount Brown limestone.

Rhizothyris obesa n. sp. (Plate XXIII, figs. 6, 10.)

The outline resembles that of *R. scutum*, but the hinge-line is slightly more curved, and there is a greater approach to an elliptical shape. The valves are markedly convex, a character which differentiates the species from both *R. scutum* and *R. elliptica*, and the shell is also more folded and the beak more incurved than in these species. Apparently corresponding to the incurvature of the beak, the foramen is slightly remigrant with an indication of pseudotela. Length of holotype, 48.5 mm.; breadth, 39 mm.; thickness, 28.5 mm.

Type locality: Foot of dip-slope, main Mount Brown limestone (D), Weka Pass. A single specimen was obtained from the uppermost Mount Brown beds, in the *Neothyris* shell-bed of Weka Pass Stream.

Rhizothyris lateralis n. sp. ([Plate XXII, fig. 8](#); Plate XXIV, fig. 4.)

Shell subcircular, hinge-line broad but slightly curved, sides convex and rounded,

beak-margins nearly straight, front rounded. Valves moderately convex; there is a broad rounded sinuation in the anterior commissure. Length of holotype, 38 mm.; breadth, 37 mm.; thickness, 20 mm.

Type locality: Mount Brown beds, Weka Pass. It is uncertain whether the specimen came from the main limestone or the uppermost limestone. No examples are known from other localities.

Rhizothyris pirum n. sp. ([Plate XXII, fig. 9](#); Plate XXIII, fig. 5.)

Shell broadly ovate or pear-shaped, with a moderately broad and curved hinge-line, sides convex and rounded, front truncated and gently rounded. Valves moderately convex, anterior sinuation slight. Length of holotype, 34 mm.; breadth, 28 mm.; thickness, 18 mm.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. There is only one other specimen referable to the species, from the escarpment of the same beds, overlooking the Weka Pass.

Rhizothyris ovata n. sp. ([Plate XXII, fig. 7](#); Plate XXIV, fig. 6.)

Shell ovate, with a moderately broad, curved hinge-line, sides lightly convex and rounded, front truncate and gently rounded. The valves are moderately convex, anterior sinuation slight. Length of holotype, 36 mm.; breadth, 28 mm.; thickness, 18 mm.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. The species is also known from the greensands of Target Gully and Hutchinson's Quarry, Oamaru, and by a single specimen from the Maerewhenua greensands. The majority of the specimens from the latter locality belong to a similar ovate species, but with a shorter beak.

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Rhizothyris amygdala n. sp. ([Plate XXII, fig. 2](#); Plate XXIII, fig. 4.)

Shell narrowly ovate or almond-shaped, beak rather short, hinge-line short and curved, sides convex and rounded, front narrowly truncated and gently rounded. Valves moderately convex, sinuation of the anterior margin broad and shallow. Length of holotype, 29.5mm.; breadth, 21 mm.; thickness, 14 mm.

Type locality: Greensands of Hutchinson's Quarry, Oamaru. No other specimens than the holotype are known. Two anteriorly imperfect specimens from the main Mount Brown limestone agree closely in shape, except that the beak is longer.

Genus *Pachymagas* Iher.

As in the case of *Rhizothyris*, specimens of *Pachymagas* are abundant in the main Mount Brown limestone (D), and they present an even greater variety of characters. Similar series occur in the Hutchinsonian green-sands of Hutchinson's Quarry, Deborah, Kakanui, and other localities near Oamaru, while there is a different but even more varied assemblage in the Curiosity Shop greensands. The complexity of the problem, combined with the large amount of material, has delayed the completion of my memoir on the Tertiary Brachiopods of New Zealand; in the present paper I have restricted myself to the description of the majority of the species that can be recognized in the Waipara area, leaving a few till more satisfactory material can be obtained.

Among the already-described species in the Oamaruan three series may be recognized. The first includes *P. parki* (Hutt.), *P. marshalli* (Andrew), and *P. trellissicensis* Thomson, and probably also the Patagonian forms *P. tehuelcha* Iher. (the genotype) and *P. gigantea* Ortmann, and the Antarctic form *P. antarctica* Buckman. The shells are large, with a prominent mesothyrid foramen and beaks which are suberect to erect and not markedly carinate. The second series includes *P. triangularis* (Hutt.), *P. huttoni* Thomson, and the Patagonian form *P. venter* Iher. The shells are also large, with large mesothyrid forams, with erect to incurved beaks which are carinate, and with flattened and broadly sinuated dorsal valves. The third series, perhaps generically distinct, includes *P. ellipticus* Thomson, a smaller shell with a small foramen which is submesothyrid, almost mesothyrid.* The majority of the specimens from the district belong to the *P. parki* series, while there is a fourth series represented by a new species, *P. andrewi*, with a large shell and a small foramen.

In *Neothyris*, which is a descendant of *Pachymagas*, the tendency is to increasing convexity, a restriction of the foramen, and the production and incurving of the beak with old age, so that one may conclude that in *Pachymagas* also the evolutionary process is from depressed to convex, from large to small foramen, and from suberect to erect and produced beak. Other characters which may be treated on evolutionary lines are the shape, the folding, and the cardinalia. The last, unfortunately, are rarely available in specimens from the district, owing to the hardness of the matrix.

***Pachymagas parki* Series.**

The species may be arranged according to shape in a series from sub-orbicular to narrowly ovate, but do not all form a strictly phylogenetic series, owing to variations in the amount of folding.

[Footnote] * Cf. p. 380.

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***Pachymagas marshalli* (Andrew). ([Fig. 7.](#))**

- 1906. *Magellania marshalli* Andrew, *Trans. N.Z. Inst.*, vol. 38, p. 456, pl. iv, fig. 3, *a, b*.

The holotype is a poorly preserved, crushed, and somewhat distorted specimen, from which one may nevertheless conclude that it was originally a nearly suborbicular shell with short beak, broad, slightly curved hinge-line, rounded convex sides, and probably a rounded front. The convexity is slight, and the folding apparently almost negligible, but in the direction of incipient ventral uniplication. The beak is erect, little produced above the hinge-line, and possesses a moderate mesothyrid foramen with well-marked beak-ridges. Length of holotype, 49 mm.; breadth, 48 mm.

The dorsal valve was partially ground down by Dr. Andrew to expose the septum. The holotype is in the Otago Museum.

Type locality: Clarendon limestone, Milburn Quarry, Otago. No specimens are known from the Waipara district.

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Fig. 7.—*Pachymagas marshalli*. Holotype. Natural size.

Smaller shells, up to 35 mm. in length, which agree closely in shape, occur in the

Mount Somers limestone, and the greensands of Curiosity Shop, Kakanui, All Day Bay, and Three Roads.

Pachymagas cottoni n. sp. Fig. 8.)

1908. *Magellania sinuata* Thomson, *Trans. N.Z. Inst.*, vol. 40, p. 101, pl. xiv, fig. 3 (not of Hutton).

Shell broadly elliptical, with a beak of moderate length, a broad, slightly curved hinge-line, nearly straight sides, and a rounded front. Convexity



Fig. 8.—*Pachymagas cottoni*. Holotype. Natural size.

moderate, anterior commissure with a broad shallow ventral sinuation, flattened along the bottom. Beak erect, foramen moderate, mesothyrid,

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attrite; the beak-ridges are sharp. Length of holotype, 48 mm.; breadth, 43 mm.; thickness, 23 mm. The species differs from *P. marshalli* only in slightly greater elongation.

Type locality: Sands below main Mount Brown limestone (D), cuesta overlooking the Weka Pass.

Smaller specimens referable to this species occur in the second creamy calcareous sandstone overlying the main Mount Brown limestone, in the Weka Pass stone at Onepunga, in the Oamaru district in the greensands of Landon Creek, Three Roads, Kakanui, All Day Bay, and Hutchinson's Quarry, and in the Caversham sandstone (A. McKay, loc. 309).

Pachymagas bartrumi n. sp. (Plate XXIV, figs. 7–9.)

Shell elongate, beak fairly short, obtuse, hinge-line nearly as broad as the shell, little curved, sides very gently convex, front slightly narrowed, rounded. Valves moderately convex, ventral valve bluntly carinate longitudinally, anterior commissure with a broad, shallow, flat-bottomed ventral sinuation. Beak nearly erect, foramen large, mesothyrid, attrite. Length of holotype, 48mm.; breadth, 38 mm.; thickness, 25 mm.

This species represents a further stage, and, so far as is known, the extreme stage, of elongation of the series *P. marshalli*, *P. cottoni*, but has an even broader hinge-line relative to the breadth of the shell.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. The species is rare in the type locality, and is not known elsewhere.

***Pachymagas speighti* n. sp. (Plate XXV, figs. 12–14.)**

Shell shield-shaped, with a rather short obtuse beak and a broad nearly straight hinge-line, whence the sides at first curve gently outwards to the middle of the shell and then taper quickly to a narrow produced front. Dorsal valve rather flat, reflected anteriorly, ventral valve moderately convex, bluntly carinate longitudinally, anterior commissure with a narrow, fairly deep, flat-bottomed sinuation. Beak nearly erect, little produced beyond the hinge-line, foramen moderately large, mesothyrid, attrite. Length of holotype, 41 mm.; breadth, 37 mm.; thickness, 21 mm.

This species, which agrees with the above three in the possession of a broad, straight hinge line, differs from them in the narrowing of the front and the more pronounced folding. All the succeeding species possess narrower, and in general more curved, hinge-lines.

Type locality: Foot of dip-slope, main Mount Brown limestone. The species is rare in the type locality. A well-preserved cast, collected by Professor Park from the Deborah limestone, agrees closely in outline, but evidently belonged to a more convex shell.

***Pachymagas clarkei* n. sp. (Plate XXVI, figs. 3–6.)**

Shell broadly elliptical, with a short, obtuse beak, a hinge-line of moderate breadth but nearly straight, gently curving sides and a slightly produced front. Dorsal valve flattened, and sharply bent anteriorly to fit the notch in the moderately convex, bluntly carinate ventral valve, anterior commissure with a deep flat-bottomed sinuation of moderate breadth. Beak erect, little produced beyond the dorsal valve, with a large mesothyrid, attrite foramen. Cardinal process short, narrow, sharp, little more than half the height of the hinge-trough. The species is shorter and broader than *P. parki*, but otherwise resembles it in shape, convexity,

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folding, and beak characters. It has, however, a much less advanced cardinal process. Length of holotype, 35 mm.; breadth, 31 mm.; thickness, 18.5 mm.

Type locality: Lower Mount Brown limestone (A), cuesta near Onepunga, where it is the commonest species.

Pachymagas haasti n. sp. (Plate XXV, figs, 47.)

Shell elliptical, beak short, obtuse, hinge-line rather narrow, slightly curved, sides moderately convex, front slightly produced and gently rounded. Valves moderately convex, the ventral with a broad rounded longitudinal fold flattened anteriorly, anterior commissure with a moderately broad, shallow, flat-bottomed, ventral sinuation. Beak nearly erect, little produced beyond the hinge-line, foramen moderately large, mesothyrid, attrite. Cardinal process not more than one-third the length of the hinge-line, considerably less in height than the socket-ridges, rounded on the upper front surface, Length of holotype, 37.5mm.; breadth, 30mm.; thickness, 20 mm.

This species resembles the elliptical forms of *P. parki* in shape and elongation and in beak characters, but is less strongly folded and possesses a less advanced cardinal process. It may be regarded as ancestral to *P. parki*.

Type locality: Greensands, Deborah, near Oamaru. The species is common in most of the Hutchinsonian localities near Oamaru—viz., Devil's Bridge, All Day Bay, Three Roads—but is rare in Hutchinson's Quarry. It also occurs in the Clarendon limestone, the Ngapara limestone, and the Maerewhenua limestone. It is rare in the main Mount Brown limestone.

Pachymagas hectori n. sp. (Plate XXIV, figs. 10–13.)

Shell broadly ovate, beak fairly short, hinge-line rather narrow and curved, sides regularly rounded, front slightly produced, rounded. Valves moderately convex, ventral valve with a broad rounded fold, flattened anteriorly, dorsal valve with a

broad, shallow, anterior sinus, anterior commissure with a broad, shallow, flat-bottomed anterior sinuation. Beak suberect, nearly erect, not produced far beyond the hinge-line, foramen fairly large, mesothyrid, attrite. Cardinal process short, low, comparable to that of *P. haasti*. Length of holotype, 39 mm.; breadth, 33 mm.; thickness, 21.5 mm.

This species differs from *P. haasti* in the ovate outline, and from *P. parki* in the less advanced folding and cardinal process.

Type locality: Greensands of Landon Creek, near Oamaru. The species is common in most of the Hutchinsonian localities near Oamaru—e.g. Rifle Butts, Three Roads, Kakanui, All Day Bay, and Deborah—but is rare at Hutchinson's Quarry. It also occurs in the Ngapara limestone, and one specimen is known from the Maerewhenua greensands (loc. 179, A. McKay). It occurs fairly commonly in the main Mount Brown limestone, while a single specimen has been obtained from the uppermost Mount Brown limestone.

There is a further species from the main limestone which differs from *P. hectori* chiefly in being narrowly and not broadly ovate. Unfortunately none of the dozen specimens which I have collected are sufficiently well preserved to serve as a type.

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Pachymagas parki (Hutt.). ([Fig. 9](#); [Plate XXV, figs. 8–11](#).)

- 1905. *Magellania parki* Hutt., *Trans. N.Z. Inst.*, vol. 37, p. 476, pl. xlvi, fig. 4.
- 1915. *Pachymagas parki* Thomson, *Trans. N.Z. Inst.*, vol. 47, pp. 394–95, fig. 2, b (but not fig. 2, a).

The holotype ([fig. 9](#)) is a distinctly ovate form, but the majority of specimens from the type locality have a similar broad but less curved hinge-line, and the sides are less convex. The front is produced as a narrow tongue. The beak is short and obtuse. The valves are moderately convex, the ventral with a longitudinal fold which is rounded and obscurely limited posteriorly, but anteriorly is more

pronounced, flattened on top and sharply limited laterally; the dorsal valve is sulcate anteriorly and sharply reflected to fit into the notch in the ventral valve; the anterior commissure shows a fairly narrow, deep, flat-bottomed sinuation. A single specimen is known in which incipient ventral biplication is shown, the anterior commissure presenting the form of a W with rounded angles. The beak is erect, not produced much beyond the hinge-line, with a moderately large, mesothyrid, attrite foramen.

Fig. 9.—*Pachymagas parki* (Hutt.). Holotype. Natural size.

The cardinalia were described and figured by me in 1915. Attention may be drawn to the prominent cardinal process, which is about half the length of the hinge-trough, higher than the socket-ridges, and somewhat swollen in front. Length of holotype, 37 mm.; breadth, 29 mm.; thickness, 17 mm.

Type locality: Greensands, Hutchinson's Quarry, Oamaru. Restricted as above to strongly folded forms, the species is known only from the type locality (where it is common), the tuffs of Whitewater Creek, Trellissick Basin (a single specimen collected by McKay), and the main Mount Brown limestone (where it is not very common). Two closely related species have been differentiated—viz., *P. McKayi* and *P. morgani*.

***Pachymagas McKayi*^{*} n. sp. (Plate XXVII, figs. 1–3.)**

Shell ovate, beak fairly long, hinge-line moderately broad, strongly curved, sides convex and regularly rounded, front somewhat produced. Valves strongly convex, especially the ventral; folding similar to *P. parki*,

[Footnote] * Named after the late Mr. A. McKay. The International Rules demand that, for a genitive, to the exact and complete name of a male an "i" should be added. The New Zealand Geological Survey, following Hutton, have generally adopted the permissible practice of commencing such names with a small initial letter, but this case shows the disadvantage of this procedure.

but hardly so pronounced. Beak produced well beyond the hinge-line, erect, foramen large, mesothyrid, attrite. Length of holotype, 44 mm.; breadth, 34 mm.; thickness, 25.5 mm.

This species, though somewhat less folded than *P. parki*, is more convex, and has a more prominent beak both as regards length and production dorsally of the hinge-line.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. The species is common in this limestone, and is unknown elsewhere.

Imperfect specimens, believed to belong to this species, from the main limestone between Mount Brown and the road, have a cardinal process more prominent even than that of *P. parki* and comparable to that of *Neothyris ovalis*.

***Pachymagas morgani* n. sp. (Plate XXVII, figs. 4–6.)**

Shell broadly ovate, beak moderately short, hinge-line narrow, not much curved, sides convex and rounded, tapering to a rather narrow produced front. Valves moderately convex, the dorsal with a narrow, shallow, median sulcus from about the middle, ventral with a broad rounded longitudinal fold and flattened sides, anterior commissure sloping on each side to a moderately deep, rather narrow, flat-bottomed sinuation. Beak suberect, not much produced dorsally of the ventral valve, foramen fairly large, mesothyrid, attrite. Length of holotype, 47 mm.; breadth, 41 mm.; thickness, 24 mm.

This species is less strongly folded than *P. parki*, and has a narrower hinge-line and more convex sides. It differs from *P. hectori* in its narrower and more produced front, due to narrower folding. The cardinalia are unknown.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass, where it is moderately abundant. It is unknown outside the Waipara district.

***Pachymagas coxi* n. sp. (Plate XXVI, figs. 10–12.)**

Shell roundly ovate, beak of moderate length, hinge-line moderately broad and

curved, sides convex and regularly rounded, front rounded. Valves moderately convex, anterior commissure with a broad, shallow, flat-bottomed sinuation. Beak suberect, hardly produced dorsally of the hinge-line, foramen large relatively to the size of the shell, mesothyrid, attrite. Interior unknown. Length of holotype, 33 mm.; breadth, 29.5 mm.; thickness, 17 mm.

This species, though smaller, agrees nearly in proportions of length and breadth with *P. morgani*, but has a more rounded front and broader folding. In these characters it agrees more nearly with *P. hectori*, but is broader, attains its greatest breadth nearer to the hinge-line, and is less convex.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. The species is fairly rare in the Mount Brown limestone, and has not been identified outside the district.

***Pachymagas huttoni* Series.**

***Pachymagas huttoni* Thomson.** (Plate XXVI, figs. 7–9.)

Trans. N.Z. Inst., vol. 47, 1915, pp. 395, 403, fig. 2, c.

This species has already been described, but the holotype has not been figured, an omission I now rectify.

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A single specimen from the Weka Pass stone at Onepunga, though only 22 mm. in length, agrees closely in all external characters with the holotype, and, moreover, possesses the same fine texture of shell and the pale purplish-brown colour which seems to be characteristic of this species. In the orginal description the shell was described as suborbicular, but it is slightly more elongate than this, and perhaps more correctly described as broadly ovate.

P. huttoni occurs commonly in the Waitaki limestone at Maerewhenua and Ngapara, and is also known from the greensands at the base of the Maerewhenua

limestone and the greensands overlying the Wharekuri limestone.

***Pachymagas andrewi* Series.**

***Pachymagas andrewi* n. sp. (Plate XXVI, figs. 1, 2.)**

Shell broadly ovate, beak short, acute, hinge-line narrow, acute, sides convex and rounded, front slightly produced, rounded. Valves moderately convex, ventral valve with a broad rounded fold and slightly flattened sides, dorsal valve reflected anteriorly, anterior commissure with a broad, fairly deep ventral sinuation, not completely flattened along the bottom. Beak erect, slightly produced dorsally of the hinge-line, foramen small, mesothyrid, attrite. Cardinal process large and swollen, comparable to that of *Neothyris ovalis*. Length of holotype, 46 mm.; breadth, 44 mm.; thickness, 21 mm. (estimated). The ventral valve of the holotype is damaged, but the folding of this valve is well shown on a paratype.

This species differs from all the preceding in the smallness of the foramen. It may conceivably belong to *Neothyris* and not *Pachymagas*. It differs from *P. huttoni* in the absence of the carination of the beak. In its small foramen it agrees with *Terebratella lahillei* Ihering, a species compared by its author with *Pachymagas venter*, and perhaps a member of that series, but it is more elongate and broadly oval instead of suborbicular.

Type locality: Creamy calcareous sandstone immediately succeeding the main Mount Brown limestone, foot of dip-slope of the latter, Weka Pass. The species is rare in the type locality, and not recognized elsewhere.

Genus *Waiparia* n. gen.

Genotype, *Pachymagas abnormis* Thomson.

A genus of the Terebratellidae with a septum showing the remains of transverse bands, and therefore presumably with a loop of the Terebratelliform pattern. Rostrum subapicate, foramen submesothyrid, having just left the hypothrid position, deltidial plates conjunct—*i.e.*, united between the foramen and the dorsal umbo. In these characters the genus differs from *Pachymagas* and *Terebratella*, in which the rostrum is truncate and the foramen mesothyrid. Cardinalia similar to those of young specimens and primitive species of *Pachymagas*, with strong socket-ridges but a slender septum, a hinge-trough with flatly inclined walls and a small cardinal process confined to the umbo. The bifurcations of the septum forming the anterior walls of the hinge-trough overhang slightly outwards, and are thus more excavate than is usual in *Pachymagas*, but much less so than the hinge-plates of *Terebratella*. The teeth of the ventral valve rise from swollen bases as in *Pachymagas*.

This genus may be considered as springing from the same stock as *Pachymagas*, but lagging behind in foraminal evolution. It possibly gave rise directly to

Pachymagas of the type of *P. ellipticus*, which possesses a foramen which is submesothyrid but almost mesothryid.

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Figs. 1, 2.—*Pachymagas andrewi* n. sp.

Figs. 3, 4, 5, 6.—*Pachymagas clarkei* n. sp.

Figs. 7, 8, 9.—*Pachymagas huttoni* Thomson.

Figs. 10, 11, 12.—*Pachymagas coxi* n. sp.

Figs. 13, 14, 15.—*Waiparia intermedia* n. sp.

Figs. 16, 17, 18.—*Waiparia abnormis* n. sp.

(All slightly reduced.)

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Figs 1, 2, 3.—*Pachymagas McKayi* n. sp.

Figs 4, 5, 6.—*Pachymagas morgani* n. sp.

Figs. 7, 8, 9.—*Neothyris anceps* n. sp.

(All slightly reduced)

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Waiparia abnormis (Thomson). (Plate XXVI, figs. 16–18.)

- 1917, *Pachymagas abnormis* Thomson, *Trans. N.Z. Inst.*, vol. 49, p. 412.

This species, which I described in 1915, is characterized by its broad hinge-line and form only slightly more elongate than suborbicular.

Type locality: Sands interbedded with main Mount Brown limestone, cuesta overlooking the Weka Pass. It is also found in the top layers of the same limestone at the foot of the dip-slope, attaining here a length of 32 mm. with a breadth of 31mm. It also occurs at Whatatutu (E. de C. Clarke coll.), and in the Awamoan mudstones of All Day Bay.

Waiparia intermedia n. sp., (Plate XXVI, figs. 13–15.)

Shell broadly ovate, beak of moderate length, acute, hinge-line moderately broad, somewhat curved, sides convex and regularly rounded, front slightly produced. Valves moderately convex, the ventral longitudinally carinate, the carina flattened anteriorly, dorsal valve anteriorly reflected and with a slight anterior sulcus. Beak erect, slightly produced dorsally of the hinge-line, foramen moderately large, submesothyrid, deltidial plates conjunct. Length of holotype, 31.5 mm.; breadth, 28.5 mm.; thickness, 16 mm.

This species is more elongate than the former, the two being about equally folded.

Type locality: Foot of dip-slope, main Mount Brown limestone, Weka Pass. The species is fairly common in this locality, some of the shells being rather more convex and more strongly folded than the holotype. It also occurs in flattened specimens in the Awamoan mudstones of All Day Bay, the Waikouaiti sandstone, and the Wharekuri greensand (McKay). There are forms still more elongate found in the greensand and mudstones of All Day Bay, and in mudstones at the junction of the Brown, River with the Aorere River, Nelson. For these a further species must be set up.

Genus *Neothyris* Douvillé.

***Neothyris campbellica* (Filhol).**

- 1885. *Waldheimia campbellica* Filhol, *Mission de l'île Campbell*, pp. 173–74, fig. 7, Nos. 1, 2.

This species was distinguished by its author from *N. lenticularis* on account of its narrower shell and more detached beak. The shell is oval with a strongly curved hinge-line, the beak passing into the sides without an angle. The beak is considerably produced dorsally of the hinge-line, but is erect and not incurved towards the dorsal valve.

As thus defined from topotypes, the species is common in the Wanganuan. There is one specimen from the uppermost Mount Brown limestone which must be referred here.

***Neothyris ovalis* (Hutt.).**

- 1873. *Waldheimia lenticularis* Hutt., *Cat. Tert. Moll. Ech.*, p. 35 (not of Deshayes).
- 1886. *Waldheimia ovalis* Hutt., *Trans. N.Z. Inst.*, vol. 18, p. 335.
- 1905. *Magellania lenticularis ovalis* Hutt., *Trans. N.Z. Inst.*, vol. 37, p. 475, pl. xlvi, fig. 2:
- 1915. *Neothyris ovalis* Thomson, *Trans. N.Z. Inst.*, vol. 47, p. 395, fig. 2, d, e.

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This species was distinguished by its author from *N. lenticularis* for much the same reason as in the case of *N. campbellica*—viz., the narrower shell—but it may be distinguished from the latter by its broader and less curved hinge-line, the sides making an obtuse angle with the beak. The beak is less produced dorsally of

the hinge-line and is erect, with a foramen rather larger than that of *N. campbellica* and *N. lenticularis*.

As thus defined the species is common in the Wanganuan, and there are several specimens from the uppermost Mount Brown limestone which may be referred here.

Neothyris-novara Iher.

- 1864. *Waldheimia lenticularis* Suess, *Reise der "Novara,"* Geol. Th., bd. 1, abth. 2, p. 56, taf. x, figs. 3a, 4a, 4b (not of Deshayes).
- 1903. *Magellania novara* Iher., *Ann. Mus. Nac. Buenos Aires*, ser. 3a, t. 2, p. 326.
- 1905. *Magellania novara* Hutton, *Trans. N.Z. Inst.*, vol. 37, p. 475, pl. xlvi, fig. 3.
- 1907. *Magellania Ameghinoi* Iher., *Ann. Mus. Nac. Buenos Aires*, ser. 3a, t. 7, p. 472 (not of Ihering, 1903).

As Ihering appears to have had before him at the time of naming this only the description and figures of Suess, the specimens treated by Suess must be regarded as the syntypes. Of these I select the specimen from Motupipi (fig. 4a, 4b) as the lectotype. This agrees with Hutton's interpretation of the species. Ihering in 1907 united the species with his *Magellania Ameghinoi*, but since the thickness of the latter is stated never to exceed half the length, whereas in *N. novara* it is always more than half, the two may be easily distinguished.

The species is broadly oval like *N. lenticularis*, but has a much straighter hinge-line. In the lectotype, and in a few specimens from the Weka Pass, the sides make no angle with the beak; but in the majority of the specimens from the Weka Pass, and also in others from the Takaka limestone, the sides are less convex and make an obtuse angle with the beak. The species is common in the uppermost Mount Brown limestone.

Neothyris iheringi n. sp. (Plate XXV, figs. 1-3.)

Shell broadly oval, beak fairly long, acute, hinge-line long and sharply curved, sides convex, meeting the beak and the rounded front without an angle. Shell moderately convex, folding slight. Beak considerably produced dorsally of the hinge-line, erect and well detached from the hinge-line, foramen small, mesothyrid, attrite. Length of holotype, 49.5 mm.; breadth, 44mm.; thickness, 28.5mm.

This species differs from *N. novara* and agrees with *N. lenticularis* in the strong curvature of the hinge-line. It is distinguished by the detachment of the beak from the latter, in which the beak is incurved towards the dorsal valve.

Type locality: Uppermost Mount Brown limestone (E), Weka Pass. The species is fairly abundant in this locality, and is unknown elsewhere.

Neothyris anceps n. sp. (Plate XXVII, figs. 7–9.)

Shell ovate, beak large, obtuse, hinge-line rather narrow, strongly curved, sides convex and rounded, greatest breadth anterior to the middle, front

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slightly produced. Valves moderately and regularly convex, folding very slight. Beak suberect, not produced dorsally of the hinge-line, foramen very large, mesothyrid, attrite, deltidial plates striate parallel to the hinge-line. The septum shows no sign of transverse bands, so that the loop is presumably Magellaniform. The cardinal process is of a primitive type, confined to the posterior part of the hinge-trough. Length of holotype, 53 mm.; breadth, 42 mm.; thickness, 27 mm.

The species is easily distinguished from other *Neothyris* by the size of the foramen.

Type locality: Creamy calcareous sandstone immediately following the main Mount Brown limestone, Weka Pass, where it is common.

Genus Stethothyris Thomson.

Stethothyris sufflata (Tate).

- 1880. *Waldheimia* (?) *sufflata* Tate, *Trans. Roy. Soc. S. Austral.*, vol. 3, pp. 157–58, pl. vii, fig. 3; pl. viii, fig. 4.
- 1885. *Magellania sufflata* Hutt., *Quart. Journ. Geol. Soc.*, vol. 41, p. 558.
- 1889. *Magellania sufflata* Tate, *Trans. Roy. Soc. S. Austral.*, vol. 23, p. 253.
- 1905. *Magellania sufflata* Hutt., *Trans. N.Z. Inst.*, vol. 37, pp. 476–77.

Specimens from the uppermost Mount Brown limestone (E), though showing considerable variation, agree closely enough externally with the Australian species in shape, convexity, and folding, and in the incurvature of the beak. In the last character senile individuals often show a beak touching the dorsal valve, so that the pedicle must have atrophied.* The cardinalia are characterized especially by the flattening of the ventral surface of the socket-ridges anteriorly, the production of the crural bases into the hinge-trough (seen in young specimens), and the swollen nature anteriorly of the cardinal process, which, though large, is not very high.

The characters of the beak and cardinal process suggest derivation from a stock of considerable antiquity, and forbid its ascription to *Neothyris*, which only appeared at this stage and did not attain similar characters until a much later period in *Neothyris lenticularis*. The characters of the cardmalia are not inconsistent with derivation from those of *Stethothyris uttleyi*, and the shell shows the early sulcation of the dorsal valve exhibited by *S. pectoralis*, so that the species seems best placed in *Stethothyris*.

The species is common from the creamy calcareous sandstone following the main Mount Brown limestone at the Weka Pass to the top of the uppermost limestone, and is unknown elsewhere in New Zealand.

Part III.—Correlations and the Classification of the Notocene.

Clarentian.

No beds belonging to this division of the Notocene have been found in the district, nor in the North Canterbury area. In this it-differs from east Marlborough, where the Amuri limestone is underlain by a great thickness of Clarentian beds (*cf.* Thomson, 1919a).

[Footnote] * Cf. Buckman, *Pal. Ind.*, n.s., vol. 3, mem. 2, p. 17, 1917.

Piripauan.

The complete fauna recorded from the *Ostrea* beds is as follows: *Nemodon* (?) sp., "Arca" *hectori* Woods, *Cucullaea* sp., *Trigonia hanetiana* d'Orb, *Ostrea* sp. cf. *dichotoma* Bayle, *Pecten (Camptonectes) hectori* Woods, *Cardium* sp., *Pugnellus waiparensis* Trechmann, and a rhynchonellid. Of these, *Trigonia hanetiana* and *Pecten hectori* are found also in the calcareous conglomerate and black grit respectively of Amuri Bluff and in the *Ostrea* bed of the Malvern Hills, and *Ostrea* sp. cf. *dichotoma* occurs also in the *Ostrea* bed of the Malvern Hills. Woods considers that the *Trigonia* and *Pecten* indicate that the *Ostrea* bed belongs to the horizon of the Amuri series of Amuri Bluff, and is equivalent to the *Ostrea* bed of the Malvern Hills.

The *Ostrea* bed of the Trellissick Basin contains *Ostrea* sp. and *Inoceramus* sp., which have not yet been obtained in specifically determinable specimens, and also a small rhynchonellid, as yet undescribed, which is specifically identical with one found in the *Ostrea* bed of the Malvern Hills. It may, therefore, be also correlated with the *Ostrea* bed of the Waipara.

Ostrea beds of similar stratigraphical position and presumably of the same age are known from the upper Motunau River (McKay, 1881), from the Mount Cass Range,^{*} and from the Harper River (Speight, 1917b). There must be other correlative beds in the area between Motunau and Amuri Bluff, but they have not been described in such a way that they can be identified and correlated.

Woods (1917) states that the fossils of the Amuri group of Amuri Bluff include only a few forms identical with species found in other parts of the world, but these and the affinities of the other species show that the fauna is of the Indo-Pacific type, and is of Upper Senonian age. Of the Waipara species, *Trigonia hanetiana* is one of the characteristic species of the Quiriquina beds of Chile, while the *Ostrea* is similar to a species found in the Senonian of other regions.

The complete saurian fauna from the "saurian beds" and Waipara greensands of the Waipara is as follows: *Platecarpus oweni* (Hector), *Cimoliosaurus australis* (Owen), *C. hoodi* (Owen), *C. holmesi* (Hector), *C. haasti* (Hector), *C. caudalis* Hutt., and *Leiodon haumuriensis* Hector. The "saurian beds" of Amuri Bluff contain an almost identical assemblage, concerning which Dr. C. W. Andrews has stated, according to Woods (1917), that it indicates an horizon near the top of the Cretaceous, and that it is very similar to the reptilian fauna of the Niobrara chalk of the United States, which is of Senonian age.

The fish-remains from the "saurian beds" comprise *Scapanorhynchus subulatus* (Ag.), a species ranging from Albian to Danian; *Odontaspis incurva* (Davis), found also in the Tertiary of New Zealand and Australia; and vertebrae of *Lamna* (?).

The Mollusca of the "saurian beds" include *Malletia (Neilo) cymbula*, which

resembles *M. pencana* (Philippi) from the Quiriquina beds; *Trigonia waiparensis* Woods, comparable in ornament with *T. parva* Brüggen from the Senonian of north Peru, and with *T. crenifera* Stoliczka from the Ariyalúr group, of southern India; and *Thracia* sp. None of these species has been found at Amuri Bluff or the Malvern Hills. The gasteropods from the Waipara have not yet been described.

The “saurian beds” and Waipara greensands are without doubt correlative with the similar beds of Amuri Bluff. Saurians are also known from the

[Footnote] * R. Speight, personal communication.

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neighbourhood of Greenhills, Gore Bay, the Jed River, and the upper Motunau, and a single bone has been obtained from the Malvern Hills in the concretionary beds above the Selwyn Rapids beds.

All the above beds which are correlatives of the Piripauan of the Waipara occur in the area between the Rakaia River and Kaikoura Peninsula, and in all these localities, except in the Malvern Hills, the Amuri limestone is found above the Piripauan. The only other beds of the same age in the South Island are those of Shag Point, doubtfully referred here. The fossils are poorly preserved, but they appear to include a *Trigonia* allied to *T. pseudocundata* Hector and *Pugnellus marshalli* Trechmann.

In the North Island, Piripauan beds may occur in the east coast of Wellington Province and in the Gisborne district, but further exploration is wanted in these regions. In the North Auckland district there is a limestone somewhat similar to the Amuri limestone—viz., the hydraulic limestone—and it is underlain in the Kaipara district by mudstones, greensands, and brown sandstones, yielding ammonites and other molluscs, and a saurian bone. Marshall (1917b) described two species of ammonites as *Kossmaticeras* with Senonian affinities, a third as *Lytoceras* sp. with Utatur affinities, an Oamaruan mollusc (*Panope worthingtoni* Hutt.) identified by Suter, and a cast of *Phacoides* (*Here*) sp., a genus which did not live before the Eocene according to Cossman; and, moreover, he considered

that the beds containing this fauna rest upon a Miocene limestone. Comment seems almost unnecessary. Woods has made it clear that the Clarentian and Piripauan faunas of Marlborough and Canterbury are typical Cretaceous faunas without any intermixture of Tertiary species. The probabilities seem to be that Piripauan beds are present in the Kaipara district, and that the Oamaruan Gibraltar limestone is faulted down, and does not really underlie the Piripauan. *Panope worthingtoni* Hutton is one of the species of which the type was missing when Suter redefined the Tertiary Mollusca, but Marshall's figure agrees very closely with Woods's figure of *Panope clausa* Wilckens from Amuri Bluff. The affinities of the specimens classed as *Lytoceras* sp. and *Phacoides (Here)* sp. may be neglected until better specimens are available, since neither retained the external ornament.

The hydraulic limestone also occurs in the Whangarei district, and Piripauan beds are also to be expected here, but no distinctive fossils have yet been found.

Kaitangatan-Amuri Limestone.

The reasons for which I have correlated the Amuri limestone with the Kaitangatan are that the Wangaloa beds of the Kaitangatan contain a fauna intermediate between those of the Piripauan and the Oamaruan, while the Amuri limestone occupies a stratigraphical position between Piripauan and Oamaruan. No common species have yet been described. Trechmann (1917) considers, on the evidence of the Mollusca, that the Wangaloa beds "should apparently be of Maestrichtian age." Chapman, on the evidence of the fish-remains and Foraminifera, considers the Amuri limestone of Danian age.

In 1916 I stated my conviction that the Amuri limestone is in itself a Cretaceo-Tertiary rock, Cretaceous at the base and Tertiary at the top, the reason for the latter statement being the occurrence in the Amuri limestone of the Trellissick Basin of an Oamaruan fauna in a tuff band 10 ft. from the top of the limestone. The rock I termed the Amuri limestone in the Trellissick Basin has the same stratigraphical position—*i.e.*, it lies above rocks with a Senonian fauna, and underlies rocks with an Oamaruan fauna—

and, although it is usually more marly than the Amuri limestone of the coastal district, it is in places quite indistinguishable lithologically from it. Speight (1917a) has accepted this correlation. Now, however, from an examination of Foraminifera from two localities, Mr. Chapman considers that it is "probably Eocene." If this view is confirmed, it certainly demands an unconformity between this rock and the underlying Piripauan beds—an unconformity of which Speight was unable to find any trace. Nevertheless, in view of Chapman's correlation, it is unsafe to take into account the molluscan fauna referred to above in attempting to correlate the Amuri limestone of the Waipara or Amuri Bluff.

Chapman's identifications of the Foraminifera make it quite clear, however, that Marshall's correlation of the Amuri limestone with the Ototara limestone is mistaken. On the basis of the Foraminifera Chapman declares the Amuri limestone Danian, and the Weka Pass stone and "grey marls" Eocene. On the same basis Marshall declares the Ototara limestone Miocene. The correlative of the Ototara limestone in the Waipara section must, then, lie above the "grey marls," and this accords well enough with the evidence, to be discussed later, from the molluscs and brachiopods.

Outside the area, north of the Rakaia River there is no limestone in the South Island that can be correlated with the Amuri limestone. It appears, however, to be present in east Wellington, and to be represented in North Auckland by the hydraulic limestone of the Kaipara and Whangarei districts. Marshall (1919) has remarked that I have objected to this correlation; but what I objected to in 1917 was his correlation of the Whangarei polyzoan limestone with the Amuri limestone by first correlating the Whangarei polyzoan and hydraulic limestone. I merely pointed out—and it is still true—that no palaeontological or stratigraphical evidence has been presented for the correlation of the Amuri limestone and the hydraulic limestone of the Whangarei district. Marshall the same year supplied the evidence so far as the hydraulic limestone of the Kaipara was concerned, and there is no reason to doubt that the hydraulic limestone of the two regions is the same. I do not agree, however, that the Whangarei polyzoan limestone is of the same age or older, any more than is the limestone of Gibraltar Rocks, in the Kaipara district. I have observed Oamaruan mollusca below the polyzoan limestone of Horahora, and have little doubt that both it and the

Gibraltar Rocks limestone are Oamaruan. The geological survey of this district, however, which is at present in progress, will doubtless settle this point.

Oamaruan.

The age of the Oamaruan has been commonly accepted as Miocene for some years, very largely on account of Chapman's determination of the Foraminifera of Waikouaiti Head, and his demonstration of the Miocene age of the older Tertiaries of Australia. Having never been willing to admit that the contact of the Amuri limestone and the Weka Pass stone, though doubtless a disconformity, could bridge the gap between Cretaceous and Miocene, I formed the opinion either that the Amuri limestone must include the Eocene or that the Oamaruan ranged down from Miocene to Eocene; and a large part of my explorations for several years past have been directed to obtaining direct evidence of the age of the Amuri limestone, and to ascertaining the fauna of the lower members of the Oamaruan. In 1915 I endeavoured to show that the beds at Waikouaiti from which the Foraminifera described by Chapman as Miocene were obtained were upper Oamaruan. There can be no doubt from the lists of fossils I have quoted

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earlier in this paper that the Weka Pass stone and "grey marls," as well as the Mount Brown beds, are Oamaruan; and, as Chapman refers the Weka Pass stone and "grey marls" to the Eocene, it follows that the Oamaruan ranges from Eocene to Miocene. The contact between the Amuri limestone and Weka Pass stone is a disconformity, but bridges only the gap between Danian and Eocene.

Former geologists, notably Hutton and Park, have correlated the Weka Pass stone with the Ototara limestone, believing the tower Oamaruan beds to be missing. Marshall, on the other hand, has correlated it with the Hutchinsonian. The evidence of the Foraminifera suggests that it correlates rather with the Ngaparan and Waiarekan. The evidence of the molluscs is indecisive; that of the brachiopods, on the other hand, is practical proof that the main Mount Brown limestone (D) is Hutchinsonian and the uppermost Mount Brown limestone (E)

Awamoan, leaving all the 800 ft. of lower beds, down to the Weka Pass greensand, for the Ototaran and Waiarekan.

Some remarks on the relative value of the Mollusca and Brachiopoda in correlation seem desirable in view of the recently expressed opinion of Marshall (1919) that the latter are far less satisfactory for purposes of correlation, the reasons being that they occur sporadically and in a small number of species as compared with the Mollusca, and that the species are hard to identify with certainty. The first is a valid objection, and is well illustrated in the Mount Brown beds, which are rich in Brachiopoda and yet have yielded only four specimens of *Terebratulina* and none of *Liothyrella*, genera which are abundant in the Trelissick Basin and at Oamaru. Nevertheless, the Brachiopoda are sufficiently widespread to enable their range to be established with a considerable degree of certainty, and it is illogical to neglect them if they are present in any rock and can be used. The small number of species is an advantage in one respect: it enables a single man to know the whole fauna intimately, and to apply to the whole of it every known method of study. This is not the case with the molluscan fauna, of six hundred or eight hundred species; and we can never expect entirely satisfactory results until we have students confining themselves to a few families, and studying these not from the point of view of New Zealand Tertiary species alone, but making themselves familiar with all the species, both living and fossil, in all parts of the world.

One marked difference between the Oamaruan brachiopod and molluscan faunas is that the former is practically an extinct fauna, not surviving the Oamaruan, except for a very small percentage, whereas the latter shows a very much greater percentage of living species. The brachiopods, therefore, would be expected to be of the greater value in correlation.

The chief disadvantages of the Tertiary molluscan fauna are the great range of the majority of the species and the different facies of the fauna according to station, which makes it a matter of great difficulty to ascertain accurately the range of any given species. Until this is known it is, of course, obvious that the occurrence of a species in a list gives little help. Marshall (1919) has given a list of characteristic species from his different series, but many of these species range widely in higher or lower series. Thus, of the Nukumaru series, Suter has determined *Melina zelandica* from the Waiarekan of the Oamaru district, and Marshall himself has recorded *Struthiolaria frazleri* from the Wangaloa beds. Of the Waipipi series, *Cardium spatiostum* is known from the Awamoan of Oamaru and the Trelissick Basin. Of the Target Gully series, *Venericardia pseutes* and *Terebra orycta* range from Waiarekan to Awamoan, while *Chama huttoni* occurs in the

Wanganuian of Castle Point. Of the Ototara series, *Ostrea nelsoniana* ranges from Waiarekan to Waitotaran, and *Lima laevigata* from Waiarekan to Hutchinsonian. Of the Wharekuri series, *Exilia dalli* has one record from the Waiarekan and three from the Awamoan, while *Polinices huttoni* has three from the Waiarekan and seven from the Awamoan. The above ranges are from my analysis of the Oamaruan fauna of Oamaru and South Canterbury described below.

In reply to the charge of neglecting the large amount of palaeontological knowledge we already have, I can but point to the above statements, which show that it is very dangerous to generalize on our existing knowledge, and which justify my caution. It seems to me that two lines of advance are open. One is the more detailed study of the species on evolutionary lines (such as I have been attempting in the brachiopods and limpets) with a view to defining valid species of limited range, and to arranging the species in an evolutionary order. Cossman's and Murdoch's criticisms of Suter's identifications illustrate the possibilities, but the best results can be expected only from an evolutionary study. The other is a careful and detailed analysis of the available lists with a view to discovering the range of the species as at present defined.

The procedure which promises the best results depends on the delimitation in New Zealand of stratigraphical or diastrophic provinces within the bounds of each of which, the various rocks of given age are strati-graphically similar and can be correlated without further demur. One such district, in which none but Oamaruan marine rocks are developed, ranges from Oamaru to Mount Somers. The sequence is everywhere—coal-beds, sands, greensands, limestones, mudstones, and sands—except for some differences at Oamaru and Mount Somers due to the development of volcanic rocks.

Marshall has stated that endless confusion would be caused by attempts to place the various beds near Oamaru in the stages as defined by me. If this is the case in a district so simple as Oamaru, a district "undisturbed by any minor stratigraphic movements," and one on which Marshall is prepared to base the whole classification of the Notocene, then we may as well give up all detailed stratigraphy in New Zealand. Neither Park nor Uttley has encountered this endless confusion, but both have greatly increased our knowledge of the district by attempts to place the beds in the various stages. While it is not denied that

there are difficulties, these are difficulties that exist in the nature of things, and not because of the adoption of certain stages, although the use of the latter has called attention to them, and will probably hasten their solution.

Taking the limestones as Ototaran (*pace* Park), we have the underlying rocks Waiarekan^{*} and the overlying rocks Awamoan, the Hutchinsonian being mostly difficult of recognition, and perhaps included in the upper of the two limestones that are usually to be distinguished outside Oamaru. Within this province there are numerous localities from which lists of fossils have been published, and in addition Mr. Suter determined all the old Geological Survey collections and also further collections made by me. These lists are as yet unpublished, but the Director of the Geological Survey has kindly given me access to them. I have divided the province into the geographical districts of Oamaru, Waitaki Valley, Waihao, Pareora, and Kakahu, and have plotted each occurrence in such a way that for each stage I have retained a record of how many districts and how many localities

[Footnote] * I have not taken into account Park's Bortonian, because in the type locality for this stage the fossils are practically all casts.

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within each district a given species has been collected from. Part of this analysis, applying to the species from the Waipara–Weka Pass district, is given below in Table V.

One immediate advantage of such a list is that it shows clearly which species are based on single or few records, suggesting, in such cases as that, for example, where a Recent species is recorded from the Waiarekan and no higher stage, that the specimens are in need of critical re-examination before this evidence for the range of the species can be fully admitted.

A striking feature of the lists is the number of species which range throughout the Oamaruan, and the comparatively few, except in the case of the Awamoan, which

are confined to a single stage. The reason for the latter is that the majority of the good fossil-localities are Awamoan—viz., Awamoa, Target Gully, Ardgowan, Otiake, Pukeuri, Mount Harris, Blue-cliffs, Pareora River, White Rock River, Holme Station, Sutherland's, and Kakahu River. The only large lists from the Waiarekan are from Black Point (where the fossils are nearly all casts), Wharekuri, Waihao greensands, and Kakahu coal-beds. I directed most of my collecting to Waiarekan localities, in order to redress the balance; but the results are still scanty compared with the Awamoan, and as a result the use of the analysis for comparison of fresh lists will tend to favour correlation with the Awamoan, as will be seen below.

The percentages of Recent species in the total faunas of the province may be estimated in two ways—viz., by actual records, or by implication: *i.e.*, if a species in the Waiarekan is also known from the Awamoan or Recent it may be credited to the intermediate rocks. The numbers of species and percentages of Recent species are as follows: By actual records—Waiarekan, 221 (Recent, 56 = 25 per cent.); Ototaran, 90 (Recent, 28 = 31 per cent.); Hutchinsonian, 97 (Recent, 36 = 37 per cent.); Awamoan, 336 (Recent, 113 = 34 per cent.): by implication—Ototaran, 178 (Recent, 69 = 39 per cent.); Hutchinsonian, 207 (Recent, 82 = 40 per cent.); Awamoan, 347 (Recent, 137 = 39 per cent.). It is to be expected that when the collections from the lower stages are as exhaustive as those from the Awamoan the percentages obtained by the two methods will approach one another more nearly, and also that there will be a regular increase from the Waiarekan to the Awamoan. It would be premature to assume that there had been a sudden introduction of new forms in the Awamoan, although that is the actual suggestion of the lists.

To ascertain the evidence presented by a fresh list from any locality, the best method appears to be to calculate the percentages of records in each stage of the species in the new list. A somewhat similar method was used by Marshall in 1919. If the analysed list is extended to include the stages older and younger than the Oamaruan, then for any given fresh list a series of percentages for each stage may be calculated which will rise to a maximum for the stage to which the list belongs. The nearer this maximum approaches 100 per cent. the higher the probability will become that the correlation is correct. The percentage of Recent species will fall into its place as only one of a series of percentages. At present, however, owing to the fact that the faunas of the various stages are so incompletely known, and that the fuller knowledge of the Awamoan fauna gives proportionately higher percentages for that stage, greater weight than will later be necessary must be attached meanwhile to the percentage of Recent species.

Applying the above method to the Wangaloa and Hampden faunas, we get the following percentages (using the method of implication):—

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Wangaloa Beds. Hampden Beds.

Precinctive species	51	42
Waiarekan	39	39
Ototaran	35	32
Hutchinsonian	35	30
Awamoan	35	32
Recent species	8	9

The percentage of precinctive species in each of these faunas exceeds that of those ranging upwards into the Waiarekan or higher beds, and justifies Marshall's conclusion that they are both older than Oamaruan, a point upon which I had previously expressed doubt so far as the Hampden beds were concerned. The table also favours the correlation of the two faunas, although it should be noted that only six species are common to both, and these six species are all also Waiarekan.^{*} We may therefore add the Wangaloa and Hampden lists as a fresh column to the analysed Oamaruan lists.

For stages later than the Oamaruan good lists are not available, and we must await Murdoch and Marshall's account of the Wanganui beds. For the purposes of this paper I have used the lists given by Hutton (1886) for Wanganui and Petane, supplementing them by unpublished determinations by the late Mr. H. Suter. These give a total of 219 species from Wanganui, with 80 per cent. Recent, and of 194 from Petane, with 79 per cent. Recent, and are therefore grouped together and treated as Castlecliffian, though they may contain a few forms from a lower horizon. For the Waitotaran I have taken such published and unpublished records as were available from Waitotara and Patea, the Wairarapa limestone, the Awatere beds, and the Greta beds, omitting the two latter, however, when the correlation of the Greta beds themselves is being discussed below. Finally, I have admitted as intermediate between the Waitotaran and Awamoan the Kawa beds described by Bartrum (1919), together with the basal beds of the Palliser Bay section. The reasons for this will be given more fully below in discussing the Greta

beds.

With this basis we may now attack the correlation of the beds of other localities in other diastrophic provinces. The logical procedure in such a province as that in which the Waipara district lies would be first to compile a similar analysis of the range of each species recorded from the Weka Pass stone, the "grey marls," the Mount Brown beds, and the Greta beds in the area within which these rocks can be recognized, and then to compare the lists so obtained with the former list from Oamaru and South Canterbury. If the correlations can be made without reasonable doubt, a combined list will extend further our knowledge of the range of the various species, and so on with the other provinces. This programme involves a great deal of further stratigraphical work and collecting throughout New Zealand, and it will be many years before it can be completely carried out. In the meantime I will show the method as applied to the species known from the district at present under discussion.

Table V gives the lists of species from the various rocks of the district, the Greta beds being also included for convenience. In these columns T signifies that the species was collected by myself, P that it is an additional species from Park's lists of 1905, and H from Hutton's lists of 1885 (b and c) and 1888. For comparison the records in the various stages, compiled as explained above, are also included, S signifying a single record, R that the species is rare (with only two or three records), C that it is common (with four or five records), A that it is abundant, and + and × one or more records.

[Footnote] * They include *Gilbertia paucisulcata* (Marshall), which Mr. Suter determined in my collections from the Waihao greensands.

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Table V.—Range of Tertiary Molluscs From The District.

*— <i>ventricosum</i> (Gray)		H		X
<i>Ampullina miocaenica</i> Sut.	T	S	R	
— <i>suturalis</i> (Hutt.)	T	+ C	R	A X
<i>Amusium zitteli</i> (Hutt.)	T	S	S	A
* <i>Ancilla australis</i> (Sow.)		T	S	A X X
— <i>hebera</i> (Hutt.)	P	T	R	A X X
*— <i>mucronata</i> (Sow)		T	S	R X X
*— <i>novae-zelandiae</i> (Sow.)	T	T	+ A	A X X
— <i>papillata</i> (Tate)	T T		R	R A
*— <i>pyramidalis</i> (Reeve)		T		S X X
* <i>Anoma furcata</i> Sut.	T			
*— <i>huttoni</i> Sut.	T	T	R	S C X X
*— <i>trigonopsis</i> Hutt.	T T T		R	C X
<i>Antigona sulcata</i> (Hutt.)	T	S	R	X
*— <i>zelandica</i> (Gray)		T		A X X X
* <i>Arcopagia disculus</i> (Desh.)		T		X X
<i>Athleta huttoni pseudorarispina</i> Sut.		T?		
<i>Aturia australis</i> McCoy	H P		R S	
* <i>Barnea similis</i> (Gray)		T		X X X
— <i>tiara</i> Tate		T		X
* <i>Calliostoma punctulatum</i> (Mart.)		P		X X
* <i>Cantharidus tenebrous</i> A. Ad.		H	S S	X
* <i>Cerithidea bicarinata</i> (Gray)		T		X X
<i>Certhiella</i> n. sp.		T		
<i>Chione chiloensis</i> (Phil.)		T		R X X
— <i>meridionalis</i> (Sow.)	P T	A R C	A X X X	
*— <i>stutchburyi</i> (Gray)	T T		R	X X
*— <i>yatei</i> (Gray)	T		S	X X
* <i>Cochlodesma angasi</i> (C. & F.)	T		S	X
* <i>Cominella adspersa</i> (Burg.)	T			X X X
*— <i>quoyana</i> (A. Ad.)	T		R	X X
<i>Corbula canaliculata</i> Hutt.	T	A	A	
<i>Crassatellites attenuatus</i> (Hutt.)	T		C X X X	
*— <i>obesus</i> (A. Ad.)	P	A	C A	
* <i>Cominella Crepidula costata</i> (Sow.)	T		C X X	
— <i>gregaria</i> Sow.)	T T	S	S A X X X	

*— <i>monoxyla</i> (Less.)	P	T	T	S	S	A	X	X	X
— <i>striata</i> Hutt.		T	T	S		A	X	X	
<i>Cucullaea alta</i> Sow.	P	H?	X + R	S	R	A			
— var. B.		T		S		S			
* <i>Cymatium spengleri</i> (Chemn.)			P				X	X	
<i>Dentalium mantelli</i> Zitt.	P		X + C	A	S	A			X
— <i>solidum</i> Hutt.	T	T	T	A	C	C	A	X	X
* <i>Diplodon zelandica</i> (Gray)	T		T		R	S		X	X
* <i>Dosinia anus</i> Phil.			P				X	X	X
*— <i>greyi</i> Zitt.	P	T	TX	A			A	X	X
*— <i>lambata</i> (Gould)			H				R	X	X
— <i>magna</i> Hutt.	P			S			R	X	X
*— <i>subrosea</i> (Gray)			T				R	X	X
<i>Drollia wanganuiensis</i> Hutt.			H			S	X	X	
<i>Epitonium lyratum</i> (Zitt.)	T	P		+ C	C	C	A		
— <i>rotundum</i> Hutt.		H							
<i>Euthria media</i> (Hutt.)	T?				S		S		
* <i>Evarne linea</i> (Mart.)			P					X	X
* <i>Fusinus spiralis</i> (A. Ad.)			H			A		X	X
<i>Galeodea senex</i> (Hutt.)	H	P	T	+ S	S	S	A	X	X
— <i>sulcata</i> (Hutt.)			T						X
* <i>Gari lineolata</i> Gray	P	T		A	S	S	A	X	X
<i>Glycymeris cordata</i> (Hutt.)		H		S		S	R		X
— <i>sulcataglobosa</i> (Hutt.)	P	T	S			C	X	X	
*— <i>sulcatalaticostata</i> (Q. & G.)		T	R	S	S	C		X	X

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* <i>Glymeris modesta</i> (Angas)	P	X
<i>Hinnites trailli</i> Hutt.	T	S
* <i>Ischnochiton maorianus</i> I [unclear:] edale	T	
* <i>Lima bullata</i> (Born.)	P	R S S X
— <i>colorata</i> Hutt.	T T	S C A X
— <i>imitata</i> Sut.	T	
— <i>laevigata</i> Hutt.	H	P S S S
*— <i>lima</i> (L.)	T	S X
— <i>paleata</i> Hutt.	P T	R R C
— <i>paucisulcata</i> Hutt.	T T	S S
* <i>Limopsis aurita</i> (Brocchi)	T T	X A S S A
— <i>insolita</i> (Sow.)	P	
— <i>zitteli</i> Iher.	T	+ S C A
<i>Lutraria solida</i> Hutt.	T	XX
<i>Macrocallista assimilis</i> (Hutt.)	P	R RC XX
*— <i>multistriata</i> (Sow.)	P	S S AXX
* <i>Mactra discors</i> Gray	P	R XXX
— <i>dubia</i> (Hutt.)	T	R X
* <i>Malletia australis</i> (Q. & G.)	T	S RA X
* <i>Mangilia amoena</i> (Smith)	P	R X
*— <i>sinclairi</i> (E. A. Smith)	T	S XX
* <i>Modiolus australis</i> (Gray)	T	R C XX
* <i>Musculus impactus</i> (Herm.)	T	XX
* <i>Mytilus canaliculus</i> Mart.	T	XX
*— <i>magellanicus</i> Lamk.	P?	X
* <i>Natica australis</i> (Hutt.)	T X S	CXXX
*— <i>zelandica</i> Q. & G.	H + R	SAXXX
* <i>Neothais succincta</i> (Mart.)	P	X
<i>Nucula sagittata</i> Sut.	T	X S S S R
<i>Olivella neozelanica</i> (Hutt.)	H	S XX
* <i>Ostrea angasi</i> Sow.	T T T	R XX
— <i>arenicola</i> Tate	T	XX
*— <i>corrugata</i> Hutt.	T C S	XX
— <i>gudexi</i> Sut.	T?	R X
— <i>ingens</i> Zitt.	T	XX
— <i>manubriata</i> Tate	T	XX

— <i>cnelsoniana</i> Zitt.	T	S	S	S	XX
*— <i>tatei</i> Sut.	T	S	S	S	XX
— <i>wuellerstorfi</i> Zitt.	P		+		XX
<i>Panope orbita</i> (Hutt.)	P	P X	R S C A		XX
<i>Paphia curta</i> (Hutt.)	T			R A	XXX
*— <i>intermedia</i> (Q. & G.)		P			XXX
<i>Pecten beetham</i> Hutt.	T	T		S	A S
— — var. B	H	T			
— <i>burnetti</i> Zitt.	T	T		S	S S X
— <i>crawfordi</i> Hutt.	T				X
— <i>difluxus</i> Hutt.			H		
— <i>fischeri</i> Zitt.	H				R
— <i>hochstetteri</i> Zitt.		T		S	S
— <i>hutchinsoni</i> Hutt.		P		S	A S
— <i>huttoni</i> (Park)	T	T	T	T	+ A C A A
— <i>palmipes</i> Tate			T		
*— <i>radiatus</i> Hutt.		P		R S	XX
— <i>triphooki</i> Zitt.		T?		R	XX
— <i>willamsoni</i> Zitt.	H	P	T		X
*— <i>zelandiae</i> Gray		T	P		S XX
— n. sp.		T			
	<i>Phos incisus</i> (Hutt.)				
		P			X
<i>Placunonomia incisura</i> Hutt.		T		S S A	
<i>Pleurotmaria tertaria</i> McCoy	H			R S	
<i>Polinices gibbosus</i> (Hutt.)		P	T	P X	A S R A XX

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<i>Polinices ovatus</i> (Hutt.)	T	R	R	R	A	X	X
<i>Protocardia alata</i> Sut.	T						
*— <i>pulchella</i> (Gray)		TX	R	S	R	R	
<i>Rissoina vana</i> (Hutt.)	T			S	X		
* <i>Seila chathamensis</i> Sut. var.	T				X		
* <i>Sigapatella novae-zelandiae</i> (Less.)	P	T	T	R	R	R	A
*— <i>tenuis</i> (Gray)	T			C	XX		
* <i>Spisula aequilateralis</i> (Desh.)	T				XX		
<i>Struthiolaria cincta</i> Hutt.	H		A	S	A	X	
*— <i>papulosa</i> (Mart.)	T	S	C	XX			
— <i>spinosa</i> Hect.	T				S	XX	
— <i>tuberculata</i> Hutt.	T			R	R	A	XX
<i>Surcula fusiformis</i> Hutt.	T	X	A	S	S	A	XX
<i>Taron brevirostris</i> (Hutt.)	T					AX	X
* <i>Tellina deltoidalis</i> Hutt.	T				XX		
*— <i>eugonia</i> Sut.	P	T	R			X	
* <i>Terebra tristis</i> Desh.	T		R	R	XX		
<i>Teredo heaphyi</i> Zitt.	T		X	A	C	C	A
<i>Thracia</i> n. sp.						T	XXXX
<i>Trochus conicus</i> (Hutt.)	T		S			XX	
*— <i>tiaratus</i> Q. & G.	T			C	XX		
* <i>Trophon corticatus</i> (Hutt.)	T				XX		
<i>Turris altus</i> (Harris)	T					A	
* <i>Turritella carlottae</i> Wats.	T		A	R	A	XX	
— <i>cavershamensis</i> Harris	P		A		A	A	
— <i>concava</i> Hutt.		T		R	RA		
*— <i>rosea</i> Q. & G.	P				XX		
*— <i>symmetrica</i> Hutt.		H	X + R	S	C	XXX	
* <i>Umbonium zelandicum</i> (H. & J.)	P				XX		
* <i>Venericardia difficilis</i> (Desh.)	T		A	R	S	A	XX
*— <i>purpurata</i> (Desh.)	T	T	R	S	C	A	XX
* <i>Verconella caudata</i> (Q. & G.)		H			S	XX	
— <i>costata</i> (Hutt.)	T	T		R	S	A	X
*— <i>dilatata</i> (Q. & G.)	T	T	S	R	A	XX	
*— <i>mandarina</i> (Duclos)	T	R		S	XX		
*— <i>nodosa</i> (Mart.)	P	+ C	S	A		X	

— <i>orbita</i> (Hutt.)		P	X
*— <i>attenuata</i> Hutt.	H		
<i>Voluta arabica</i> Mart.		T T	R A XX
— <i>corrugata</i> Hutt.		P T	+ R R R A X
*— <i>elongata</i> Swains		P	A X
— sp. cf. <i>protorhysa</i> Tate	T	T	
* <i>Zenatia acinaces</i> (Q. & G.)		P	S S S A XX
Total number of species, 166	19 9	8 45 43 95	
Number of Recent species	1 3	1 18 15 64	
Percentage of Recent species	5 33	12½ 40 34 67	

Column.

1. Weka Pass stone.
2. "Grey marls."
3. Lower Mount Brown beds (below limestone D).
4. Main Mount Brown limestone (D).
5. Uppermost Mount Brown beds (E).
6. Greta beds.
7. Wangaloa fauna from Marshall (1917c).
8. Hampden beds from Marshall (1919).
9. Waiarekan stage of Oamaru and South Canterbury.
10. Ototaran stage of Oamaru and South Canterbury.

11. Hutchinsonian stage of Oamaru and South Canterbury.

12. Awamoan stage of Oamaru and South Canterbury.

13. Kawa Creek beds from Bartrum (1919) and Palliser Bay basal beds.

14. Waitotaran stage.

15. Castlecliffian stage.

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If we now calculate the percentage of records in the various stages, using the method of implication, we obtain the following results:—

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Table VI.

—	1	2	3	4	5	6	7
Percentage recorded from Wangaloa and Hampden beds	26	19	22	12	20	26	11
Percentage recorded from Waiarekan	42	50	88	62	66	60	38
Percentage recorded from Ototaran	52	58	100	62	75	69	42
Percentage recorded from Hutchinsonian	42	54	100	75	73	69	46
Percentage recorded from Awamoan	52	61	100	75	80	83	69
Percentage recorded from Kawa Creek beds	10	23	44	25	58	53	70
Percentage recorded from Waitotaran	5	19	44	25	49	49	69*
Percentage recorded from Castlecliffian	5	15	33	13	40	37	77
Percentage of Recent species	5	15	33	13	40	34	67

1. Weka Pass stone.
2. Weka Pass stone and “grey marls” combined.
3. “Grey marls.”
4. Lower Mount Brown beds.
5. Main Mount Brown limestone.
6. Uppermost Mount Brown limestone.
7. Greta beds.

It will be seen that the analysis favours the correlation of all the beds up to the top of the Mount Brown limestone with the upper Oamaruan, and, if we group together the Weka Pass stone and “grey marls,” of all with the Awamoan. Against this we have the positive evidence of the Foraminifera that the Weka Pass stone and “grey marls” are lower than Ototaran, and of the brachiopods that the main Mount Brown limestone is Hutchinsonian. It is obvious, therefore, that the range of the Mollusca is not yet sufficiently known to give confidence in its use in correlation, which tends unduly to favour correlation with the Awamoan.

If we examine in detail the list of species from the Weka Pass stone, we find that the species which are responsible for the relatively high value of the Awamoan records are only three—viz., *Struthiolaria spinosa*, *Turris altus*, and *Pecten fischeri*—all recorded from the Awamoan only. The finding of any two of these, or of the species without any record—viz., *Epitonium rotundum*, *Lima imitata*, *Pecten beethami* var. B, *Pecten williamsoni*, *Voluta attenuata*, and *Voluta* sp. cf. *protorhysa* Tate—in the Waiarekan or lower beds would bring the percentage of Waiarekan species up to that of the Awamoan.

The collections are scarcely large enough to use the percentage of Recent species with confidence. This method would place the Weka Pass stone with the Wangaloa and Hampden beds, the “grey marls” with the Ototaran, the middle Mount Brown beds again with the Wangaloa and Hampden beds, the main Mount Brown limestone and the uppermost Mount Brown limestone in the Hutchinsonian or Ototaran. A curious coincidence in the percentages is that the uppermost limestone shows a lower percentage than the main Mount Brown

limestone, just as do the Target Gully beds compared to the upper Hutchinsonian in Target Gully, and the total Awamoan fauna compared to the total Hutchinsonian fauna of Oamaru and South Canterbury. In the present case little stress can be laid upon this point, as the list from the main Mount Brown limestone contains so many species collected by Park in 1905 from an horizon not quite definitely determined.

There is still another way in which the molluscan evidence can be looked at—viz., from the point of view of the range of the species within the district. Thus *Pecten huttoni* and *Dentalium solidum* range through

[Footnote] * In calculating this percentage the records from the Greta and Awatere beds were excluded and only those from the North Island localities, or records by implication, were used

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the 900 or more feet of strata from the Weka Pass stone to the uppermost Mount Brown beds, and in Oamaru range through a similar thickness of beds which probably formed at much the same rate. This suggests that the whole of the Oamaruan is represented in the Waipara sequence, and that the Weka Pass stone correlates with the Ngaparan and Waiarekan, and the uppermost Mount Brown beds with the Awamoan.

The general conclusions to be derived from the evidence of the Mollusca is, then, that taken by itself it is not conclusive as to exact correlation with Oamaruan stages, and does not stand in the way of the positive correlations demanded by the brachiopods and Foraminifera.

The range of the brachiopods occurring in the district is shown in the following table:—

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Table VII.—Range of Tertiary Brachiopods from the District.

	—	1	2	3	4	5	6	7	8	9	10
<i>Aetheia gaulteri</i> (Morris)		X						W	O	H	A
<i>Hemithyris nigricans</i> (Sow.)					X			H	A	W	
<i>Terebratulina suessi</i> (Hutt.)			+					W	O	H	
<i>Terebratulina cf. cancellata</i> Koch				+							
<i>Bouchardia minima</i> Thomson					+			O			
<i>Magadina waiparensis</i> Thomson	X										
— <i>browni</i> Thomson				+	X						
<i>Rhizothyris curiosa</i> Thomson					X		O				
— <i>media</i> Thomson						X					
— <i>scutum</i> Thomson				+	X		O	H			
— <i>rhizoida</i> (Hutt.)				+			H				
— <i>elongata</i> Thomson				+			H				
— <i>curta</i> Thomson				+	X		O	H			
— <i>crassa</i> Thomson					+						
— <i>elliptica</i> Thomson				+	X		O	H			
— <i>fortis</i> Thomson				+	X						
— <i>obesa</i> Thomson				+	X						
— <i>lateralis</i> Thomson					?	?					
— <i>pirum</i> Thomson					+						
— <i>ovata</i> Thomson				+			O	H			
— <i>amygdala</i>					cf.			H			
<i>Pachymagas cottoni</i> Thomson				+	X		H				
— <i>burtrumi</i> Thomson				+							
— <i>clarkei</i> Thomson	+										
— <i>haasti</i> Thomson				+			O	H			
— <i>hectori</i> Thomson				+	X		O	H			
— <i>parki</i> (Hutt.)				+			H				
— <i>McKayi</i> Thomson				+							
— <i>morgani</i>				+							
— <i>coxi</i> Thomson				+							
— <i>huttoni</i> Thomson	+						O	H			
— <i>andrewi</i> Thomson						X					
<i>Waiparia abnormis</i> (Thomson)					X						
— <i>intermedia</i> Thomson				+		?	A				
<i>Neothyris campbellica</i> (Filhol)					X			W			

— <i>ovalis</i> (Hutt.)	X	W
— <i>novara</i> (Iher.)	X	
— <i>iheringi</i> Thomson	X	
— <i>anceps</i> Thomson	X	
<i>Stethothyris sufflata</i> (Tate)	X	

Column.

1. Weka Pass stone.
2. Lowest Mount Brown limestone (C).
3. Second Mount Brown limestone.
4. Main Mount Brown Limestone (D).
5. Uppermost Mount Brown beds.
6. Waiarekan.
7. Ototaran.
8. Hutchinsonian.
9. Awamoan.
10. Wanganuian.

The letters in columns 6–10 are the initials of the stage-names, which help to guide the eye better than an asterisk.

Owing to the fact that so few brachiopods are recorded from the Waiarekan and the Awamoan elsewhere, the percentage of records of the Waipara species from the various Oamaruan stages, though favouring the correlation of the main Mount Brown limestone with the Hutchinsonian, is little more conclusive than in the case of the molluscs. It is shown in the following table:—

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Table VIII.

—	1	2
Percentage of species recorded from Waiarekan	4	0
Percentage of species recorded from Ototaran	32	28
Percentage of species recorded from Hutchinsonian	48	33
Percentage of species recorded from Awamoan	8	6
Percentage of species recorded from Wanganuiian	0	16
Percentage of species not recorded elsewhere	40	44

1. Main Mount Brown limestone (D).

2. Uppermost Mount Brown beds.

When the affinities of the species not recorded elsewhere are taken into consideration, the case for the correlation of the main Mount Brown limestone with the Hutchinsonian, and for the uppermost Mount Brown beds with the Awamoan, becomes much stronger. The fauna of the former horizon consists entirely of species closely related to Hutchinsonian forms, with the exception only of *Bouchardia minima*, known elsewhere only from the Ototaran, and *Magadina browni*, not known in the southern Oamaruan localities. The fauna of the uppermost Mount Brown beds contains characteristic large species, not easily overlooked, which are absent from the southern Oamaruan localities—viz., *Stethothyris sufflata*, *Neothyris novara*, *N. iheringi*, and *N. anceps*—suggesting that either this horizon is unrepresented at Oamaru, or that it does not there yield brachiopods, which is the case with the Awamoan, while the Hutchinsonian

affinities of part of the remainder, mainly *Rhizothyris*, are offset by the Wanganuian affinities of another part, *Hemithyris* and *Neothyris*.

The species of *Rhizothyris* and *Pachymagas* which range from the main Mount Brown limestone into the overlying beds consist for the most part of species not so advanced as regards elongation and folding as those confined to the main limestone. The explanation seems to be that the more primitive stocks had a longer range, while the more highly evolved forms, possessing no further potentialities of evolution, were narrowly restricted in time. The occurrence of the two species *Rhizothyris elongata* and *Pachymagas parki* only in the Hutchinson Quarry greensand and in the main Mount Brown limestone would of itself favour the correlation of these two beds, but when the advanced nature of their evolution is taken into account it enormously strengthens the case for the correlation. Combining all three points of view, we may conclude that the evidence is sufficiently strong to, support definitely the correlation of the main Mount Brown limestone with the Hutchinsonian and of the uppermost beds with the Awamoan. The evidence of the brachiopods as to the correlation of the beds below the main limestone is inconclusive.

Combining all lines of evidence, we find the following correlations indicated:—

Uppermost Mount Brown beds—Awamoan.

Main Mount Brown limestone—Hutchinsonian.

Lower Mount Brown beds—Ototaran.

“Grey marks” and Weka Pass stone—Waiarekan.

Wanganuian

The Greta beds have a wide distribution in the neighbouring Lower Waipara, Upper Waipara, Greta, and Motunau districts, where the nature of the beds and

of the fossils are generally similar to those of the Middle Waipara and Weka Pass. They are also known to occur in the Oaro Valley, near Amuri Bluff. No considerable collections of any extent or recently named are available from any of these localities. In 1913 I collected carefully from the Greta beds of the Lower Waipara, but obtained only twenty-seven species, of which twenty, or 74 per cent., are Recent species. The extinct species were *Callistoma waiparensis*, *Crepidula gregaria*, *Lutraria solida*, *Pecten triphooki*, *P. crawfordi*, *Ostrea arenicola*, and *O. nelsoniana* (?).

Owing to the absence of a comprehensive list of Waitotaran fossils from the typical locality, the percentages of records of the various stages shown in Table VI favours correlation of the Greta beds rather with the Castlecliffian than with the Waitotaran, but the presence, of such forms as *Ostrea ingens* suggests that the true correlation is with the Waitotaran. With this the percentage of Recent species, 67 per cent., is also more in accord. Marshall gives 60–70 per cent, for the Waipipi series, which apparently includes the Waitotaran, and, 80–90 per cent. for the Castlecliff series. Final decision as to correlation of the Greta beds must be postponed until lists from the Wanganui-Patea districts are available.

Only a small number of species are common to the Greta and Awatere beds, although the latter have usually been correlated with the former Park (1905) obtained forty-two species from the Starborough Creek beds, of which 71 per cent, were Recent; from the same beds I obtained fifty-seven species, of which only 51 per cent, were Recent. The two lists combined give seventy-seven species, of which 60 per cent, are Recent.

Marshall (1919) has suggested that the Greta and Awatere beds may occupy a position intermediate between the Target Gully series (Awamoan, with 30–40 per cent, of Recent species) and the Waipipi series (Waitotaran, with 60–70 per cent, of Recent species). The list of species from the Greta beds, numbering ninety-five, with 67 per cent, of Recent species, is now sufficiently extensive to make it very improbable that the suggestion is correct. In the Middle Waipara district the Greta, beds follow directly upon the uppermost Mount Brown beds, with only 34 per cent, of Recent species, and the sudden doubling of this percentage gives a strong presumption of unconformity. If beds bridging the palaeontological gap can be found in any other part of New Zealand the evidence for unconformity will be conclusive.

In 1913 I pointed out that the Starborough Creek beds of the Awatere Valley were underlain by a great thickness of beds, in the lower parts of which Miocene (*i.e.*, Oamaruan) types such as *Cucullaea* and *Limopsis* occurred. The collection from, Tatchell's Creek was not in very satisfactory condition, but yielded *Ancilla*, sp., *Cardium spatioseum* Hutt. ?, *C. maorinum* Sut. ?, *Chione meridionalis* (Sow.) ?, *Cominella lurida* (Phil.), *Dentalium solidum* Hutt., *Leda semiteres* Hutt. ?, *Limopsis aurita* (Brocchi), *L. catenata* Sut., *Maculopeplum elegantissimum* (Sut.) ?, *Mytilus striatus* Hutt., *Ostrea angasi* Sow.?, *Panope orbita* (Hutt.), *Pecten huttoni*

(Park), *Struthiolaria cincta* Hutt. ?, *S. tuberculata* Hutt., *Turritella symmetrica* Hutt. ?, *Verconella dilatata* (Q. & G.) ?, and *Voluta corrugata* Hutt. This fauna appears to be characteristically Oamaruan, so that if the beds containing it underlie the Awatere series conformably an intermediate fauna should be found.

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In 1919 I pointed out that the blue mudstones of the Palliser Bay district, which in their upper part contain a Waitotaran and probably above that also a Castlecliffian fauna, also contain Oamaruan species near the base. Those collected were *Antigona zelandica* (Gray), *Cominella adspersa* (Brug.), *C. purchasi* Sut., *Dosinia anus* (Phil.), *D. subrosea* (Gray), *Dentalium solidum* Hutt., *Galeodea senex* (Hutt.), *Paphia curta* (Hutt.), *Polinices gibbosus* (Hutt.) ?, *Struthiolaria tuberculata* var., *S. papulosa* var. While the Oamaruan affinities of this fauna are apparent, three species—viz., *Cominella-adspersa*, *C. purchasi*, and *Dosinia anus*—are not known from the Oamaruan of Otago and South Canterbury. It seems quite possible that this fauna will prove to be intermediate between the Awamoan and the Waitotaran.

In 1919 Bartrum also described a series of beds at Kawa Creek which overlie Oamaruan beds unconformably, but contain a fauna with strong Oamaruan affinities, although the percentage of Recent species is 62 in a collection of 74 species. The percentage of records in the various stages is as follows: Wangaloa and Hampden beds, 8; Waiarekan, 42; Ototaran, 50; Hutchinsonian, 54; Awamoan, 64; Waitotaran, 62; Castlecliffian, 68. Probably when a fuller list of Waitotaran species is available for comparison Bartrum's conclusion that the fauna is intermediate between Awamoan and Wanganui will be substantiated.

Diastrophic Provinces In New Zealand.

In 1917 I discussed the application of diastrophic criteria to the correlation and classification of the younger rocks of New Zealand, and while agreeing, with Marshall, Speight, and Cotton (1911) and later expressed views by Marshall on a certain diastrophic unity of all these younger rocks, necessitating the use of an

inclusive name, for which I proposed "Notocene," I gave briefly the evidence for the existence of minor diastrophic districts during the general relative crustal inactivity between the great post-Hokonui and Kaikoura deformations. This evidence consisted of the differences in age of the oldest and youngest marine Notocene rocks of different districts, proving differences in the dates of sea-advance and sea-retreat in these districts, and also differences in age of the main limestone member of the sequence in different districts—viz., the Amuri, Ototara, and Takaka limestones—proving that the period of maximum sea-advance was not everywhere contemporaneous. To avoid confusion between geographical and diastrophic districts, I propose now to call the latter "provinces."

Marshall (1919), who appears to have misunderstood the argument, states, "I can reasonably hold that no proof has been given of these supposed local diastrophic movements in New Zealand, and I can quote the Oamaru district, at least, as one in which, the Tertiary strata are continuous over a large district without any indication of being affected by local diastrophic action." It is evident that I stated the argument too briefly by omitting to define more explicitly the diastrophic provinces. This omission I remedied last year (1919, p. 310), when I defined the provinces of the east coast of the South Island. The Oamaru geographical district, which is understood as comprising the coastal area between the Kakanui and Waitaki Rivers, but excludes Shag Point, forms, with the adjacent Waitaki, Waihao, Pareora, Kakahu, and Mount Somers districts, a diastrophic province extending from the Kakanui to the Rakaia Rivers, and I quite agree with Marshall that within it there is no diversity of diastrophism exclusive of local volcanic phenomena. Excluding the variations due to the development of volcanic rocks, found chiefly in the Oamaru and Mount Somers districts, the stratigraphical sequence and fossils of these districts are almost identical. The

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diastrophic history of the whole of this province appears to have been as follows: Emergence of the pre-Notocene rocks during Clarentian, Piripauan, and Kaitangatan, ending with peneplanation; submergence with sedimentation in the Ngaparan or Waiarekan, attaining its maximum in the Ototaran; a cessation of

sedimentation before the deposition of the Hutchinsonian, perhaps due to standstill of land and sea during which a phosphatization of the upper surface of the Ototara limestone took place; gradually shallowing of the sea during the Hutchinsonian and Awamoan, followed by emergence at the end of the Awamoan; deposition of terrestrial gravels during the Wanganui; block-faulting, with tilting of the Oamaruan and Wanganui beds about the close of the Wanganui.

The Middle Waipara and Weka Pass district, on the other hand, forms part of a diastrophic province extending from the Rakaia River to Kaikoura Peninsula. The stratigraphical sequence is not so constant as in the southern province, owing to an overlap traceable in the older beds, and there are still large parts of the province that have not been described in detail. The diastrophic history appears to have been as follows: Emergence of the pre-Notocene rocks during the Clarentian, without complete attainment of peneplanation; partial submergence and sedimentation during the Piripauan and Kaitangatan, with progressive overlap on the diversified surface; a cessation of sedimentation before the deposition of the Oamaruan, probably due to a standstill of land and sea, during which a phosphatization of the Amuri limestone took place; renewed depression of the Amuri limestone and the old land, leading to an overlap of the Weka Pass stone over the Piripauan and Kaitangatan on to the now peneplaned pre-Notocene (lower Oamaruan); shallowing of the Oamaruan, sea with oscillations of movement during which the "grey marls" and Mount Brown limestones were deposited, with interformational unconformities (upper-Oamaruan); uplifts, perhaps of the nature of block movements, exposing fresh areas of pre-Notocene rocks to rapid erosion, with deposition of the Greta beds (early Wanganui); uplifts, with folding or tilting and erosion of the whole marine Notocene, and deposition of the terrestrial, Kowhai beds (late Wanganui); blockfaulting about the close of the Wanganui, with renewed folding or tilting of both the marine and terrestrial Notocene series.

The diastrophic histories of these two areas are thus seen to be markedly dissimilar. In the northern province marine beds, both older and younger, are developed which have no counterpart in the southern; the nature of the beds of correlative age (Oamaruan) is different in the two areas; and the relationship of certain beds is different. The greatest difficulty in the geology of each area is the nature of the conditions which, permitted phosphatization of the upper surfaces of certain limestones. Whatever these conditions were, they happened at different times in the two provinces. The stratigraphical unity within the boundaries of each province, and the diversity between the two, are salient facts that demand recognition.

Two of the classifications proposed, for the younger rocks of New Zealand have failed to recognize the existence of the diversity of stratigraphical and diastrophic history in the above and other provinces—viz., the Cretaceo-Tertiary classification of Hector and the single rock-series classification of Marshall. In

each of these a supposed uniformity of stratigraphy has been assumed by the mistaken correlation of the Amuri and Ototara, limestones. The majority of the other classifications—those of Hutton, von Haast, Park, Morgan, and Woods—recognize the distinctness of these limestones, and therefore part at least of the diversity of the above provinces, but explain the facts by postulating important earth-movements between

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different members of the series, causing unconformities of regional classificatory value. They fail, however, to recognize the grander fact that all the younger rocks were deposited in a period of relative crustal inactivity between the epochs of major diastrophism, and on this account should be grouped into one grand system. This is recognized in the classifications of Marshall and Thomson. Each of the above types of classification will now be examined in detail with regard to its applicability to the palaeontological and stratigraphical facts brought out in this paper, and in relation to the explanation it offers for the diversities exhibited in the three main diastrophic provinces of the east coast of the South Island.

The Cretaceo-Tertiary Formation of Hector.

It has been stated by Park that the theory of a conformable succession bridging the gap between the Cretaceous and Tertiary in New Zealand was first proposed by Hutton, but later abandoned by him, and was afterwards taken up by Hector. I have failed to discover the evidence for this statement in any of the published writings of Hutton, though Hector (1892) states that when he used the term "Cretaceo-Tertiary" in 1877 it was a revival of a term which had been in abeyance for some years. Hector's adoption of the formation in 1877 appears to be a direct outcome of the views he always held as to the Mesozoic age of all the coalfields in New Zealand. Thus when Provincial Geologist of Otago he classed the marine rocks of Oamaru, Hampden, Caversham, &c., under a Tertiary Oamaru series, but the coal-measures of Kaitangata, Clutha, Shag Point, &c., under a Carbonaceous series, and considered it as possibly upper Mesozoic.

In 1870, after he had visited the Waipara district, the North Canterbury rocks now included in the Notocene were grouped by Hector in the *Catalogue of the Colonial Museum* as follows:—

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Tertiary.	B. Upper or <i>Struthiolaria</i> series	Motunau, Lower Gorge of the Waipara River.
	C. Middle or <i>Cucullaea</i> series	Waikari, Lyngdon, Hurunui Mound., Upper Treliwick.
	D. Older or Ototara series	Deans, Weka Pass, Curiosity Shop, Selwyn River, Lower Treliwick.
Mesozoic	E. <i>Leda</i> marks or Aotca series	Conway River, Waiau-ua.
	F. Chalk and chalk marls	(Amuri Bluff).
	G. Ferruginous sandstones or Waipara series	Boby's Creek, Culverden,

In this grouping of the *Leda* marls (which subsequently were termed the “grey marls”) with the Chalk or Amuri limestone and the Waipara series in the Secondary as opposed to the Mount Brown beds of the Deans in the Older Tertiary, the Cretaceo-Tertiary formation was clearly foreshadowed. In 1877 Hutton included the “grey marls” in his Oamaru system, and the Amuri limestone and underlying beds in his Waipara system. Hector (1877A), in commenting on Hutton's paper, rejected Hutton's classification, and in a table of beds of Amuri Bluff included the “grey marls” and fucoidal limestone (Weka Pass stone) with the Amuri limestone in a Chalk group, recognizing also two lower groups, which he named the Greensand group and the Amuri group. In the following volume of *Reports of Geological Explorations* (1877B) he used the name of Cretacco-Tertiary formation for a part of the sequence in the Kaipara district, and in the following volume again (1877C) it appeared for the first time in a general table of New Zealand formations, though not in its final form. The following table shows the various names applied to the divisions or series of the formation.

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

1877c.	1879.	1884.	1886.	1887c.
<i>a.</i> Cardita beds, Grey marls	<i>a.</i> Grey marls.	<i>a.</i> Waitemata	<i>a.</i> Grey marls. <i>a.</i> Grey marls.	
<i>b.</i> Ototara and Weka Pass stone.	<i>b.</i> Ototara and Weka Pass stone.	<i>b.</i> Ototara.	<i>b.</i> Ototara series.	<i>b.</i> Ototara stone.
<i>c.</i> Fucoidal greensands.	<i>c.</i> Fucoidal greensands.	<i>c.</i> Mawhera.	<i>c.</i> Mawhera series.	<i>c.</i> Fucoidal greensands.
<i>d.</i> Chalk marls and Amuri limestone.	<i>d.</i> Amuri limestone, chalk, marls, and chalk with fints.	<i>d.</i> Chalk.	<i>d.</i> Chalk series.	<i>d.</i> Amuri limestone.
<i>e.</i> Marly greensands.	<i>e.</i> Marly greensands.	<i>e.</i> Waireka.	<i>e.</i> Waireka series.	<i>e.</i> Island sandstone.
<i>f.</i> Island sandstone (Reptilian beds).	<i>f.</i> Island sandstone (Reptilian beds).	<i>f.</i> Bobby's Creek.	<i>f.</i> Coal series.	<i>f.</i> Coal formation of New Zealand.
<i>g.</i> Coal formation and black grit	<i>g.</i> Black grit and coal formation.	<i>g.</i> Hororata.	<i>g.</i> Black grit series.	<i>j.</i> Black grit
		<i>h.</i> Coal.	<i>h.</i> Prophylite breccia series.	<i>h.</i> Propylite breccias.
			<i>i.</i> Great conglomerate	<i>i.</i> Conglomerate. series.

The beds below the black grit of Amuri Bluff were placed in a distinct Lower Greensand formation, and the horizon of the black grit was correlated with, the coal-beds of the Waipara and all the other chief coal-measures of the country. This had the effect of removing from the Cretaceo-Tertiary formation the ammonites, belemnites, *Trigoniae*, &c. found so abundantly in the calcareous conglomerate of Amuri Bluff. In 1892 Hector admitted that the Lower Greensand, formation could not be maintained as a distinct formation, and considered it a local expansion of the *Ostrea* bed of the Waipara district, a view later demonstrated to be correct by Woods (1917).

Hector's Cretaceo-Tertiary theory rested on two claims: first, that all the rocks of the Waipara district from the coal-measures up to and including the "grey marls" formed a single conformable "formation" and palaeontological unit, and were separated from the overlying Mount Brown beds by an unconformity; and, secondly, that all the important coal-measures in New Zealand, together with the conformably associated rocks, belonged to the same "formation."

As regards the first claim, Hector appears never to have studied the contact of the Amuri limestone and Weka Pass stone carefully. In his first account of the district he did not discriminate between the two rocks, and after Hutton had made the distinction, and had claimed the contact as an unconformity, emphasizing its palaeontological importance as a plane above which no Cretaceous fossils ranged, and below which no Tertiary fossils occurred, Hector apparently made no special study of the contact, and was content to rely on McKay's attempts to combat Hutton's criticisms. He insisted strongly, however, on the existence of an unconformity between the "grey marls" and the Mount Brown beds, publishing a map of the Weka Pass in support of his contention. The map was, however, little more than a diagram, and does not appear to have been based on a detailed survey. Hector was either unaware of, or ignored, the range of Tertiary Mollusca above and below the unconformity, and made no attempt to analyse their range, contenting himself with a statement of characteristic species from the Cretaceo-Tertiary and higher formations, species which are now known to have a considerable range above or below the rocks he included in each formation.

McKay (1887A) made a more serious attempt to meet Hutton's criticisms. He reaffirmed the conformity of the two rocks on the ground of their parallelism of

dip and strike, and attributed the so-called shattering of the Amuri limestone to jointing and a subsequent working-down of the loose greensand into the joint-planes. He endeavoured to refute Hutton's statement that pebbles of Amuri limestone were enclosed in the Weka Pass greensand by publishing an analysis of a phosphatic nodule as a proof that all the supposed pebbles were concretions, and he made a very strained comparison of the pebbles with concretions in the Waipara greensands. From later analyses it is now clear that the analysis quoted by McKay referred to one of the phosphatic concretions found rarely near the contact, and not to the majority of the supposed pebbles, which are only slightly phosphatized, and are undoubtedly fragments of Amuri limestone. McKay also published an analysis of Amuri limestone which showed a high percentage of insoluble residue described as sand, and argued from this that Hutton's statement that the Weka Pass stone overlapped the Amuri limestone on to the old rocks on the neighbouring Mount Alexander Range had no significance, as a, sandy limestone might easily pass in a few miles into a sandstone. Here again McKay's analysis has been shown by later chemical study not to be typical of the Amuri limestone. In answer to Hutton's

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contention that no Tertiary species were found, below the contact McKay published a list of Tertiary species found below the Amuri limestone in North Canterbury and Marlborough. As no descriptions or figures of these species were supplied, and as the statement rested solely on McKay's identifications, it did not gain acceptance, and Woods's later study of the Cretaceous Pelecypoda does not bear it out. It should be noted, however, that Henderson (1918) collected a shell from beds below the Amuri limestone of the Cheviot district which was determined by Suter as *Malletia australis* (Q. & G.). The existence of a few of the wide-ranging Oamaruan Mollusca below the Amuri limestone would not excite surprise, and, though invalidating the absolute truth of Hutton's contention, would not destroy the truth of the claim that the faunas known from the rocks above and below the contact are characteristically distinct. Hector's first claim, that the Cretaceo-Tertiary formation, is a satisfactory unit in the classification of the Waipara sequence, has been destroyed by Hutton's criticisms, reinforced by

later studies.

It should be noted that von Haast adopted a grouping of the rocks different from those of both Hector and Hutton, and included all the beds from the coal-measures to the top of the Weka Pass stone in a Waipara system of Cretaceo-Tertiary age. The correlations he claimed for this system were those of Hutton's Waipara system and not those of Hector's Cretaceo-Tertiary formation. Park also in 1905 adopted the same grouping as von Haast for his Cretaceous Waipara system, in the mistaken belief that the Weka Pass stone contained no Tertiary fossils. Hutton's criticisms, reinforced as above, are equally valid against these groupings of the Waipara rocks.

Hector's second claim for the correlation in the Cretaceo-Tertiary formation of all the important coal-measures rested on the following general argument:—

"In northern Canterbury, as far south as the Rakaia River, the coal rocks are overlaid by fossiliferous strata, which, besides the Plesiosauroid reptiles for which the Waipara district is famous, contain a few secondary genera, such as *Belemnites*, *Aporrhais*, *Inoceramus*, and *Trigonia*; but the great mass of the associated molluscan fauna agrees with that of the coal rocks in other parts of New Zealand, while the specially Cretaceous forms are rare, or absent from the fossiliferous horizons immediately overlying the coal-seams. If, therefore, after eliminating the comparatively few fossils which form the peculiarities of two localities, the bulk of those remaining are found to be the same, there need be no hesitation in considering strata showing the same succession of like characters in its different divisions as belonging to the same series; and, if in any one of these localities there is evidence that the beds are of Cretaceous age, the other must be regarded as of that age also. But if, in addition to this, there be, in those localities where the lower beds lack fossils proving their Cretaceous age, a presence of Cretaceous forms in the higher beds of the same series, the correctness of the correlation will in this way be corroborated. It is partly by evidence of this kind that the Cretaceous age of several of our coal-bearing areas is sought to be established.

"In South Canterbury, on the east coast of Otago, and on the west coast of the South Island markedly, Cretaceous fossils are found in the calcareous members of the higher part of the coal-bearing series. The Cretaceous character of the Echinodermata found in the Cobden limestone, also present in the Ototara stone, warrants the reference of these beds to a period anterior to that of any Tertiary deposit in the Islands, the oldest

of which is at least Middle Eocene, and separated by an unconformity from the underlying beds. To distinguish this latter the term 'Cretaceo-Tertiary' has been made use of, as it is believed that the series bridges over the gap which separates the Lower Eocene from the Cretaceous rocks of Europe." (Hector, 1882, pp. xxii–xxiii.)

Park (1888A) in commenting on the stratigraphical and palaeontological difficulties in the correlation of two distinct groups of beds, "the one characterized by a fauna and flora with a distinctly Tertiary facies, the other by forms of an equally pronounced Secondary type," put forward another argument as accepted by the supporters of the correlation, although Hector himself does not seem to have used it in his writings: "The relation existing between these two groups has not been very satisfactorily determined, but they are at present supposed by the Survey to be in a manner horizontal equivalents—that is, the result of contemporaneous deposition, the Tertiary strata being taken to represent the shallow-water, and the Secondary strata the deepwater, conditions of the same period

It appears probable also that the fossils of the Selwyn Rapids beds in the Malvern Hills greatly strengthened McKay and Hector in their belief in the correctness of the correlation of the "saurian beds" and Waipara greensands with the greensands underlying the Ototara limestone in South Canterbury and Otago. The Selwyn Rapids beds lie a little distance above an *Ostrea* bed extremely similar to that in the Waipara district, and the nature of the rocks is similar to that of the "saurian beds." No one has ever questioned that the Selwyn Rapids beds belong to a horizon below the Amuri limestone. The majority of the fossil Pelecypoda, however, belong to or closely resemble genera which are common in the Tertiary, and von Haast originally believed the fauna to be a Tertiary one. As these beds lie geographically between the North and South Canterbury localities, they seemed to offer themselves as a stepping stone in correlation. The Cretaceo-Tertiary formation was supposed for some geographical reason to contain fewer distinctively Cretaceous forms as it was traced south.

The flaw in Hector's argument, by which it falls to the ground, is the incorrectness of his premise that the great mass of the molluscan fauna associated with the saurians in northern Canterbury agrees with that of the coal rocks in other parts

of New Zealand. Woods's examination of the Pelecypod fauna associated with the saurians failed to bring to light a single species known from the rocks of the Oamaru and South Canterbury or the West Coast coalfields, and there is little reason to suppose that the case will be any better when the gasteropods are described.

Hutton (1885 B, C) perceived clearly the flaws in Hector's arguments, but his criticisms were weakened by two circumstances. The first was that the Upper Cretaceous faunas were not described, and the only satisfactory collections were those of the Geological Survey, which were inaccessible to him. The second was his own mistake in regard to the Pareora system. In this he included the Awamoan beds and all the Otago and South Canterbury localities now correlated in the Awamoan; but he also included in it the Waiareka greensands, the Enfield beds, and the Hampden beds, which are clearly below the Ototara limestone. He pointed out the distinctively Tertiary facies of the faunas of these beds, as opposed to the Cretaceous facies of the beds below the Amuri limestone; but in claiming that these beds lay above the Ototara limestone he gave McKay (1887B) a handle for upsetting a part of his criticism, although a part that was not really essential to the problem. Consequently Hutton's criticism of the correlations assumed by the Cretaceo-Tertiary theory failed to carry conviction to Hector and McKay, or to gain general acceptance.

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Park's revision of the marine Tertiaries (1905) helped to emphasize the purely Tertiary nature of the supposed Cretaceo-Tertiary rocks of South Canterbury and Otago. The recognition by Uttley and Thomson (1914) of the infra-position of the Waihao greensands in respect to the Ototara limestone, together by the demonstration by Woods (1917) of the purely Cretaceous nature of the beds below the Amuri limestone in North Canterbury, removed the weaknesses of Hutton's position. His criticism thus reinforced is absolutely destructive of the correlations assumed by Hector.

The Cretaceo-Tertiary theory thus failed both in its classification of the rocks of

the northern province (Rakaia River to Kaikoura Peninsula), and in its correlation of the rocks of the southern province (Kakanui River to Rakaia River). By falsely correlating Piripauan with Waiarekan rocks it failed to recognize the diversity between these two provinces. It failed also, owing to false correlation of the Piripauan and Clarentian rocks, to recognize the diversity between the northern of these two provinces and that extending from the Hapuku River to Cape Campbell. The Cretaceo-Tertiary theory of Hector must be absolutely discarded. Until we have new accounts of all Notocene localities, however, it will be necessary for the student to have a clear understanding of Hector's classification and its fallacies, because for many localities McKay's accounts of the stratigraphy are still the only or the best accounts available, and they are all couched in terms of this classification.

Hutton's Classification and its Successors

Hutton's final classification (1900) of the younger rocks of New Zealand differed little, from that he proposed in 1872, and was as follows:—

Camozoic system:—

Wanganui series Newer Pliocene.

Glacier epoch Older Pliocene.

Pareora series Miocene.

Oamaru series Oligocene.

Waipara system Upper Cretaceous.

His views of the diastrophic history during these periods are contained in the following extracts: "About the middle of the Jurassic period folding of the rocks [of the Hokonui system] occurred along the same northeast and southwest axis; the Alps were formed, and the present, land of New Zealand may be said to have been born, for since then it has never been submerged.... In the Upper Cretaceous the land subsided, and New Zealand was reduced to comparatively small limits.... A little before the commencement of the Tertiary era the rocks were folded once more, the land rose again.... This was the last folding of rocks in New Zealand on an extensive scale, for all the younger rocks usually lie in the same position in which they were originally deposited, and circle round the bases of the hills formed by older rocks. Not only was the last touch given in the Eocene period to the internal structure of the mountains, but the chief valleys were also deeply scoured out, so that when the land sank again in the Oligocene period these valleys were filled up with marine limestones and other rocks. The Oligocene and Miocene were periods of depression separated by a slight upheaval which lasted only for a short time.... In the older Pliocene came the last, great upheaval. All the islands were joined together, and the land stretched away to the east and south.... On the mountains of the South Island large glaciers were formed, and the torrential rivers running from them tore into disconnected fragments the

Miocene marine rocks which obstructed their valleys,

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... Subsidence seems to have commenced first in the southern portion of the North Island.... At a later date sinking began in the South Island also.... This sinking has again been followed by an elevation of all parts of New Zealand, the centre of the North Island rising as a large flat dome, on the summit of which stand Ruapehu and Tongariro; while the South Island has also been elevated several hundred feet. And this elevation appears to be still going on."

Hutton excluded the Greta beds from his Wanganui series, and thus did not recognize one of the factors distinguishing the North Canterbury from the South Canterbury and North Otago diastrophic province. The explanation his classification gives for the other differences between the two provinces depends on extensive folding between the periods of deposition of the Waipara system and the Oamaru series.

Speight and Wild (1918) have amply demonstrated that there was no extensive folding between the deposition of the Amuri limestone and the Weka Pass stone, and the palaeontological evidence shows that the gap between the two rocks is not nearly so extensive as Hutton supposed. Park (1905) claimed that the Pareora series was an integral part of the Oamaru series, and Uttley and Thomson (1914) and Gudex (1918) have demonstrated that it forms the upper part; Hutton's slight upheaval between the two series (Oamaru and Pareora) was postulated owing to a misreading of the stratigraphy of the Waihao district, and has no existence in the sense in which he claimed it, though there is probably a disconformity below not the Awamoan but the Hutchinsonian.

The great flaw in Hutton's scheme of classification was, however, his failure to recognize the magnitude of the post-Wanganui movements, the Kaikoura orogenic movements, the demonstration of which we owe to Cotton (1916). Owing to his exclusion of the Greta and Awatere beds from his Wanganui series and their correlation in his Paeroa series, Hutton postulated a great upheaval after

the latter, followed by a glacial epoch and a subsidence during which the Wanganui beds were deposited, with a later elevation. We now know that the great upheaval culminated after the deposition of the Wanganui beds, and that to it are due many of the effects which Hutton referred to the post-Hokonui folding. Hutton, therefore, failed to recognize the necessity of grouping his Waipara and Cainozoic systems into one grand one, sharply distinct from all others in New Zealand, and, while there are great elements of value in his classification and correlations, his scheme must be profoundly modified.

Park (1905) corrected two errors in Hutton's work—viz., the unnecessary separation of the Pareora and Oamaru series, and the mistaken correlation of the Greta and Awatere beds in the Pareora series; but he retained the major faults of Hutton's scheme—viz., the erroneous conclusion as to extensive folding between the Waipara and Oamaru systems, and the failure to recognize the bearing of the Kaikoura orogenic movements.

Morgan (1916C) proposed a general classification of the younger rocks as follows:

Pliocene.

Local unconformities.

Upper Miocene.

Probable local unconformities.

Middle and Lower Miocene.

Unconformity.

Eocene.

Unconformity (?).

Cretaceous (with possibly some early Tertiary strata).

He considered that from the Middle Miocene to the Pleistocene differential movements in some part or another of New Zealand were almost constantly in progress, and consequently that a series of local stratigraphical breaks exists, no two of which are exactly synchronous, but that in all parts of New Zealand there is a decided unconformity at the base of Hutton's Oamaru system, or series. So far as the facts under discussion are concerned no serious criticism of this scheme can be made, except that the rocks he terms "Lower Miocene," which include the base of the Oamaruan, are probable Eocene.

Woods (1917) has not proposed any general classification of the younger rocks other than Cretaceous, but speaks of the "Cenomanian overlap" in the Clarentian, and the Senonian transgression in the Piripauan, correlating these two periods of local sea-advance in New Zealand with world-wide transgressions. If these transgressions were considered to result solely from differential movements of sea-level their localization in parts of the New Zealand area would have to be ascribed to original differences in relief. As a matter of fact, Woods also admits differential movements of the land surface, for he postulates an uplift in east Marlborough after the Lower Utatur (Clarentian) period, since the Middle Utatur beds are not known to be represented there. Woods considers the Amuri limestone as probably, Eocene, and unconformable to the Cretaceous, and therefore presumably the result of a third transgression. There is, however, no stratigraphical evidence for unconformity below the Amuri limestone either in the Waipara or at Coverham, and the much greater thickness of this rock at Coverham receives no explanation.

Marshall's Classification.

Marshall has successfully demonstrated the general fact that the younger rocks in most localities form an accordant series, without important angular unconformities between the various beds, and, further, that the beds in any one locality are those of a sedimentary cycle with progressive characters of depth of deposition towards the middle limestone members. He claims for these that they are not merely general facts but universal facts for the New Zealand area; that there were no differential land-movements during the deposition of the beds; that the lack of angular unconformities proves the absence of palaeontological

disconformities; that there is only one main limestone in the series in any one locality; that it was deposited at the period of maximum submergence, and consequently that the limestones are correlative in all areas; and that the localization of the various beds, or, in other words, the differences between the provinces I have defined above, can be explained solely by overlap on a surface of high relief. All this is claimed in support of his classification of all the younger rocks as a completely conformable ensemble in the Oamaru system, ranging in age from Senonian to Pliocene.

Most of these claims are open to serious criticism. Angular unconformities are rarely seen, but are nevertheless not absent; while palaeontological disconformities are also present. For instance, in the Kaiwhata River, east Wellington, there is a conglomerate containing boulders of Cretaceous sandstones, greensands, and basalts, similar to those outcropping near by, and also boulders of shell-rock, apparently derived, containing Oamaruan fossils, including *Pecten huttoni*. The conglomerate has a mudstone matrix and passes up into mudstones. There is obviously an unconformity here between two members of the younger rock-series. Morgan and Henderson have described unconformities in numerous places, and it cannot reasonably

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be doubted that they occur. Disconformities, or planes representing periods of standstill and non-deposition, are also known—e.g., that between the Weka Pass stone and Amuri limestone, and that between the Hutchinson Quarry beds and Ototara limestone. The probability of a palaeontological disconformity between the Greta beds and the Mount Brown beds has been discussed above. Important differential earth-movements were certainly operative in the production of the great Marlborough conglomerate. There is more than one limestone in North Canterbury and in North Auckland—e.g., in the Waipara there are the Amuri limestone, the Weka Pass stone, and the Mount Brown limestones. The main limestones are of different ages in various localities, and there are at least three distinct calcareous horizons in the younger rocks—viz., those of the Amuri limestone, the Ototara limestone, and the Wairarapa limestone—with possibly a

fourth in the Takaka limestone, each of these rocks representing in their respective localities the period of maximum submergence. The claims made by Marshall for his Oamaru system are not justified on the facts.

Marshall has not elaborated the possibilities of simple overlap, combined with subsequent (Kaikoura) differential movements, in explanation of the localization of various beds, and it will be instructive to do so. I am indebted to Dr. J. Henderson for this suggestion. According to this hypothesis, if the sea-bottom seaward of the Oamaru district were to be uplifted and dissected it would reveal in the seaward part a sequence like that of the Clarence Valley, followed inland by one like that of the Waipara, with finally the Oamaruan sequence farthest inland. The Oamaru district differs from the Waipara and Weka Pass district, and that in turn from the Clarence Valley, in that it has not been so much uplifted by the Kaikoura movements. The Waipara district should be succeeded inland by an area similar to the Oamaru district, if erosion has not destroyed it. This is probably the case for the Piripauan and the Amuri limestone are unknown on the Culverden side of the Hurunui-Waiau depression where Oamaruan beds are found. As the sea commenced to withdraw again after the maximum overlap in the Oamaruan, the lower Wanganuan beds should not be found so far inland as the Oamaruan; and this too is the case, for the Greta beds are not, so far as I know, found inland of the Amuri limestone. Similarly, in east Marlborough, the Clarence and Awatere Valleys with their Clarentian beds should be followed inland by an area like the Waipara with Senonian beds and Amuri limestone, and this in turn by an area like Oamaru. The latter may be represented by the Picton area, but the Senonian intermediate area is missing. Towards the upper Clarence any such beds might have been destroyed by uplift and erosion, but in the upper Wairau they should surely have been preserved. Again, the Clarence Valley area should preserve not only the lower Wanganuan as well as the Oamaruan, but also the upper Wanganuan, which is not the case.

The arrangement of the three provinces along the coast-line, with the Waipara type between the Oamaru and Clarence Valley types, is again in accord with the hypothesis; but this demands a progressively greater elevation of the two northern areas either by warping or by block-faulting. This is found in east Marlborough, but there is little evidence of it in North Canterbury.

It will thus be seen that this hypothesis that simple overlap with subsequent differential elevation is the cause of the present localization of the various types of stratigraphical sequence is in accord with many of the facts, but by itself cannot satisfactorily explain them all. It does not explain, for instance, why the lower Wanganuan beds are confined within the

boundaries of the Oamaruan overlap in North Canterbury, but transgress these bounds in the lower Awatere Valley. Differential earth-movements during the Notocene must also be invoked to explain the facts of distribution as well as those of the relationships of some of the superposed series of rocks.

Marshall (1919) has combated my criticisms of his use of the term "Oamaru" for his system, and, as the nomenclature of the younger rock-series as a totality is a matter of considerable importance, it seems advisable to criticize further his reasons for wishing to retain the term.

"1. Historical: (a.) The locality is the one from which the first collections of fossils in New Zealand was made." Actually the first fossils mentioned in geological literature were those collected by Dieffenbach in the Chatham Islands, and at East Cape, Parengarenga, Kawhai, and Whangaroa. These were determined generically by Gray, as mentioned in Dieffenbach's *Travels*. Mantell also observed fossils in the Wanganui district before he visited Oamaru.

"(b.) Hutton's Oamaru system included nearly all the strata in the district, and his Oamaru system includes the majority of the rocks classed in the Oamaru system by me. The retention of the name will serve to keep alive the memory of the man who did so much spade-work in the palaeontology and stratigraphy of New Zealand." It is true that Hutton included nearly all the rocks of the Oamaru district in his system, but he excluded the Awamoia beds. His system did not include the Shag Point beds or the Amuri limestone and underlying beds, which are included by Marshall. If the Clarentian is also included by Marshall—and I fail to see how any consistent grounds can be found for excluding it—then in the Clarence Valley area his Oamaru system will embrace more than seven times the thickness of the beds which in that area correlate with Hutton's Oamaru system.^{*} Hutton's name will live for his spade-work in palaeontology and his clear reasoning in stratigraphy without the retention of the Oamaru system, and it is difficult to see how an extension of his system to embrace the Waipara system can be considered otherwise than as a desire to forget his memory, since he spent nearly thirty years of his life in endeavouring to secure recognition for his separation of the two systems.

"3. In the Oamaru district there is a fuller development of the various strata of a

fossil-bearing nature than elsewhere." To establish this Marshall includes in the Oamaru district the whole area between Shag Point and the Waihao River, although it has hitherto included only the area between the Kakanui and Waitaki Rivers. But, granting this, he quotes the Wharekuri, Waihao greensands, and Bortonian as separate horizons, although it is more than probable that they are about the same. The Oamaru district, thus conceived, includes only Piripauan, Kaitangatan and Oamaruan rocks, whereas the Waipara district includes all these together with the overlying fossiliferous Greta beds (Waitotaran) and unfossiliferous Kowhai beds (perhaps Castlecliffian), while the Clarence Valley possesses a still fuller sequence. No single locality, however, has the complete sequence of the younger rocks.

Marshall has countered by suggesting that "Notocene" should mean either that this is the farthest southern point where such rocks have been found or that the formation is common to southern latitudes. In science a term takes the meaning its author gives to it, and my definition of "Notocene" is perfectly explicit.

[Footnote] * This is admitting the Clarentian as 3,000 ft., the Amuri limestone as 2,000 ft. (both low estimates), and the Weka Pass stone and "grey marls" as 700 ft. (a high estimate).

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Diastrophic History of the East Coast of the South Island.

Although my proposal of the term "Notocene" was made before all the facts brought out in this paper were known to me, the reasons which I advanced for this grouping of the younger rocks were stated in terms sufficiently general to admit of considerable latitude in detail, and the new facts do not in any way invalidate the usefulness of the grouping. All the Notocene rocks in the three provinces in the eastern part of the South Island were deposited between the two eras of major (mountain-building) diastrophism, the post-Hokonui (early Cretaceous) and Kaikoura (late Pliocene or Pleistocene) orogenic movements. That the intervening period, during which the Notocene rocks were deposited,

was one of relative crustal stability is proved by the general accordance of the Notocene rocks and the absence of planes of acute angular unconformity. Not only was it not claimed that there were no unconformities or disconformities, or that there were not minor diastrophic movements during this period of relative stability, but the existence of the latter, in combination with differential movements of sea-level, was postulated to explain the stratigraphical diversity of the various provinces.

An attempt may now be made to analyse more closely the succession of events which gave rise to the main elements of the stratigraphy of the three provinces. That there were world-wide transgressions and regressions of the sea during the period from middle Cretaceous to the present day cannot be doubted, and these must have left their trace in New Zealand. The areas affected by these eustatic movements, however, are not the same for each movement, consequently there must have been also differential movements of the lithosphere in the Notocene. Moreover, there seems to have been a tendency, up to the close of the Oamaruan at least, for the sea to keep possession of the area it gained from the land, suggesting that the area was prepared for the transgression by a down-warping movement which continued in the same area from one transgression to another.

The first transgression, the "Cenomanian overlap," covered only a part of east Marlborough, now occupied by Clarentian rocks. A subsequent regression is perhaps indicated by the thinning-out of the Amuri limestone towards the old shore-line in the neighbourhood of the Bluff River and Herring River, but in the Coverham area deposition appears to have gone on uninterruptedly until the upper Oamaruan. I formerly suggested that the Clarentian sea gradually enlarged its borders and that the basal Notocene beds in the Puhipuhi Mountains would prove to be intermediate between Clarentian and Piripauan. This hypothesis has not yet been tested. The next transgression, the Piripauan (Senonian), affected a large area between Kaikoura Peninsula and the Rakaia River, attaining its greatest penetration of the present land in the latter neighbourhood. That the surface at this time was still fairly diversified seems to be proved by the overlap of the various Piripauan beds in the Waipara district. The Piripauan sea still covered the area of the Clarentian transgression, there depositing the basal beds of the Amuri limestone, but the fresh area gained from the land was considerable.

The Piripauan rocks are succeeded, apparently without any stratigraphical break, by the Amuri limestone, the deposition of which demands a clear sea of considerable depth. The area occupied by this limestone is, however, closely restricted within that occupied by the Piripauan beds, and there is no overlap over the Piripauan recorded except for the very slight one I have described east of the Weka Pass. Indeed, the Amuri

limestone is absent from part of the Piripauan area—viz., the Malvern Hills—and, according to Chapman's determination of the age of the supposed Amuri limestone of the Treliwick Basin, from that area also. Whether this absence is due simply to the replacement of calcareous by clastic deposits on approaching the shore-line, or to local uplifts, remains uncertain. If the former were the case a littoral fauna of different age from the Piripauan should be found. What remains certain is that the Amuri limestone sea did not appreciably widen its borders over the Piripauan sea, though it was probably deeper, and consequently we cannot speak of a Kaitangatan transgression in North Canterbury, but must suppose that the Piripauan sea was deepened, without being extended, by local downwarping or block-faulting.

The succeeding Oamaruan rocks, which can hardly demand as deep a sea as the Amuri limestone, transgress widely over the latter formation to the west and south, and the extension of the sea-margin thus indicated was not a gradual one but a sudden one. The surface of the land before this transgression is known to have been of very low relief—*i.e.*, a peneplain—and the attainment of such a surface demands a period of standstill of the strand-line.* This is in accord with the contact between the Weka Pass stone and the Amuri limestone, which represents a period during which deposition practically ceased, perhaps by a shallowing due to regressions, and boring and solution of the upper surface of the Amuri limestone took place. The general lithological similarity of the Oamaruan beds of South Canterbury with the Piripauan beds of North Canterbury suggests similar conditions of coastal relief, so that, although there is direct evidence for a sufficiently diversified surface during the Piripauan to admit of overlap, the relief must have been small. Consequently the period of time required for peneplanation during standstill of the strand was probably not great. The significance attached to the contact between the Amuri limestone and Weka Pass stone by Hutton and Park, as representing a period of uplift and great erosion, was a mistaken one, and the time interval between the two rocks was very much less than they supposed. Nevertheless the contact was a correct one to choose for classification, and Hutton's Waipara and Oamaru systems are two well-defined natural divisions of the rocks in North Canterbury, whereas Hector's Cretaceous-Tertiary formation was an unnatural one.

The Oamaruian transgression and regression were not perfectly regular eustatic movements with the Ototara limestone as the middle member representing the period of maximum depression of the land. The contact between the Ototara limestone and the Hutchinson Quarry greensand is very similar to that between the Amuri limestone and Weka Pass stone, and was probably due to a similar cause—viz., a sudden shallowing of the sea, followed by a period of standstill. There is a similar contact in South Canterbury between a lower foraminiferal limestone and an upper polyzoan limestone or calcareous sandstone exhibited both at Waihao and on Mount Craigmore, in the Pareora district. No palaeontological evidence is forthcoming, however, for the correlation of these two phosphatic horizons, and in the Totara Valley, near Pleasant Point, there is another phosphatic horizon at the top of the upper limestone. Similarly, in the Waipara district, the presence of bored contact between the Weka Pass stone and the “grey marls,” and the unconformities in the latter rocks and between them and the lower Mount Brown limestone in the Weka Pass, are suggestive of considerable oscillation of movement during the Oamaruian.

[Footnote] * I am indebted to Dr. Cotton for calling my attention to this important conclusion.

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The absence of marine rocks above the Awamoan in South Canterbury and North Otago, and the probable unconformity between the Mount Brown beds and the Greta beds, suggests a marked regression at the close of the Oamaruian. The succeeding transgression of the Greta and Awatere beds affected an area quite different from that affected by the Oamaruian transgression, these beds being entirely absent from Otago and South Canterbury, and in North Canterbury, so far as is at present known, being confined within the area of the Piripauan beds. In the Awatere district, however, they overlapped the underlying Notocene rocks on to the pre-Notocene. This distribution can hardly be explained as the result simply of a shallower transgression, though no doubt it was shallower than that of the Oamaruian, but demands differential crustal movements for its explanation—viz., uplift in the south preventing transgression of the sea; uplifts to the west in

North Canterbury restricting the area of the transgression and exposing a surface of pre-Notocene rocks of marked relief to erosion resulting in the gravels of the Greta beds; and subsidence in the Awatere area. Differential crustal movements at about the same or a slightly earlier period are also demanded in east Marlborough by the presence of the great Marlborough conglomerate. Park's separation of the Greta beds under the Wanganui system in 1905 was a correct classification.

The Greta transgression was brought to an end by earth-movements which caused tilting of the marine Notocene rocks in North Canterbury, and during the subsequent erosion the terrestrial Kowhai beds were deposited. Finally came the major block-faulting of the Kaikoura orogenic movements, by which all the Notocene beds were warped or tilted and the Southern Alps and Kaikoura Mountains came into existence as high ranges. The subsequent history comes into the Notopleistocene, and does not fall within the scope of this paper.

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Art. XXXIV.—Additional Facts concerning the Distribution of Igneous Rocks in New Zealand: No. 2.

By J. A. Bartrum, Auckland University College.

[*Read before the Auckland Institute, 22nd December, 1919; received by Editor, 31st December, 1919; issued separately, 16th July, 1920.*]

Plate XXVIII.

In these notes I wish to record a few identifications of rocks from various places, some possessing considerable interest; others are quite ordinary types, but none the less it may be useful to have their occurrences placed upon record.

Quartz-Norite, Cleddau-Hollyford Saddle, South-West Otago.

This rock was gathered, with others, by Mr. R. W. Holmes, Engineer-in-Chief, New Zealand Public Works Department, from the Cleddau-Hollyford Saddle in 1890. In section it appeared to contain an unusual pyroxene, and after some study was sent to Dr. J. A. Thomson, Director of the Dominion Museum, who was so good, as to give the rock considerable attention, and who very kindly has handed over to me the results of his work. His observations corroborated and considerably amplified my own, but unfortunately sufficient information for exact determination is not available from the section, and Mr. Holmes was unable to find the remainder of the rock from which the chip for sectioning was originally taken. I am also greatly indebted to Dr. Thomson for other help, particularly for pointing out that a mineral in this same rock, carelessly identified by me without full investigation as apatite, is probably zoisite, a fact made almost certain by its

high index of refraction, straight extinction, low polarization tints, distinct biaxial character with high optic axial angle, and, so far as I can judge from rather unsatisfactory tests, positive optical character.

The rock itself is a fairly coarse-grained dioritic type showing no outstanding characteristics in hand-specimen. Under the microscope it is seen to be a moderately typical norite but for two considerations: first, the plagioclase, which slightly exceeds the ferro-magnesian minerals in amount and with these latter comprises practically the whole of the rock, is somewhat acid, being in the main andesine-labradorite; secondly, there is distinct acidity, signalized by the presence of a little interstitial quartz. The chemical analysis given below, for which I am indebted to the Dominion Analyst, through the courtesy of Mr. P. G. Morgan, Director of the New Zealand Geological Survey, fully exemplifies these characteristics, and shows that chemically the rock is an intermediate type. Mineralogically, however, it is very closely allied to the norites, and for this reason I have classed it with them.

The structure is coarse and even-grained, the ferro-magnesians occasionally being recognizably ophitic to the plagioclase. Of the former group of minerals, one that would ordinarily be identified unhesitatingly as hypersthene is probably the most prominent, whilst pale-green augite and deep

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Fig. 1.—Quartz-norite, Cleddau-Hollyford Saddle, illustrating the structure and the mineral relationships. The field of the photograph coincides with a portion of the diagrammatic sketch of the text-figure, and the identification of the minerals is possible from the labelling of that sketch. The enclosure of hypersthene by augite is evident at the left-hand end of the horizontal diameter, whilst the penetration of the same augite crystal by zoisite (dark) is also recognizable. The interstitial quartz is very obvious. In the lower right-hand quadrant it is just possible to recognize some fine lamellae of augite intergrown with a crystal of hypersthene-like pyroxene (dark). Crossed nicols. Magnification, 35 diameters.
Fig. 2.—Dolerite, Silverdale, Auckland. The general ophitic structure can readily be

recognized, as also the bar-like growths of iron-ore. Crossed nicols. Magnification, 20 diameters. Fig. 3.—Basalt, near old wharf, Ti Point, Whangateau Harbour. A typical olivine phenocryst. fringed by a rim of oxidation, set in a groundmass in which augite plays an important part. Ordinary light. Magnification, 35 diameters. Fig. 4.—Basalt, Ohakune ballast-pit. A central crystal of olivine (dark) with wide celyphitic rim of augite (mainly white). Some feldspar laths show up in the groundmass, but the olivine laths are here inconspicuous owing to clouding by haematite, whilst abundant vesicles also render the slide dark. Crossed +cols. Magnification, 21 diameters.

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reddish-brown biotite are also very common. Reasons will be given later for the belief that probably a third pyroxene is also present. The hypersthene is in fairly idiomorphic crystals, and preceded the augite, whilst the biotite is later, for its large fresh crystals poecilitically enclose pyroxene, iron-ore, and even quartz grains. The pyroxenes all show imperfect schiller structure; they are occasionally fringed by a little bright grass-green hornblende, which from its association appears largely resorption-product, though perhaps in part outgrowth. Ilmenite is fairly abundant in coarse irregular masses, but magnetite also is common.

Diagrammatic Sketch ($\times 45$) Illustrating Relations of Zoisite to Other Minerals, and General, Structure. (See [Plate XXVIII, fig. 1.](#))

Au. =augite; Hy.= hypersthene; Pl. = plagioclase; Q. = quartz; Z.= zoisite.

Amongst the primary minerals I must finally mention the mineral identified at first by me as apatite, but recognized by Dr. Thomson as zoisite. It is in occasional rather allotriomorphic crystals up to 0.6 mm. in diameter, and one crystal is encased in a zone of iron-ore. In the instance portrayed by the figure above and the photomicrograph of [Plate XXVIII, fig. 1.](#), and in one other, the zoisite is enwrapped (by augite in the text-figure) in a manner that makes it certain that it was formed before the later stages of crystallization of the rock, and

therefore is primary. The plagioclase includes occasional rutile needles.

An Undetermined Pyroxene.

A number of crystals of a pyroxene were observed in this rock, which in many respects greatly resembles hypersthene, but from other considerations I am inclined to believe must be referred to a closely allied mono-clinic pyroxene of a series either identical with or analogous to that of which the now well-known enstatite-augite is a member. These pyroxenes show a microscopic twinning lamination parallel to their elongation, and in addition are frequently intergrown with minute plates of obvious mono-clinic pyroxene approaching diopside, besides containing irregular inclusions of this latter mineral. The pleochroism distinctive of hypersthene

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is general, the optical character is negative, and the elongation positive, whilst the optic axial angle is small. Most important of all, however, the extinction, whilst often nearly straight, reaches generally as high as 5° with the composition-planes of the lamellae, and in one or two crystals angles of over 15° are got with the cleavage. Were it that only one or two crystals showed the obliquity of extinction one might suspect some inaccuracy of observation, but at least eight in the slide show it. Further, even greater obliquity of extinction, with similar very finely microscopic twinning, is shown by nearly a dozen crystals of apparently identical hypersthene-like pyroxene in a noritic rock discovered at Milford, and described later in this paper (see p. 420).

In some instances the lamellae are here much broader than in others, whilst the extinction angles generally range up to 15° , but in one case up to as much as 42° . As a rule, the lamellae extinguish together in the one direction, but this is by no means invariably the case. In the Milford, as in the Cleddau-Hollyford rock, there is parallel intergrowth with fine lamellae of augite. It may be thought that the crystal in which the extinction angles of the lamellae reached 42° exemplifies a similar parallel intergrowth with augite, but this is not so, for the lamellae are very

distinct and comprise the whole mineral, which certainly is not an ordinary monoclinic pyroxene, for it is optically negative and has the distinct hypersthene-like pleochroism already noted. There is, however, one peculiarity of this crystal that may have a bearing upon the matter—namely, the optic axial angle appears to be large.

Only one further observational fact now remains to be mentioned in connection with this pyroxene, but it is of importance: the plane of the optic axes coincides with the composition-plane of the lamellar twin. Since the extinction is oblique, this plane must be at right angles to the plane of symmetry—that is, to the 100 plane—as in normal hypersthene. The lamellar twin appears not to follow the plane 110 frequent in the inter-growths of rhombic and monoclinic pyroxenes, for all the sections showing the lamination distinctly are approximately at right angles to the optic axial plane; nor is it the common 010 plane.^{*} It is much more reasonably the 100 plane observed by Bowen in artificial clino-enstatite.[†] On this supposition, however, it is difficult to understand why the lamellae often appear all to extinguish in the same direction.

Enough data are available to show that a monoclinic pyroxene of unusual type is exhibited in the sections from the Cleddau-Hollyford and the Milford rocks. It approaches hypersthene, but differs from it in its oblique extinction, and it seems probable that it is a monoclinic member of a series embracing this latter. It is obvious that much of the mineral in the sections that is apparently hypersthene may really be this mono-clinic pyroxene viewed in sections lying near the orthopinacoid.

Chemical Classification.

An analysis of the Cleddau-Hollyford quartz-norite by the Dominion Analyst gave the results tabulated in column A below. In columns B and C the analyses of somewhat similar rocks are quoted from Iddings.[‡]

[Footnote] * See H. Rosenbusch, *Mikroskopische Physiographie der Mineralien und Gesteine*, vol. 1, pt. 2, p. 149, 1905.

[Footnote] † N. L. Bowen, The Ternary System Diopsid-Forsterite-Silica, *Am. Journ. Sci.* (4), vol. 38, pp. 207–64, 1914.

[Footnote] ‡ J. P. Iddings, *Igneous Rocks*, vol. 2, p. 218, 1913.

The norms and classifications calculated by the C.I.P.W. quantitative method are also appended.

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

	A.	B.	C.
SiO ₂	52.46	53.50	52.8
Al ₂ O ₃	18.58	22.20	17.8
Fe ₂ O ₃	4.76	3.60	1.2
FeO	4.03	2.64	4.8
MgO	4.72	2.00	4.8
CaO	8.56	9.45	12.9
Na ₂ O	3.86	4.26	3.0
K ₂ O	1.14	0.61	0.5
H ₂ O	0.57	1.50	1.2
TiO ₂	0.60	0.45	0.5
CO ₂			
P ₂ O ₅	0.51		
MnO	0.14	0.35	
	99.93	100.56	99.5

Norms and Classification.

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

	A.	B.	C.
Quartz		2.64	4.2
Orthoclase		6.67	3.3
			2.8

Albite	32.49	36.2	25.2
Anorthite	30.02	39.8	33.6
Diopside	7.07	5.8	24.8
Hypersthene	11.08	3.4	7.0
Magnetite	6.96	5.1	1.6
Ilmenite	1.22	0.9	0.9
Apatite	1.24		
(Water)	(0.57)	(1.5)	(1.2)
	99.96	100.2	99.3

Classification II.5.3(4).4 (Andose.) II.5. 4. 5 II .5.4. 5

- A. Quartz-norite, Cleddau-Hollyford Saddle, New Zealand. (Dominion Analyst.)
- B. Quartz-gabbro, Carrok Fell, England.
- C. Gabbro, Druim an Eidhne, Isle of Skye.

The norm agrees well with the observed mineral composition, although it is difficult to account for the apatite shown by the norm and indicated by the chemical analysis: apatite appears to be practically absent from the section examined.

Another more typical coarse norite was amongst the material collected by Mr. Holmes from the Cleddau-Hollyford Saddle. The plagioclase (labradorite) and ferro-magnesian minerals are subequal; of the ferro-magnesians, hypersthene and augite are both plentiful, the former the more so; it is often finely lamellar as in the quartz-norite, but the extinction appears here to be straight. A brownish-green hornblende clouded by dust-like iron-ore occurs in large crystal which poecilitically enclose the pyroxenes and some feldspar. Some of the augite is intergrown with the amphibole; it is occasionally lamellar, passing to diallage. The hypersthene

is largely converted to a finely fibrous, tufted, almost colourless aggregate bordered by green; it is referred with some diffidence to tremolite and actinolite.

Norite, Wairau Creek, Milford, Auckland.

I found a very-well-rounded boulder about 5 in. in diameter included in the sandstones of the Waitemata beds at the mouth of Wairau Creek, a little north of Lake Takapuna, and quite unaccompanied by other boulders or pebbles. It is a very coarse norite with plagioclase (medium labradorite) a little more plentiful than the ferro-magnesian minerals, which are hypersthene (including an allied pyroxene dealt with on p. 417) and less abundant diallage. The hypersthene is being converted into talc, and particularly adjacent to cracks there is chloritization and the entrance of fine pyrite.

Dolerite, Swinging-basin, Silverdale, Auckland.

This occurs as coarse angular blocks several feet in diameter, unearthed during excavation for the swinging-basin at the Silverdale (Wade) wharf on the Weiti Stream, which flows to the east coast about twenty miles north of Auckland. Though apparently the actual outcrop is not laid bare, yet this cannot be far distant, unless—a suggestion their comparative freedom from weathering would negative—the blocks come from the formerly overlying Waitemata beds now removed by erosion from the stratigraphically lower hydraulic limestone of this area, but which contain large blocks of andesite and perhaps other igneous types not far distant on Whangaparaoa Peninsula. The site of discovery of the dolerite is immediately adjacent to where McKay maps one of his serpentine dykes^{*} (which, however, I was unable to locate during my brief visit), and the idea suggested itself that there might be some connection between the intrusion of the two rocks. Professor W. N. Benson remarks anent this point, after examination of the dolerite section, "It does not contain albite, and is more like the post-peridotitic than the pre-peridotitic of my New South Wales dolerite dykes."[†]

Macroscopically the rock is a very dark finely holocrystalline type with inconspicuous glistening lath-like feldspars and prominent chloritized ferro-magnesian mineral. In section the most striking feature is the ophitic structure; the mass consists largely of large labradorite laths, between which is faintly pleochroic partially chloritized pink augite in somewhat columnar crystals, and a profusion of irregular iron-ore growths and skeleton crystals enwrapped by the pyroxene (see photomicrograph, [Plate XXVIII, fig. 2](#)). The feldspars are fairly fresh, but a little secondary calcite and a very great deal of chlorite developed from the augite are present.

Basalt,

“Sugarloaf,” Matakana-Leigh Road, Rodney County.

The “Sugarloaf” is a conical knob a little west of the main road from Matakana to the Omaha, and about two miles from Matakana. It is mapped as igneous by Cox in his report on the geology of the Rodney and Marsden

[Footnote] * A. McKay, On the Occurrence of Serpentine Dykes in Cretaceous-Tertiary Strata near the Wade, Auckland, *Rep. Geol. Explor. during 1883–84*, pp. 99–101, 1884.

[Footnote] † Letter dated 13th September, 1918.

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Counties,^{*} and is in fact a basalt neck breaking through the massive concretionary greensands of the Waitemata series, which are well exposed near by. The basalt is a fairly typical holocrystalline type, rich in coarse idiomorphic phenocrysts of olivine and pale-greenish augite, with numerous smaller intermediate crystals of plagioclase showing good fluxional arrangement. The groundmass is largely of small feldspar laths enclosing a moderate number of pyroxene grains and small magnetite crystals.

Basalt,

Ti Point, Whangateau Harbour, Rodney County.

This occurrence is referred to as a dyke and also mapped by Cox in the paper just quoted. Several sections were cut from various parts of the mass forming the small peninsula of Ti Point. There is often good fluxional banding shown in the field, but the differences in section are unimportant, except that flow structure is better shown in some sections than others. There are resemblances to the Auckland basalts, but the chief differences lie in the more sharply idiomorphic nature of the large very abundant olivine phenocrysts, and the greater proportion of augite in the finely holocrystalline groundmass (see photomicrograph, [Plate XXVIII, fig. 3](#)). Feldspar scarcely occurs in the first generation, and augite is

unimportant. The olivine is almost invariably oxidized on its margins, and stained thereby a deep reddish. This phase of oxidation accompanying extrusion is even better exemplified by a basalt from Ohakune, next to be described.

Mr. H. G. Cousins, Director of the Teachers' Training College, Auckland, closely studied this rock some years ago, and very kindly has allowed me to read his unpublished thesis thereon. He shows that the eruption has burst through the Waitemata beds, and concludes, mainly from considerations of denudation, that the period of extrusion was probably Upper Miocene. I entirely agree with him that it was probably not contemporaneous with that of the basalts of Auckland, but much earlier.

Basalt, Public Works Department Ballast-pit, Ohakune.

I am indebted to Mr. F. E. Mason, of the Seddon Memorial Technical College, for specimens of this rock. My sections are decidedly interesting, and deserve comment. Much of the material is highly scoriaceous, and stained a deep chocolate-red through oxidation.

The phenocrysts are coarse glomeroporphyritic groups of colourless augite and a few olivine crystals. In the groundmass are but a few augite crystals, with subequal parts of plagioclase laths and another mineral comprising the main portion. This other mineral is also lath-like, is greatly stained by haematite as a result of oxidation of contained ferrous compounds during the final phases of the eruption, and seems certainly to be olivine, for it has straight extinction, very high refraction and birefringence, and a high optic axial angle. The optical character was not satisfactorily determined. Fine iron-ore is moderately abundant. Occasionally, as the photomicrograph ([Plate XXVIII, fig. 4](#)) depicts, the olivine phenocrysts are enwrapped more or less celyphitically by a rim of augite.

[Footnote] * S. H. Cox, Geology of the Rodney and Marsden Counties, *Rep. Geol. Explor, during 1879–80*, pp. 13–39, 1881.

**Hypersthene-Andesite,
South-east Flank of Mount Hikurangi, Whangarei District.**

A greyish porphyritic rock with idiomorphic phenocrysts of hypersthene, coarse plagioclase from the acid end of the series, and rare brownish-green hornblende. There are in addition numerous smaller lath-like feldspars, arranged with noticeable parallelism, and some fairly large sporadic iron-ore crystals, enclosed with the major phenocrysts in a somewhat lithoidal irresolvable matrix in which magnetite specks furnish the only recognizable mineral, and which appears to be densely cryptocrystalline. The hypersthene is not plentiful, and is only in small crystals in the two sections cut, though occasional crystals reaching as much as 1½in. in length can be gathered in the field.

Art. XXXV.—*The Conglomerate at Albany, Lucas Creek, Waitemata Harbour.*

By J. A. Bartrum, Auckland University College.

[*Read before the Auckland Institute, 22nd December, 1919; received by Editor, 31st December, 1919; issued separately, 16th July, 1920.*]

Plate XXIX.

About 200 yards up-stream from the lower wharf at Albany (see locality map), conglomerate bands outcrop which have given rise to abundant cobbles strewing the banks of Lucas Creek in the vicinity. They are without doubt members of the local Tertiary sequence known as the Waitemata beds, but their horizon therein is doubtful, for folding and faulting are common in the sandstones on the shores of the upper Waitemata Harbour (into which Lucas Creek flows) and obscure the sequence. The writer is inclined to place the conglomerate bands amongst the lowest of the Waitemata beds in the near vicinity of Auckland, but there is at present no means of fixing their absolute horizon, and, as the purpose of this paper lies rather in the direction of describing the interesting assortment of rock-varieties in the bands than in discussing their stratigraphy, this aspect will not

receive further attention herein.

The main band of conglomerate near Albany is about 12 ft. thick, and has a strike that is approximately north-east by east and south-west by west, and a dip of 45° up-stream to the north-west by north. About 20 ft. beneath it is a similar band of smaller cobbles 2 ft. in thickness. Not many yards down-stream the direction of dip is reversed, the sandstones dipping gently in an approximately south-east direction. The actual reason for the reversal is obscure: it may be anticlinal structure, for there is evidence at Riverhead favouring this explanation, although the conglomerate was not found to reoccur in the down-stream section.*

[Footnote] * A much-weathered coarse conglomerate is exposed at Cut Hill, about two miles south-south-east of the Albany outcrop, but it appears that this band is not the same as the Albany one.

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The material of the bands consists of very-well-rounded pebbles and boulders usually a few inches in diameter, but reaching as much as 1½ ft., set in fine mortar; they appear typical sea-beach drift, a conclusion borne out by the discovery of shell-fragments in a somewhat calcareous fine grit-conglomerate

about 20ft. to 25ft. in depth overlying the upper conglomerate band, and outcropping, therefore, up-stream from it. In facies these boulders consist mainly (perhaps 90 per cent.) of rocks of holocrystalline igneous character, many distinctly gneissic in structure, along with grey-wackes, andesites, and occasional trachytes and cherts.

No attempt was made to trace these conglomerate bands across the low hills, rising to about 400 ft. above sea-level, immediately west of Lucas Creek, because of the heavy overburden of residual clay general upon the hills of the district; they were looked for and picked up again in the low-lying wide basin adjoining the Rangitopuni and Mahoenu Streams (see locality map), into which the roads from Albany to Riverhead descend, and where one can find not only distinctive shoading but also several outcrops adjacent to the main road to Riverhead. About two miles east of this latter place, just above the conglomerate is a quartz-rich grit which passes into a fine grit-breccia about 1 ft. in depth, containing fragments of wood, pumice, and a very dense felsitic mica-rhyolite in fragments ranging up to $\frac{1}{2}$ in. in diameter. The dip is about 80° to the south-south-west. In the main conglomerate band of this outcrop jasperoid argillite, greywacke, and a good deal of andesite, some of it very coarsely porphyritic and very strongly oxidized, are frequent, in addition to the dioritic types common at Albany. Towards Riverhead the band of grit-breccia characterized by the pumice and other rhyolite thickens considerably, and the material also is coarser, forming a very curious firmly cemented breccia where it is exposed in the tideway near the paper-mills at Riverhead. It is not far above the main conglomerate band—here of much smaller pebbles than elsewhere; below this latter also are several distinct bands, each about 2 ft. in depth, of fairly coarse conglomerate. The tide was unsuitable for close investigation of these bands during the writer's visit, but they did not appear to be of special interest.

Petrography of the Conglomerate Bands.

In a recent volume of these *Transactions* the writer (Bartrum, 1917) described gneissic diorites discovered in loose boulders at Albany, and suggested that they had come from a boulder-bed known to outcrop near by in the Waitemata beds. Upon visiting the locality he soon found that his surmise was correct, and recognized several other rock-types in addition to the two represented in the specimens first given to him. There are several plutonic types, which nearly all show the effects of considerable pressure, notably granulation in various stages of intensity. The complete list is as follows—

(A.) *Rocks of sedimentary facies.*

1. Greywackes (fairly common).

2. Jasperoid argillite (rare).

3. Chert (rare).

No particular attention was accorded the pebbles of sedimentary facies, as the writer's interest lay chiefly with the igneous types, so that the above list-may be very incomplete. The greywackes and argillite are obviously derived from the "Maitai" rocks, which from the basement of the Waitemata beds. The chert resembles rocks of similar appearance which

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Fig 1.—Granodiorite. The lower half of the photomicrograph illustrates a large crystal of amphibole ophitically enclosing plagioclase. Above this, granulation and shadow extinction are just detectable in the quartz. Crossed nicols. Magnification, 20 diameters.

Fig. 2.—Banded dioritic gneiss. The granulitic structure is well exhibited. Crossed nicols. Magnification, 21 diameters. Fig. 3.—Dolerite showing the lath-like form of the feldspars, which are ophitically enwrapped by amphibole. Crossed nicols. Magnification, 21 diameters.

Fig. 4.—Trachyte. The upper portion of the coarse white mineral is plagioclase, the lower sandstone, the intervening dark area being a gap in the section. Crossed nicols. Magnification, 21 diameters.

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are common in the hydraulic limestone member of the Oamaru system of Marshall (1911, pp. 22 *et seq.*); such an origin would raise no fresh difficulty, for Hector (Cox, 1881, p. 29) and Henderson (1914, p. 157) have observed pebbles of the hydraulic limestone itself in Tertiary conglomerates in various places in the Warkworth-Mahurangi district and elsewhere, from which Henderson has deduced the discontinuity of sequence of the rocks of the Oamaru system in that district, which is not far distant from Albany.

(B.) *Rocks of igneous origin.*

1. Granodiorite (granulated).
2. Quartz-diorite (granulated).
3. Banded dioritic gneiss.
4. Diorite (granulated).
5. Anorthosite.
6. Dolerites.
7. Andesites of varied type.
8. Trachytes.
9. Rhyolite (not in the main boulder-band itself).

The granulated diorites preponderate amongst the igneous types, and must constitute 80 per cent. of the pebbles in the outcrop of the conglomerate at Albany.

Description of Types.

1. *Granodiorite (granulated).*

A fairly common type. A fresh coarse-grained rock, outwardly dioritic and rich in hornblende. In section notably and coarsely ophitic (see [Plate XXIX, fig. 1](#)). The light-coloured minerals comprise nearly two-thirds of the rock: basic andesine is the most abundant of them, and next in order come orthoclase and quartz, this last interstitial and abundant. The darker minerals consist of a very little coarse iron-ore and large hornblende crystals enclosing smaller ones of andesine in perfect ophitic manner. A little apatite furnishes the only accessory besides the iron-ore. The effects of severe pressure are very obvious—shadow extinction and granulation of quartz and sometimes orthoclase, and bending of the twinning lamellae of the plagioclase.

2. *Quartz-diorite (granulated).*

This type was described in an earlier paper by the writer (Bartrum, 1917, p. 423); it approaches the granodiorite mineralogically, but differs from it structurally.

3. *Banded Dioritic Gneiss.*

The banded structure is quite obvious in hand-specimen. In section it is somewhat lost sight of owing to the mosaic-like structure resulting from complete granulation (see [Plate XXIX, fig. 2](#)). In composition it is practically the same as the general granulated diorite next to be described, and there is no need to supplement the brief description of this type published in the earlier paper just referred to.

4. *Diorite (granulated).*

Judging by macroscopic examination, the vast majority of the pebbles and boulders of the conglomerate belong to this type—a moderately fine even-grained dioritic rock, showing numerous glistening feldspars and darker amphiboles. Usually under the microscope there is sufficient granulation

of the borders of the crystals to give an appearance approaching that of a mosaic, owing to the rather equidimensional rounded crystals of green amphibole and plagioclase in approximately equal proportions. A little iron-ore is present, and usually sphene, the latter sometimes quite plentiful. Pyrite is a common secondary adjunct. Much of the amphibole is fibrous, and in cases is developed as uralite from central kernels of unchanged augite. In one or two sections the feldspars have a distinct broad lath-like form.

5. Anorthosite..

A boulder of this rock about 18 in. in diameter was found in the debris of an outcrop of conglomerate alongside the Albany-Riverhead Road. Macroscopically it is a greyish or bluish-white crystalline rock resembling marble, and weathering to a white kaolinitic product. It has small patches of green chlorite, and others of a reddish-brown mineral which apparently is a chloritized mica allied to biotite, and which shows distinct pearly cleavage-faces.

Seen in section, almost the whole of the rock appears as a highly refractive colourless mineral. Its allotriomorphic equidimensional crystals are very strongly cleaved, are fractured, and are separated by zones of a weakly refractive substance which also penetrates the fractures in the main mineral and has every appearance of being a derivative from it. A little chlorite (perhaps derived from biotite) and zoisite are also present.

The mineral constituting the mass of the rock shows some perthitic intergrowths, much irregular twin-lamination, and occasional definite twin-lamellae giving extinction angles of 45° on either side of the composition plane. It was tentatively identified by the writer as a basic plagioclase, and Dr. J. Allan Thomson has been kind enough to confirm this identification. The residuum of feebly refractive mineral was regarded by the writer as a zeolite, but Dr. Thomson suggests that it is largely a more acid feldspar.

No exact quantitative chemical analysis of the rock was made, but Mr. A. H. Bowell, of Auckland University College, performed tests which showed that it is essentially a silicate rich in alumina and lime, with only traces of iron and

potassium, and very little magnesia. No attempt was made to ascertain the sodium content.

The writer is convinced that this rock is a plutonic type, for he considers that the finely crystalline material is secondary in origin; he therefore classes it as an anorthosite, a rock of somewhat rare occurrence.

6. *Dolerites.*

Three specimens of dolerites were collected showing slight differences in the hand-specimen, and only with difficulty separable from the diorites. In mineralogical character they are very similar to the diorites, for they consist of amphibole and basic andesine, the former slightly in excess of the latter. Coarse irregular ilmenite is general, and is sometimes associated with sphene. There is usually a little secondary pyrite and epidote. There are two important differences from the diorites: (a) absence of granulation or other signs of intense pressure, (b) structure. It is on the basis of the structure that they are here classed as dolerites; the texture is coarse and even-grained, and the amphibole has markedly ophitic relations to the long irregular laths of feldspar, as [Plate XXIX, fig. 3](#), well shows.

Some of the greenish amphibole is fibrous uralite obviously derived from augite, as in the diorites, for cores of unreplaced earlier mineral survive. Generally the amphibole is a coarse green hornblende, but often it is a finely bladed, or even granular, apparently secondary variety.

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7. *Andesites.*

In general the andesitic material is much weathered and altered, the ferro-magnesian minerals in particular having been affected. It was not to be expected, considering the wealth of variety of our Auckland andesites, that any new types would be revealed. Several varieties, however, were discovered, some with plagioclase as the chief phenocryst, others with some or other ferro-magnesian

mineral more prominent in the first generation; but as a rule chlorite and other secondary aggregates greatly mask the original nature of the rocks. Mention may be made of the following varieties:—

Hypersthene-andesite.—Macroscopically a particularly coarsely porphyritic type with coarse phenocrysts of pyroxene and feldspar. The hypersthene is accompanied by some augite and is largely replaced by calcite. Some small serpentine pseudomorphs suggest olivine. The groundmass is hyalopilitic.

Pyroxene-andesite.—Another very coarsely porphyritic andesite, rather light grey in colour. In section phenocrysts of colourless hypersthene are both abundant and coarse, along with large equally colourless augite crystals. Most of the rest of the rock is composed of much smaller phenocrysts and intermediate lath-like crystals of plagioclase, there being quite a minor amount of the microcrystalline residuum of feldspar, pyroxene, and a little magnetite. There is some coarse totally resorbed hornblende.

Another interesting andesite, in which plagioclase is the only important phenocryst, shows an abundance of branching growths of iron-ore in the groundmass. The ferro-magnesian phenocrysts are small, infrequent, and greatly altered. There are common inclusions of aggregated quartz grains, often with epidote and chlorite, around which the iron-ore growths form a conspicuously dense halo-like border. Coarse secondary epidote is frequent.

8. Trachytes.

These are rare; only two types were found, both typical trachytes, so far as macroscopical examination is concerned, but one characterized by a little biotite and the other by a little hornblende.^{*} In section both types show many idiomorphic plagioclase phenocrysts, with more numerous but smaller sanidine ones.

In the hornblende-bearing type the amphibole is the green variety, and is in scattered idiomorphic crystals. The groundmass is almost entirely feldspathic: a few plagioclase laths are clear-cut and determinable, but the main mass is of small ill-defined crystals lacking the albite lamination, and presumably alkali-feldspar. Plate XXIX, fig. 4, shows the general structure fairly well.

Though the biotite of the biotite variety is apparent in the hand-specimen, the only section cut shows no phenocrysts of that mineral, but numerous small shreds of it in a groundmass built up almost wholly of narrow laths of feldspar which lack the albite twinning and often show good fluxional arrangement.[†]

9. Rhyolites.

Fragments of a curious white porcellanous felsitic rhyolite are frequent, along with

pumice and other material, in a thin band of grit-breccia

[Footnote] * A third variety has been found since the above was written; it is a silty rock with phenocrysts of conspicuous greenish-brown hornblende.

[Footnote] † A third type has been found recently; it has fairly conspicuous phenocrysts of brown amphibole.

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already described as exposed about two miles from Riverhead alongside the Albany-Riverhead Road, and again near the paper-mills at Riverhead itself, where the fragments are much coarser. The finer portions of the grit-breccia are largely angular quartz grains with flakes of biotite, small grains of the whitish rhyolite, and some of fine argillite.

The rhyolite exhibits a few corroded quartz phenocrysts of moderate size, and plentiful small rather rod-like flakes of brown biotite in a dense ground-mass of minute microlites of feldspar, which are arranged more or less in parallelism with the biotite flakes, and are enwrapped by a small amount of irresolvable base from which they have only imperfectly separated.

Significance of the Material of the Albany Conglomerate.

The probable origin of the sedimentary material included in the conglomerate has already been sufficiently considered (see p. 424), for it raises no point of especial interest. The igneous constituents, however, present a very different case.

There is very general agreement amongst New Zealand geologists (Fraser and Adams, 1907, table facing p. 22) that the eruptions of andesite which have contributed so largely to the building of Coromandel Peninsula and other northern parts of Auckland Province probably began before the Miocene, and thus before the period of formation of the Waitemata beds, which are commonly regarded as Upper Miocene in age. Andesitic eruptions have evidently been common since pre-Jurassic times, for andesitic pebbles are found in Jurassic

rocks in the Cape Colville Peninsula (Fraser and Adams, 1907, p. 52), at Port Waikato (Bartrum, 1917, p. 422), and elsewhere. The writer has observed andesitic debris capping hills adjacent to the hill route between Riverhead and Helensville, not many miles from Riverhead, which may represent an extrusion of pre-Waitemata time.

Rhyolites are first known in the Auckland Province from the supposedly pre-Jurassic sediments (Tokatea Hill series) of Coromandel Peninsula (Fraser and Adams, 1907, p. 43), and have considerable importance from early in the Tertiary (Fraser and Adams, 1907, table facing p. 22). Their only special interest as concerns this paper is that they have not been recorded previously from any of the other conglomerate or grit bands in the Waitematas.^{*}

The presence in abundance of gneissic rocks in the Albany conglomerate raises an interesting question regarding the earlier geological history of the North Island of New Zealand, but so large a one that it is inadvisable to deal with it at all fully in a paper such as this, devoted mainly to petrographic description. Briefly, the facts are these:—

1. Gneissic plutonic rocks occur in the North Island of New Zealand in conglomerates at Alexandra, in the King-country (Park, 1893); at the gorge of the Waipaoa River, Poverty Bay (Sollas and McKay, 1906, pp. 175 *et seq.*); in Cretaceous or early Tertiary beds in the Whangaroa district (Bell and Clarke, 1909, p. 50); in "Maitai" conglomerates in the Hautotara Mountains of south-east Wellington (Sollas and McKay, 1906, p. 185); and, as now recorded, at Albany.

[Footnote] * This statement requires some modification: C. E. Fox (1902, p. 462) records fragments of pumice. Their presence is, however, no necessary indication of the vicinity of a rhyohtic terrain, for pumice can be naturally transported immense distances by water. An interesting example of this fact is furnished by the presence of abundant pumice in sub-recent shore-deposits at the Big Omaha, south of Cape Rodney, which has probably been carried by the coastal drift around Cape Colville from the east coast.

2. The basement rocks* of the North Island consist of shales and greywackes which are largely unfossiliferous and therefore of uncertain age, though in part mid-Mesozoic (Marshall, 1911, p. 20). These rocks were subjected to compression in the later Mesozoic which locally was moderately intense, but caused no noteworthy metamorphism in the North Island area. In the Whangaroa district, it is true, schistosity is locally developed in altered igneous rocks associated with the basement strata of that district (Bell and Clarke, 1909, p. 44), though it is still by no means certain that folding movements earlier than the late Mesozoic may not have affected them. In the South Island metamorphism is very general in the members of the oldermass associated with rocks lithologically similar to those of the basement rocks of the north, but it is probable that this metamorphism long antedated the late Mesozoic orogenic movements (Morgan and Bartrum, 1915, pp. 67–71).[†]

Plutonic intrusions are rare in the North Island, but such as there are perhaps synchronize with the vastly greater ones of the west coast of the South Island. Fraser and Adams (1907) assign a pre-Jurassic age to the Moehau intrusion of Coromandel Peninsula, whilst Marshall inclines to the belief that the olivine-norite at Ahipara, in North Auckland, underlies the Mesozoic ("Maitai") beds of that district—an important conclusion—and considers the schillerization of the augite of the norite evidence of intense pressure. It is necessary to add that it is obvious from his paper that Marshall (1908) believes that this pressure was associated with the late Mesozoic orogenic movements. In the South Island some at least of the granite and other batholithic intrusions, if not Palaeozoic, were certainly very early Mesozoic in age, for pebbles of granite and other plutonic types are found in a conglomerate near Nelson (Marshall, 1904).

Having regard, then, to the probable early date of the plutonic intrusions of the North Island, and to the lack of noteworthy metamorphism throughout the sediments of the oldermass, there is surely justification for more than a suspicion that the gneissic constituents of the conglomerates already mentioned are vestiges of a land area which antedated the period of deposition of the Mesozoic ("Maitai") sediments, and which suffered in turn folding and severe erosion so that intrusive batholiths were uncovered and caused to protrude. Support is afforded this idea by the presence of dioritic material in Jurassic shales in

Coromandel Peninsula (Fraser and Adams, 1907), of granitic pebbles in Jurassic sand stones at Kawhia (McKay, 1884), and of a foliated granite in a conglomerate in the "Maitai" rocks of the Hautotara Mountains of south-east Wellington (Sollas and McKay, 1906, p. 185); but it must be admitted that these plutonic rocks have not been found in the lowest rocks of the sequence either at Coromandel or Kawhia, whilst they are absent from many other known conglomerate bands in the basement rocks. Much can be argued both for and against this view that the writer is inclined to favour with regard to the significance of the gneissic boulders, but one cannot ignore the possibility that these rocks disclose a glimpse of the early geological history of the North Island of which we are ignorant. In the present state of our knowledge it is impossible to come to any conclusions as to the exact date of the abyssal injections, beyond that

[Footnote] * The "oldermass" of Cotton (Cotton, 1916).

[Footnote] † Mr. Morgan favours an Aorere age (Ordovician) for several great rock-units in Westland and south-west Nelson usually grouped in the Maitai system of early to mid-Mesozoic age.

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it was pre-Jurassic, but the conviction grows upon the writer that Professor Park's (Park, 1893, pp. 358-59) early view of the great scientific importance of the discovery made nearly thirty years ago of gneissic rocks in the King-country was not an exaggerated one.^{*}

Summary and Conclusion.

In the Albany-Riverhead district conglomerate bands occur in the Waitemata (probably Upper Miocene) beds, two of which are particularly well exposed near Albany, and contain material of very varied petrographic nature. The various igneous types are described above, and it is pointed out that the gneissic rocks there and in other conglomerates elsewhere in the North Island perhaps furnish evidence of a terrain injected by batholithic intrusions, subjected to

compressional stresses and eroded before the deposition of the main mid-Mesozoic sequence of the North Island.

The occurrence of anorthosite is particularly interesting in view of the limited distribution of this type of rock.

In conclusion, the author would like to thank Mr. A. H. Bowell, of Auckland University College, for performing chemical tests upon the anorthosite, and Dr. J. A. Thomson, Director of the Dominion Museum, for most valuable help in the determination of this same rock.

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[Footnote] * The writer would add that since writing the above he has been fortunate enough to find several bands of conglomerate in the "Maitai" rocks outcropping in the north of Great Barrier Island, and that in these bands there are abundant granite boulders and occasional garnet-granulites, if macroscopic appearances are not deceptive.

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Art. XXXVI.—*On some Examples of New Zealand Insects illustrating the Darwinian Principle of Sexual Selection.*

By G. V. Hudson, F.E.S., F.N.Z.Inst.

[Read before the Wellington Philosophical Society, 24th September, 1919; received by Editor, 31st December, 1919; issued separately, 16th July, 1920.]

Notwithstanding constant attempts to refute or profoundly modify Darwin's theory of natural selection, or the "survival of the fittest," it cannot be denied that this theory remains to this day the only satisfactory explanation of the innumerable instances of adaptation to conditions which are manifest to the most casual observer of plants and animals. It is not, however, my intention this evening to give instances of the operation of natural selection amongst our New Zealand insects, although practically every species might be utilized in corroboration of Darwin's great theory. My object on this occasion is to direct attention to Darwin's subsidiary theory of sexual selection, which some of his immediate followers were convinced had been a most potent factor in the

evolution of the more advanced attributes of the higher animals, but which has unaccountably been allowed to drop into the background by many present-day biologists. Some may perhaps urge that the theory of sexual selection, as propounded by Darwin in his *Descent of Man*, is an out-of-date doctrine, superseded by more precise modern researches into the minute structure of organisms. Before, however, any such general statement can be accepted a more complete explanation than that afforded by sexual selection must be given of the actual facts existing in nature, and this I think I can safely say has not yet been done. Without further preliminaries I will now direct attention to a few of the facts referred to, and will use our New Zealand insects in illustration of my remarks.

1. Order Hemiptera. Suborder Homoptera.

The suborder Homoptera includes the cicadas, lantern-flies, and their allies, as well as the aphides, scale insects, &c.

The family Cicadidae, often popularly known as "locusts" or "singers," the first name being most misleading, is one of the best-known families of New Zealand insects. We have upwards of a dozen species, of which the largest, *Melampsalta cingulata* is often extremely abundant in the late summer. At this season the singing of the males, as they rest on the branches of trees and shrubs, is sometimes almost deafening, and the noise may be best likened to that produced by a number of frying-pans simultaneously in operation on a very hot fire. This sound is produced by two complicated organs connected with the respiratory system of the male, and situated on the underside of the base of the abdomen. It is solely confined to that sex. The singing is undoubtedly attractive to the female, and close observation of the insects in their natural haunts often discloses the fact that the keenest rivalry exists between two or more males to captivate a female by means of their music. It is impossible to assign any other use to these complicated organs, and the instinct to use them, than that here indicated. The sound emitted certainly does not intimidate the enemies of the cicada, as they are all much preyed

upon by birds; and even if it did repel certain potential enemies, such special means of protection would be far more necessary for the preservation of the female whilst depositing her eggs than it would be for the male.

2. Order Orthoptera.

In the small order Orthoptera, which includes the wetas, grasshoppers, crickets, walking-sticks, and allied insects, we have several striking instances of the operation of sexual selection.

The Stenopelmatidae, or wetas, were long supposed to be destitute of sound-producing organs, although possessing an auditory organ on each of the tibiae of the anterior pair of legs. A careful examination of the side of the second abdominal segment of both sexes, however, reveals the presence of about six minute file-like organs, which are operated upon by the inner edge of the base of the femur of the hind legs, these legs being raised above the insect's back when it is stridulating. By this means the weta can produce a harsh grating sound, which is employed to intimidate enemies and also possibly as a call or lure to the female. This stridulation of the weta may often be heard in the bush at night.

In the males of the true grasshoppers with short antennae (Acridiidae) a long file-like structure is situated on the inner side of the thigh of the hind leg, and the sound produced is used to attract the female.

In addition to the stridulating-apparatus, the male of our commonest weta (*Deinacrida megacephala*) has a huge head and jaws, the corresponding parts in the female being of the ordinary size. These males are sometimes found in holes in trees and similar situations, and are often accompanied by several females, the proportion of the sexes in this particular species being about one male to three females. As wetas come abroad only at night, it is difficult to obtain much precise information regarding their habits; but I think there can be little doubt that a very keen rivalry must exist between the males, and the great head and formidable jaws have been acquired as the result of this rivalry, the most ferocious, powerful, and well-equipped males having alone succeeded in leaving descendants. Apart from theoretical considerations, the preponderance in the number of females, the

reverse proportion to that usually subsisting amongst insects, is strong presumptive evidence that a large proportion of males must perish, and the only conceivable means by which this unusual disparity in the numbers of the sexes could be brought about is through the destruction of the weaker individual males during their contests to possess the females.

In the Locustidae, or long-horned grasshoppers, a vein on one of the wing-cases of the male is furnished with minute ridges, and the sound is produced by the insect rubbing this against a raised vein on the other wing-case. *Coedicia olivacea*, a beautiful leaf-like insect occurring in Australia, which to my knowledge has been common round Nelson for thirty-five years, is an excellent example of this family. In the autumn evenings its chirping may often be heard in all directions.

In the true crickets (Gryllidae) both wing-cases bear file-like organs which are rasped together by the insect and thus produce the well-known chirping. Our example of this family is the black Australian cricket (*Gryllus servillei*), which is also very abundant in the Nelson Province, and its stridulation is a most familiar sound on fine summer evenings.

Referring to the diversity of these special sound-producing organs in the males of the Orthoptera (crickets and grasshoppers) and the Hemiptera-Homoptera

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(cicadas), Darwin remarks that "throughout the animal kingdom we often find the same object gained by the most diversified means; this seems due to the whole organization having undergone multifarious changes in the course of ages, and as part after part varied different variations were taken advantage of for the same general purpose. The diversity of means for producing sound in the three families of Orthoptera and in the Homoptera impresses the mind with the high importance of these structures to the males, for the sake of calling or alluring the females. We need feel no surprise at the amount of modification which the Orthoptera have undergone in this respect, as we now know, from Dr. Scudder's remarkable discovery, that there has been more than ample time. This naturalist

has lately found a fossil insect in the Devonian formation of New Brunswick, which is furnished with ‘the well-known tympanum or stridulating-apparatus of the male Locustidae.’ The insect, though in most respects related to the Neuroptera, appears, as is so often the case with very ancient forms, to connect the two related Orders of the Neuroptera and Orthoptera.”^{*}

The males of the walking-stick insects, or Phasmidae, are extremely attenuated creatures, whilst the females are much stouter and larger, and exhibit such great structural differences that, in the absence of exact knowledge to the contrary, they might easily be referred to a different species, or even genus. In both sexes the appearance of the insect is most perfectly adapted for concealment amongst vegetation, and the extraordinary disparity between the sexes in this case is very difficult to explain.

3. Order Neuroptera.

In the order Neuroptera, which includes the termites, stone-flies, mayflies, dragon-flies, caddis-flies, &c., there is little direct evidence of the operation of sexual selection. In one of our largest may-flies, *Ichthybotus hudsoni*, the male has two caudal setae which are very much longer than the three possessed by the female. It is difficult to say, however, which sex is the more ornamented. Of much greater interest for the purposes of this paper are the nuptial dances in which the may-flies engage, and which must often arrest the attention of those who are not entomologists. This flight takes place shortly before sunset, and during its performance the may-flies rise and fall in the air almost in perpendicular lines, and it is at this time that pairing takes place. Of these remarkable dances Dr. Sharp remarks that to the may-flies themselves the movements may, by the number of the separate eyes, by their curved surfaces, and by the innumerable facets composing them, be multiplied and correlated in a manner of which our own sense of sight allows us to form no conception. We can see on a summer's evening how beautifully and gracefully a crowd of may-flies dance, and we may well believe that to the marvellous ocular organs of the flies themselves these movements form a veritable ballet-dance.

Amongst our small slender-bodied dragon-flies (Agrionina), often known as “demoiselles,” the males of *Xanthagrion zealandicum* have crimson bodies, the females being dull bronze; and in *Lestes colensonis* the body of the male is marked with much more vivid blue than that of the female. In the tribe Cordulina it is noteworthy that the male of *Somatochlora smithii* has a brilliant metallic-green head, legs, and thorax, the same parts in the female being much duller.

[Footnote] * *Descent of Man*, 2nd ed., pp. 288–89, 1890.

4. Order Diptera.

In the great order Diptera, which includes all the two-winged flies, there is usually very little difference in colour between the sexes, and the only striking differences noticeable, so far as our New Zealand species are concerned, occur amongst the Tipulidae, or "daddy-long-legs," in which the males of some of the species either have very long antennae, or antennae furnished with long plumes or branches. The supposed use of these elaborate antennae to the male will be explained when we consider the secondary sexual characters of the Lepidoptera. The male of one of our handsomest Tipulidae, *Cerozodia plumosa*, has magnificently branched antennae. The female is at present unknown, and is possibly semiapterous. This at least would explain why collectors have not yet succeeded in finding her.

5. Order Lepidoptera.

Notwithstanding the fact that ornamental colouring is more in evidence in the great order Lepidoptera, comprising the varied tribes of the butterflies and moths, than in any other order of insects, instances of the direct operation of sexual selection are perhaps not quite so numerous or so striking as might have been anticipated. It is true that in the case of many species, especially amongst tropical butterflies, the males are more brilliantly and beautifully coloured than the females; yet, on the other hand, there are many thousands of species where both sexes are equally ornamental. In such cases Darwin assumes that the highly ornamental colours and patterns were first acquired by the males through sexual selection and afterwards equally inherited by both sexes. He points out that in considering the effects of sexual selection in the Lepidoptera it must be borne in mind that the courtship of butterflies is a prolonged affair. The males sometimes fight together in rivalry; and many may be seen pursuing or crowding round the same female. Unless, then, the females prefer one male to another, pairing must be left to mere chance, and this does not appear probable. If, on the other hand, the females habitually, or even occasionally, prefer the more beautiful males, the colours of the latter will have been rendered brighter by degrees, and will have been transmitted to both sexes or to one sex, according to the law of inheritance which has prevailed. The process of sexual selection will have been much facilitated if the conclusion can be trusted, arrived at from various kinds of

evidence, that the males of many Lepidoptera, at least in the imago state, greatly exceed the females in number.^{*}

So far as New Zealand is concerned, there is not a great number of Lepidoptera where the males are more strikingly ornamental than the females. The tropical-looking *Hypolimnas bolina*, a wide-ranging species, found through the Pacific islands and Australia, and casually in New Zealand, has the male blue-black, with a large white blotch in the middle of each wing surrounded by a wide ring of iridescent blue. The female is rather variable, black, with white and orange-brown markings; and, although highly ornamental, almost entirely lacks the brilliant glistening blue which is so characteristic of the male.

The females of our common tussock-butterfly, *Argyrophenga antipodum*, are usually much lighter coloured than the males, and the same applies in a more marked degree to the female of our small mountain-butterfly

[Footnote] * *Descent of Man*, 2nd ed., p. 317, 1890.

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Erebia butleri. In this respect these Satyrid butterflies show a striking resemblance to many of their European relatives which have the females lighter coloured than the males, but it is perhaps questionable whether they can be called more brilliant.

A much more striking instance of the direct operation of sexual selection is afforded by our very interesting endemic little butterfly *Chrysophanus boldenarum*. In this species the male is of a most resplendent metallic purple, the female being dull yellowish-brown with a row of blue spots around the margin of each wing. This butterfly frequents stony places in river-beds, where the males may constantly be observed displaying their brilliant colours to the rather dingy-looking females, which generally appear to regard their attentions in an unconcerned manner. Again, the male of our small blue butterfly *Lycaena labradus* is, in common with the males of most members of the genus throughout

the world, a glistening blue, whilst the female is drab-grey.

Probably of greater interest than colour and wing-markings are the special scent-producing organs which exist in certain male butterflies and other Lepidoptera for the purpose of attracting the female, and of which no trace can be found in that sex. Attention was first directed to these organs by Fritz Müller in 1877, who at the same time emphasized their significance in connection with Darwin's theories, which were then steadily gaining ground in the scientific world.^{*}

We have in New Zealand several good examples of special scent-producing organs in male Lepidoptera. In the male of that strong-flying, very wide-ranging butterfly *Danaida plexippus* there is a pocket-like structure situated on the hindwing, close to vein 2, which is absent in the female, and is undoubtedly a scent producing organ. Amongst moths the male of our beautiful moss-green Noctuid *Erana graminosa* has a large fold in the costal edge of the forewings which conceals an extensible tuft of long pink hairs. These hairs when stirred with a pin emit a most agreeable vanilla-like perfume. A similar structure exists in the male of *Rhapsa scotosialis*. The remarkable lobe in the much-contracted hindwing of the males of our curious genus *Tatosoma* is a pocket-like organ, which in the absence of any evidence to the contrary must also be regarded as scent-producing. The male of *Declana leptomera* has large tufts of hair on the tibiae of the hind-legs, similar tufts being found amongst some of our smaller Lepidoptera, and it is almost certain that these structures are for the purpose of emitting perfumes agreeable to the female.

A very great many observations have been made during recent years by Drs. Dixey and Longstaff on the scent-organs and scents emitted by tropical butterflies; and the use of these special structures by the males, for the purpose of attracting the females, has been placed practically beyond a doubt. At the same time it must not be forgotten that certain species of butterflies emit odours of a disagreeable nature which serve to protect them from the attacks of birds and other enemies; but in these instances the scent-producing power is not confined to the male sex.

In regard to our moths, a fair number exhibit considerable differences in the colouring and markings of the sexes, but except in the case of one or two day-flying species the males are not more brilliant or more beautiful than the females. The sexes of *Xanthorhoe semifissata* and

[Footnote] * For translation of Fritz Müller's papers on this subject see appendix to Dr. Longstaff's work, *Butterfly-hunting in many Lands*.

X. orophyla are almost identical in colour, but have very different markings. *Selidosema fenerata* differs strikingly in both wing-outline and colour, the forewings of the male being pale yellowish-brown, those of the female pale grey. The sexes of our beautiful forest-dwelling moths *Azelina gallaria* and *A. ophiopa* differ in size, colour, and wing-outline. *Declana glacialis*, a brilliant day-flying mountain species, which almost certainly mimics the distasteful species belonging to the genus *Metacrias*, has the male much more brilliantly coloured than the female, and this is almost certainly due to the operation of sexual selection.

In the family Tortricidae remarkable sexual disparities exist in certain species belonging to the genus *Harmologa*, which are found high up on our southern mountains, and fly rapidly in the hottest sunshine. Of these probably the largest and handsomest species is *Harmologa trisulca*, recently discovered at Arthur's Pass. The male is a very rich reddish-brown with a vivid orange-yellow longitudinal stripe on the forewings, the hindwings being dark greyish-brown. In the female the forewings are dull ochreous and the hindwings pale straw-colour. The other mountain species of the genus exhibit a similar class of colouring, but in the lowland species, which fly at dusk or by night, the difference between the sexes is unimportant, and the males are not more brilliantly coloured than the females.

Our largest native lepidopteron, the well-known *Hepialus virescens*, exhibits most striking sexual differences in wing-outline, colouring, and markings. All these characters are, in the female, more concordant with the usual type of the genus than in the male, and it is a fair inference that the peculiarities of the male have been more recently acquired. The general colouring of both sexes of *Hepialus virescens* is equally protective when the insect is resting amongst foliage; but probably that of the male is more beautiful, and certainly brighter, than that of the female, and hence may have arisen through sexual selection. In connection with our insect, it may perhaps be of interest to mention that in its close British ally the Ghost-moth (*Hepialus humuli*) all the wings of the male are snow-white, the forewings of the female being dull-yellowish and the hindwings grey. Of this species Mr. Richard South tells us that the males may be seen in the evening, sometimes in numbers, in grassy places, swaying themselves to and fro without

making progress, and appearing as though they dangled from the end of an invisible thread; the female flies straight, and, as a rule, in the direction of one or other of the pendulous males.^{*} In this case it would appear that the unusual disparity in colour between the sexes has been beneficial to the species in enabling the female to discover the male, a reverse arrangement to that usually subsisting. In the Shetland Islands the white male of the Ghost-moth is usually replaced by a variety (*thulensis*) in which the male is coloured very similarly to the female, and this is explained by the fact that in that northern latitude the summer nights are never dark, and the conspicuous white colouring of the male is not necessary.

In many species of moths, especially those having females of obscure or retiring habits, the antennae of the males are heavily branched on each side, or, as it is technically termed, bipectinated, those of the female being slightly branched or simple. In these species the males have the power of discovering a female even when situated at a considerable distance. Collectors habitually turn this fact to good account, for if they happen to

[Footnote] * R. South, The Moths of the British Islands, ser. 3, p. 361.

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breed a female they can, by enclosing the same in a gauze-covered box and placing it at an open window, attract quite a large number of males. Experiments have been made to ascertain the means by which the males are enabled to find the female when situated at such remote distances, and the mode of tracking by scent does not afford a satisfactory explanation. In fact, there appears to be little doubt that the mysterious faculty is located in the heavily branched antennae and that some sort of communication is set up of the nature of wireless telegraphy.

6. Order Hymenoptera.

In this important order, which includes the ants, bees, wasps, ichneumon flies,

and their allies, the principal differences between the sexes relate to special structures, such as the pollen-bearing apparatus of the hive-bee, useful to the female in tending the young. They do not, therefore, concern us in connection with the subject of this paper. A few of the Hymenoptera are brilliantly coloured in both sexes, and in those instances where warning colours are not indicated this may be due to the effects of sexual selection.

7. Order Coleoptera.

The order Coleoptera, comprising the beetles, is the highest order of insects, and also contains the greatest number of species, of which about 150,000 are known to science. Commencing with that division known as the Lamellicorns, on account of the structure of their antennae, we find that a striking disparity between the sexes exists in our native stag-beetles. The males of the genus *Lissotes* have a large head and jaws and a very large prothorax, these salient features being strikingly absent in the females. Amongst allied genera in the tropics the most bizarre forms exist, many of the males having huge horny processes on the crown of the head and on the back of the prothorax; and unless these extraordinary structures are useful in making an impression on the female sex it seems impossible to assign any reason for their presence in the male sex alone.

The male of our interesting, though dull-coloured beetle, *Rhipistena lugubris*, has the joints of the antennae furnished with long lateral processes, the whole organ forming a conspicuous fan. This remarkable structure is also present in the female, but in a very reduced form. In the male of our most beautiful Longicorn beetle, *Coptomma variegata*, the antennae are nearly twice as long as in the female, and in a variable degree this disparity prevails amongst the numerous Longicorns we have in New Zealand. The male in the curious genus *Exilis*, a genus belonging to the Anthribidae, a family of weevils, also possesses enormously long antennae, those of the female being often less than half the length. The male of *Psepholax coronatus*, a short stumpy-looking weevil, has a conspicuous coronet of spines on the back of each of its elytra. This structure is entirely absent in the female and in all the other members of that extensive genus of weevils. Very striking sexual differences are also present in *Paranomocerus spiculus*, the male of this fine weevil being fully twice the size of the female, and furnished with a long rostrum and very long elbowed antennae.

All the sexual disparities amongst our native beetles are, however, completely overshadowed by those present in the huge Brenthid *Lasiorhynchus barbicornis*, undoubtedly one of the most striking and interesting insects we have in New Zealand. The male, which is usually about twice the length of the female, has an enormous rostrum, with the antennae

arising from its extremity. The rostrum of the female is of a totally different structure, with the antennae arising from its middle. Many years ago Dr. Sharp, one of our greatest authorities on the Coleoptera, was so impressed by the extraordinary sexual disparities exhibited by this beetle that he wrote to the late Mr. Helms, at Greymouth, requesting him to endeavour to find out something about the insect's habits. Mr. Helms, who was then one of our keenest entomologists, replied that the female *Lasiorhynchus barbicornis* is indefatigable in her boring efforts, but that the huge male stands by as a witness, apparently of the most apathetic kind. I am not aware that later observers have elicited any further information on this interesting subject.

In addition to the above special examples it should perhaps be added that some beetles are brilliantly coloured and have beautiful markings, and nearly all are ornamented with elaborate sculpture. From a strictly utilitarian standpoint it is difficult to see how such endowments are of any direct benefit to the possessor in the ordinary struggle for existence; but if the principle of sexual selection be admitted the presence of such elaborate adornments is quite intelligible.

This completes the examples specially selected for the purpose of this paper. It should perhaps be explained that other instances of the operation of sexual selection could have been found, even amongst our native insects, but it has not been deemed desirable to extend the paper to an undue length. To those who have studied Part II in Darwin's *Descent of Man* it will be unnecessary to state that even more convincing examples can be found amongst other classes of animals (notably birds), and also in other lands. It may be safely said that sexual selection has been a most powerful factor in organic evolution, operating in countless instances wherever its progress has not been stopped by the more rigorous principle of natural selection. Darwin clearly demonstrated that sexual selection has taken a very prominent part in the evolution of man, and there is no reason why its effects should not continue in the future. That a principle of such profound importance should receive so little practical attention is indeed surprising. We constantly hear of the paramount importance of education, and latterly we have heard a great deal about the benefits of discipline and of physical training. Every naturalist knows, however, that the effects of the most vigorous and successful training are not inherited by the offspring of those who are

trained: each generation has to start to learn afresh. Not so, however, in the case of selection, the effect of which is permanent. It is a fact of the highest certainty that individuals possessing certain special attributes, if selected for breeding purposes, will transmit those attributes to their offspring. Hence we can see why the effects of sexual selection are so manifold throughout the whole animal kingdom.

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Art. XXXVII.—*The Leaf-mining Insects of New Zealand.*

By Morris N. Watt, F.E.S.

[Read before the Wanganui Philosophical Society, 3rd December, 1919; received by Editor 31st December, 1919; issued separately, 16th July, 1920.]

Plate XXX. Introduction.

Perhaps no other class of insects is so fascinating to study as the leafminers. Inconspicuous and retiring in their habits, these tiny atoms easily escape notice; this and their microscopic size have kept these insects among the least known in any country. But actually their study is comparatively easy. Their life-cycle is so short, especially the active or larval part of it, that there is little worry about procuring fresh food. Infected leaves can be kept fresh sufficiently long if placed in a damp atmosphere and the air not allowed to stagnate. I have found glass Petrie dishes invaluable for this purpose; a piece of damp blotting-paper in the bottom of the dish keeps the interior sufficiently moist, and if the lids be lifted fairly frequently, so as to change the air, a plentiful crop of moulds is prevented. Leaves can be kept sufficiently fresh in this way for several weeks—quite long enough to allow the larvae to pupate. In other cases branchlets bearing the infected leaves may be kept in water in vases; and where the larval stage is long, or the observer wishes to watch the insects under natural conditions, the entire food-plant, if not too large, may be carefully transplanted. Occasionally it has been

necessary to transfer a larva from a withered leaf to a fresh one, a small artificial gallery being first constructed under the cuticle of the fresh leaf and the larva coaxed into it. In the case of one minute weevil-larva eight such transfers had to be made during the three months of larval life. Some larvae do not confine themselves to one leaf, and destroy several or many in their lifetime. The members of another class of larvae are pseudo-miners; they act the part of miners for a part only of their larval existence. It is not sufficient to observe these insects in a state of captivity; it is essential to observe them in the field Rearing them is the only way in which the collector can obtain perfect specimens (otherwise un procurable) in plenty for his collection. There are no slack months in the year for the investigator of leaf-mining insects; they are almost as plentiful in winter as in spring, and undoubtedly winter is the time to look for new species.

Of the seventy species that I have at present under observation the great majority are either new or only recently described. There are indications that New Zealand possesses a large number of leaf-mining insects. I have never yet failed to come home from an expedition with several species new to me. It has therefore become necessary to divide the paper into a number of parts; and for the sake of order and completeness each part will deal separately with a single genus or group in so far as they are known. Odd species will be published in separate parts The parts at present in hand are: The genus *Bedellia*; the Nepticulids; several species belonging to the genus *Glypteryx*; the Elachistidae; the genus *Gelecia* (all belonging to the Lepidoptera); new species of the genus *Phytomyza* (leaf-mining Diptera); the leaf-mining weevils. There is also in preparation a monograph on the New Zealand gall-producing insects.

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Part I.—The Genus *Parectopa* (Lepidoptera).

This part comprises the life-histories of—(1) *Parectopa citharoda* Meyr., (2) *P. zorionella* Hudson, (3) *P. panacitoresens* n. sp., (4) *P. panaci-vermiforma* n. sp., (5) *P. panacicorticis* n. sp., (6) *P. panacifinens* n. sp., (7) *P. aellomacha* Meyr., (8) *P. panacivagans* n. sp.

Of the remainder of the genus, *P. aethalota* Meyr. (*Trans. N.Z. Inst.*, vol. 21, 1889, p. 185), *P. leucocyma* Meyr. (*Trans. N.Z. Inst.*, vol. 21, 1889, p. 184), and *P. miniella* Feld. (see *Trans. N.Z. Inst.*, vol. 21, 1889, p. 185) have not yet been observed. These complete the genus in New Zealand as at present known.

Those studied are all miners of the long-gallery type, and all except *P. citharoda* make their cocoon and pupate in the terminal part of the mine. *P. citharoda* offers other interesting details distinct from the rest of the genus. At present the only ova found and described belong to *P. citharoda*. Owing to lack of time and material I have had to omit the descriptions of the larvae of this genus, but a complete account will be given later in a supplementary part, which it is hoped will also include the species not given in the present paper. From what little I have seen of the larvae, there will be some extremely interesting points to bring to light. In my early paper on *P. citharoda* I gave a short sketch of the setal plan, but in light of more recent work this needs revision, and Fracker's nomenclature ("The Classification of Lepidopterous Larvae." *Illinois Biological Monographs*, vol. 2, No. 1, 1915) should be adopted. The head-capsule and head-setae need investigation.

The Chief Characteristics of the Parectopa Pupa.

In shape long and slender, more or less bluntly rounded at the head (except for the pointed cephalic plate), and gradually attenuated towards the other extremity. Length averaging from 5 mm. to 8 mm. Attached to the front in its uppermost part is a heavily chitinized cutting-plate (the cephalic plate) directed upwards and forwards; on either side of this, and about midway between it and the base of the antenna, is usually a short stout incurved cornu; while in front of the cephalic plate is a pair of prominent tubercles bearing each a long slender seta. The antennae cover a portion of the outer lateral part of the pigmented eye, and extend usually the whole length of the body; they are segmented and free in their lower part. Mandibles are present, one on either side of the labrum, but are small. The maxillary palpi are very distinct in *P. citharoda*, adjoining the margin of the antennae externally and occupying the lower border of the eye, between it and the first legs and maxillae; in the other species, however, they are obscure and doubtful. The labial palpi are long and slender, and about one-sixth of the body-length. The maxillae are long and slender, and usually reach to about midway between the ends of the first and second legs; usually a portion of the lateral margin of the upper fifth of the maxilla is encroached upon by the femur of the first leg. The third legs appear from below the second, and extend generally as far as the seventh abdominal segment. Forewings long and narrow, with pointed incurved extremities, and occupying about one-half the body-length. The ventral appendages, with the exception of the wing-tips, third legs, and antennae at their caudal extremities, are not free. The prothorax is much narrower in the mid-dorsal region than laterally. Mesothorax is the longest segment of the body, and is extended caudally. Metathorax about as long as the abdominal segments, and the wings occupy a narrow strip

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Fig.1.—*Parectopa citharoda*

Fig. 2.—*P. zorionella*.

Fig. 3.—*P. panacitorsens*.

Fig. 4.—*P. panacivermiforma*

Fig. 5.—*P. panacicorticis*.

Fig. 6.—*P. panacifinens*

Fig. 7.—*P. panacitorsens* (North Island variety)

Fig. 8.—*P. aellomacha*

Fig. 9.—*P. panacivermiforma* (South Island form)

Fig. 10.—*P. panacivagans*.

(All magnified about 5 diameters.)

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as far as the second segment. Abdominal segments of about equal length, except for the terminal three; dorsum thickly covered with very fine spines movement can take place between 4–5, 5–6, 6–7; spiracles small, circular, slightly elevated, covered by the wings in the first abdominal segment, obsolete in the eighth, absent in the ninth and tenth. Cremaster absent, the terminal segment being bluntly rounded or produced into two finger-like processes, each bearing a minute apical hook. Setae present, slender; a dorsal pair on meso- and meta-thorax and abdominal segments except the last; a dorso-lateral pair and a lateral pair on most of the abdominal segments, details of which are given under the different species.

The pupa is extruded from the cocoon as far as about the first legs, and always with its dorsal surface next the surface of the leaf on or in which the cocoon is constructed. The appendages are therefore outermost. As soon as the imago has become freed it retreats to the underside of the leaf, where it shelters quietly while the wings expand and dry.

Meyrick ("Revision of the New Zealand Tineina," *Trans. N.Z. Inst.*, vol. 47, 1915 p. 227) gives the chief characteristics of the Gracilariidae as: "Head with appressed scales. Antennae 1 or over 1. Labial palpi slender, ascending, tolerably pointed. Maxillary palpi moderate, filiform, porrected. Forewings with 7 and 8 stalked or separate. Hindwings lanceolate or linear," And he then divides the three genera as follows:—

Middle tibiae not thickened:—

- (a.) Posterior tibiae with bristly projecting scales above: *Acrocercops*.
- (b.) Posterior tibiae without bristly scales: *Parectopa*.

Middle tibiae thickened with dense scales; posterior tibiae without bristly scales: *Gracilaria*.

Hence the absence of the thickening of scales on the middle and posterior tibiae is the distinguishing characteristic of *Parectopa*.

(1.) **Parectopa citharoda Meyr. (The Wattle *Parectopa*). (Plate XXX, fig. 1.)**

Parectopa citharoda Meyr., *Trans. N.Z. Inst.*, vol. 48, 1916, p. 418; Watt, *loc. cit.*, pp. 407–13.

For the sake of completeness I recapitulate below the chief points from my earlier paper on this species, together with a little new material that I have noted since publishing the paper referred to.

Meyrick's Original Description.

“ . 10 mm. Head probably white (injured). Palpi white. Thorax white, patagia dark fuscous. Abdomen dark grey, sides obliquely striped with white, ventral surface white. Forewings very narrow, moderately pointed; dark bronzy-fuscous, towards apex lighter and more bronzy; five slender white blackish-edged streaks from costa, first three very oblique, first from $\frac{1}{4}$, reaching half across wing, second from middle, reaching more than half across wing, its apex closely followed by a short fine dash, third shorter, fourth fine, direct, reaching termen, dilated on costa, fifth just before apex, fine, inwardly oblique, cutting through a small round blackish spot; a white dorsal streak from base to middle, terminated by an oblique projecting streak reaching nearly half across wing; a white triangular spot on dorsum beneath apex of second costal streak; a short outwardly-oblique white streak from tornus: cilia greyish, with white bars on costal markings, and dark-fuscous median and apical lines above apex separated with whitish. Hindwings dark slaty-grey: cilia fuscous.”

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In all perfect specimens the head is white.

This pretty little moth may be found basking in the sun on the leaves of its food-plant, or flying about the shrub. Few were seen to fly far from the bush even when beaten out. It is not very shy, and can be knocked straight into the killing-bottle

without using the net. Its attitude of rest is peculiar, the body being held at an acute angle to the surface of the leaf, with the head lowermost, almost touching the leaf; the hind legs are kept close to the body, and elevate the hinder part in the air, while the first and second legs are held almost at right angles to the body, close together, and slightly forwards. The *Panax* moths rest with the head end elevated. There are several broods during the summer, larvae being found at any time between the months from July to March. Most possibly the larva hibernates in the cocoon.

Distribution.

Wanganui. During the last few years this moth has become very plentiful wherever its food-plants happen to be growing. In December of 1919 the young leaves of the wattles in the Virginia Lake Reserve were badly infected. I also came across new and old mines in the Botanical Gardens in Wellington in September.

Food-plants.

The Australian broad- and narrow-leaved wattles (*Acacia pycnantha*, *Acacia saligna*). Indigenous food-plants still unknown. It would seem as though this moth had been introduced from Australia.

Egg-laying.

The eggs are laid on either side of the young tender leaves in no specially favoured part. They are also to be found on the young stems and seed-pods. The egg is flat, water-like, slightly rounded above, with a narrow irregular margin or rim round the circumference. Average dimensions 0.65 mm. by 0.45 mm. No marked sculpture except very minute white elevations arranged in a somewhat hexagonal pattern. Shiny; colour a pale transparent white; strongly cemented to the leaf; period of incubation about fourteen days.

The Mine.

The mine may be on either side of the leaf; is a long, narrow, slightly expanding gallery, more or less tortuous in direction, and generally up and down the long axis of the leaf. Total length from 7 in. to 8 in. Colour of early part of mine white, with a thin brown or black central line of frass;



Fig. 1.—Mine of *P. citharoda* in *Acacia saligna*. (Natural size.)

later a somewhat lighter green than the rest of the leaf-surface; this portion of the mine loosely packed with fine frass granules. The cuticle over old mines rapidly

dies and becomes brown. Badly infected leaves wither and fall from the tree. The final inch or so of the mine is often expanded into a somewhat irregular, narrow, elongated blotch.

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The Larva.

In the first stadium the minute larva is light green in colour, head light brown; it bears no setae. These do not appear till the third and last stadium, in which the general colour is light greenish-yellow with a faint white spiracular line. Length 6–7 mm.; spiracles minute, circular; prolegs on segments 3, 4, and 5, each armed with a single short transverse bar of about seven hooklets. Body covered with minute hairs. Revised details of the chaetotaxy will be given in a future paper, together with details of the head-sclerites, &c., when a comparison of all the *Parectopa* larvae will be given. Number of larval stadiums three, the first and second about ten days each, the third about twenty days. When full-grown the larva leaves the mine and descends to the vegetation round the foot of the tree, amongst the dry fallen leaves of which it constructs its cocoon.

The Cocoon.

This is an extremely pretty little structure of white silk; usually constructed in some concavity; its upper and outer surface slightly rounded, and covered with minute white fleecy globules, the majority of which may be removed by blowing upon them. These globules are excreted by the larva during the construction of the cocoon, and are ejected from the interior through rents torn in the covering of the cocoon by the larva itself, eighty to a hundred or more being so ejected. The construction of the cocoon occupies about two days.

The Pupa.

Colour white, to light yellow, to black with obscure white markings (see description of a typical *Parectopa* pupa above). The following are the chief

characteristics: Head bluntly rounded; cephalic plate small, having a comparatively broad, transverse, semicircular, serrated cutting-edge; the plate is quadrilateral, being continued dorsally, and is depressed just behind the cutting-edge; the antennae extend some distance past the terminal abdominal segments; clypeus somewhat prominent, and bears a small tubercle and seta on either side just above the labrum; no lateral cornua or frontal tubercles; maxillary palpi quite distinct, fairly broad, sculptured with fine transverse rugae; labrum and mandibles a little distance above the lower margin of the eyes; maxillae narrow in their entire length, and about one-fifth of the body-length; first legs extend beyond the termination of the maxillae and meet in the mid-line, about one-quarter the body-length, their femora occupying a long narrow strip along the outer lateral margin of the maxillae; second and third legs as in type; prothorax quadrilateral, occupying a narrow strip between the antennae, only slightly narrower in the mid-dorsal region; setae present but extremely minute, only the dorsal pair being present in the meso- and meta-thorax and first abdominal segment; in segments 2 to 6 inclusive the same three pairs of setae as in type; in segment 7 the dorsal pair only, and no setae were discovered in segments 8, 9, and 10; no cremaster, terminal segment bluntly rounded and bare; movement takes place between 4-5, 5-6, 6-7, but the pupa is not active; no sign of any lateral flanges on the abdominal segments; average length of pupa 4-5 mm. A table of the chief measurements was given in the earlier paper, which the above notes are not intended to replace. Duration of the pupal stage, eleven days to a month or longer, according to climatic conditions.

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Dehiscence.

The front, with its cephalic plate, clypeus, labrum, eyes labial palpi, and maxillae, becomes separated in one piece, but remains attached at the lower extremity of the maxillae by loose slips. There is a slight splitting along the dorsal margin of the antennae, but no violent rupture takes place, and the antennae and first and second legs retain their connection and position in one piece on either side. The vertex remains attached to the prothorax, but is cleft down its vertical suture; this

cleft, continuing and dividing the prothorax, extends about half-way down the mid-dorsal region of the mesothorax.

(2.) **Parectopa zorionella Hudson (The *Coprosma Parectapa*). (Plate XXX, fig. 2.)**

Parectopa zorionella Hudson, *Ent. Mo. Mag.*, 3rd ser., vol. 4, p. 62, 1918.

The Imago.

Since Mr. Hudson's description of this little moth is not readily accessible to all entomologists in New Zealand, I take the liberty to reprint it here: "The expansion of the wings is in. The forewings are elongateoblong with the costa strongly arched; very dark brownish black *with very vivid steely-blue reflections; there is a large semicircular silvery-white spot on the costa a little beyond the middle; an oblique silvery-white bar beyond ¾, and two much smaller bars just before the apex; there are three minute silvery spots on the dorsum.* The hindwings are dull steely-grey. The cilia of the forewings are black; of the hindwings dark grey tinged with bronze towards the body."

The adult moth is not by any means common in the field, possibly owing to the widespread destruction of the larvae and pupae by hymenopterous parasites; the great majority of mines that I have examined were so infested. Mr. Hudson says the imago may be found among light scrub in November. I myself have not seen the moth outside my breeding-dishes. As soon as it has emerged from the cocoon it retreats to the shelter of the underside of the leaf, where it rests in its peculiar attitude of head elevated, while its wings spread and dry.

Distribution.

The mines of this moth are common on Mount Egmont to an altitude of nearly 4,000 ft. I have found them there during the last three years, and take the following extracts from my notebook: "10/1/17, only old vacated mines found; 22/4/17, old mines, fresh mines, and larvae plentiful, no pupae; 23/12/17, mines and pupae." Of those obtained 22/4/17 the imagos emerged about the middle of August following. Mr. Hudson records the perfect insect in November in the Botanical Gardens, Wellington, where I have found the mines quite plentiful in February, but chiefly parasited. I was in Wellington again in June and found many mines, but all empty; in September I found no mines; in December a number of pupae were obtained, and from these the imagos emerged about the end of the same month. Pupae obtained on Egmont in the beginning of January all emerged during the month. A few mines have been found in Wanganui, but so far none in the South Island. I am able to note that since the preparation of this paper Mr. George Howes found pupae at Waitomo about the end of March, 1920. It would appear as though there were two, if not three, broods in the year.

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Food-plants.

Coprosma grandifolia (kanono, raurakau), *C. tenuifolia* (karamu), *C. lucida* (karamu), *C. robusta* (karamu), *C. retusa* (taupata).

It was chiefly in the young plants of these shrubs that the mines were found, and within a foot or so of the ground. No doubt other species of *Coprosma* are also attacked.

Egg-laying.

The ovum has not yet been observed. It is laid, however, invariably on the under-surface of the leaf, and as a rule near the midrib, and in the lower (basal) half of the leaf. Laid singly, and rarely more than two on any one leaf.

The Mine.

The larva mines directly into the leaf through the bottom of the egg. The mine is at first a long, slender, slightly tortuous, gradually widening gallery; the first centimetre or so being on the under-surface of the leaf, close against the cuticle, showing up white and silvery by reflected

Fig. 2.—Mine of *P. zorionella* in *Coprosma*. (Two-thirds natural size.) (x—x, point where the mine leaves the under-surface of the leaf and comes close under the upper cuticle.

light. The remainder of the mine, however, is on the upper surface. In the last stage the gallery expands, more or less abruptly, into a large irregular blotch. The gallery at first is about 0.5 mm. in width, its

Fig. 3.—Trace of mine of *P. zorionella* in *Coprosma*. (Two-thirds natural size.) (×—
x, point where mine changed from lower to upper portion of the leaf.)

margins regular; on the upper surface of the leaf, however, the margins become irregular and slightly serrated, the margin of the blotch being very irregular as a rule, but the dentations are comparatively large and rounded. The gallery may attain a length of from 4 in. to 6 in., according to the

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limits of the leaf in which, it is contained; in small leaves it becomes incorporated in and obliterated by the blotch—so much so that no sign of any gallery can be found. It usually follows the midrib or margin of the leaf along its greater extent, sometimes being deflected by the coarser veins; in this manner its course may be slightly tortuous, but rarely markedly so. The midrib forms an impassable barrier except at its upper end. The irregular blotch may cover an expanse of about $1\frac{1}{2}$ square inches. Colour of the mine conspicuously white or light green, sometimes discoloured a bright reddish-brown, but patchy in character. That part of the leaf covering the blotch is, in fleshy leaves, more or less mottled in shades of green according to the closeness of the mine to the outer cuticle. Frass exceedingly scanty, black, finely granular, occupies a thin line near one side of the gallery, sometimes abruptly changing from one side to the other. After the first moult the granules are irregularly scattered over the floor of the mine. Leaves are seldom found containing more than two mines. The blotch is almost invariably bounded on the outside by the margin of the leaf.

The Larva.

The first moult occurs about 6 cm. or 7 cm. from the commencement of the gallery. Structural details of the larva are reserved for a future paper.

The Cocoon.

The cocoon is a delicate structure of white silk within the blotch part of the mine. It is oval in outline, and compressed above and below. Average size 10 mm. by 4 mm. The head end may be slightly broader than the other. It is not conspicuous from the exterior, a very slight puckering of the leaf around its circumference, and a small degree of fullness in that part, alone betraying its presence. On holding the leaf up against the light the pupa may be distinguished by its shadow, and its health determined by the vigour of its movements when so disturbed. There is no evidence on the exterior of any prepared place for exit.

The Pupa.

As seen from the side the pupal outline is rounded at the head (except for the cephalic plate), and more prominent dorsally, There is a slight stricture in the dorsal outline at the prothorax, otherwise the dorsal outline is almost straight. Ventrally there is a fairly deep stricture between the eye and the first leg, occupied by the maxillae. Ventral profile somewhat rounded, the body becoming slightly attenuated towards the caudal extremity. A ventral view of the pupa shows the cephalic plate occupying about one-third of the width of the head between the antennae; the outline from its base to the antenna is almost straight; the greater diameter is opposite the caudal extremity of the labial palpi, the body from here becoming gradually attenuated caudally.

The head: Cephalic plate well developed into a long, slender spear-point, about one and a half times the length of the eye, twice as long as its ventro-dorsal diameter at its base, projected forward at an angle of about 45° to the long axis of the pupa; the pair of frontal tubercles bear long and slender setae, slightly longer than the cephalic plate; no trace of lateral cornua. Eyes large, prominent, only slightly covered by base of antenna. Labrum situated between eyes at about their middle, Mandibles small but encroaching caudally upon the labrum. Labial palpi

about midway between first and second legs.

Fig. 4.—Pupa of *P. zorionella*, ventral view.

Fig. 5.—Lateral view of head.

Fig. 6.—Dorsal view.

cp, cephalic plate; *A*, antenna; *F*, front; *LP*, labial palpi; *Max*, maxillae; *L₁ L₂, L₃*, first, second, and third legs; *W₁*, forewing; *V*, vertex; *E*, eye; *P*, prothorax; *mp*, maxillary palp; *M₃*, mesothorax; *Mt*, metathorax; *W₂*, hindwing. (All figures of pupae are carefully drawn to scale, but all are not necessarily to the same scale.)

Maxillary palpi obscure. Antennae segmented, parallel in their lower three-fifths, but separated by the second and third legs, extended whole length of body.

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Thoracic appendages: Legs as described in type; first legs about twice as long as labial palpi; second legs constricted in their middle one-third by the first legs and maxillae; about one-third as long again as the first, and terminate just above tips of forewings; second legs terminate just below the junction of segments 6 and 7, about half-way between the ends of second legs and antennae. Forewings reaching about the middle of the fifth segment, pointed, and slightly incurved. Prothorax constricted mid-dorsally. Mesothorax as in type. Metathorax as in type, wings not extending beyond first segment. Abdominal segments, spiracles, and setae as in type, also the thoracic setae. The first abdominal segment bears only the dorsal pair of setae. All the setae are directed caudally. There is a slight lateral ridge on segments 2–8 inclusive. The dorso-lateral seta is situated just dorsal to the ridge, below the level of the spiracle, is shorter than the lateral seta, which is situated close against the dorsal margin of the wing in segments 2–5, and caudal to the spiracle. On segments 5–8 inclusive there is a second rather more prominent lateral ridge, ventro-lateral and parallel to the other; the lateral seta and spiracle are situated between these two ridges.

The pupa is very active if disturbed, twirling its abdomen in great haste; movement occurring between segments 4–5, 5–6, 6–7. Segment 9 bears only the dorsal pair of setae, while 10 bears no setae at all, but has a short pair of fleshy tubercles ventrally, each armed with a minute hook; there is a pair of minute tubercles dorsally, while caudally the segment is prolonged into two fairly stout finger-like protuberances, each armed with a minute hook at the tip.

Colour of pupa before dehiscence: Head black, eyes dark red, ventral appendages black with white markings, mesothorax black, metathorax and abdominal segments light grey.

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Chief Measurements of Pupa.

Measurement at	Length from Tip of Cephalic Plate.	Transverse Diameter.	Ventro-dorsal Diameter.
	Mm.	Mm.	Mm.
Base of eyes	0.88	0.82	0.71
End of labial palpi	1.65	1.00	0.88
End of first legs	2.59	0.94	0.94
End of maxillae	3.00	0.94	0.94
End of second legs	3.76	0.82	0.88
End of forewings	4.00	0.76	0.82
End of third legs	4.76	0.58	0.59
End of antennae	5.88	0.28	0.29
Extreme length	5.88		

Dehiscence.

The pupa is extruded through the upper cuticle of the leaf as far as the third or fourth abdominal segment. The legs become separated in one piece on either side, but remain attached at their lower extremities by small slips. The front, with cephalic plate, eyes, labial palpi, maxillae, and antennae, remains in one piece, but is not lost. Dorsally there is a rupture across the epicranial suture, thus freeing

the front and its appendages, and down the mid-dorsal arm of this suture, extending through the prothorax and upper two-thirds of the mesothorax.

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**(3.) Parectopa panacitornsens n. sp. (The *Panax* Underside Moth).
(Plate XXX, fig. 3.)**

The Imago.

9 mm. Head and thorax white; antennae grey-whitish; palpi white with indistinct ring of black at apex of second joint, and a distinct subapical ring of black on terminal joint; abdomen grey-whitish; legs white, ringed with black, posterior tibiae white. Forewings light fuscous, markings white, interrupted with ochreous; a narrow dark-ochreous streak along costa at base to , a small indistinct white area at , a slightly larger and more distinct one at , a square white patch at $\frac{1}{2}$, a narrow outwardly-oblique white streak at reaching nearly two-thirds across wing, a small transverse white bar near apex, a broad white streak along dorsum from base to , interrupted at $\frac{1}{4}$ and by an outwardly-oblique wedge-shaped spot of ochreous, that at $\frac{1}{4}$ being very dark; cilia dark grey with two black lines. Hindwings and cilia dark grey.

There is also a North Island variety, which attacks *Nothopanax Sinclairii*. (Plate XXX, fig. 7.)

8 mm. Head light grey-whitish; palpi white with two black rings; antennae grey-whitish. Thorax grey-white with narrow central streak of fuscous dividing caudally into a small V-marking. Abdomen dark grey; legs white with black rings. Forewings golden brown irrorated with black; markings white, tending to be indistinct; cilia light brown with a distinct black line, blackish externally. Hindwings dark grey; cilia dark grey on costa, lighter bronze-grey on dorsum.

Distribution.

Several mines were found at Aberfeldy, in the Wanganui district, in May of 1918, but all were old. Several mines with pupae were obtained in the Bush Reserve, Flagstaff, Dunedin, early in November, 1919, and these emerged during the first week of December.

The North Island variety is a fairly common little moth in season on Mount Egmont at 3,000 ft. Numbers of mines were found in the vicinity of the North Egmont House and Dawson's Falls, and beside the track on the way up the mountain. Pupa were obtained fairly plentifully in December and early January, and these emerged during January and February. First found in December, 1916. No larvae or fresh mines were found during a short trip taken to the mountain in April of 1917.

Food-plant.

Nothopanax arboreum (whauwhaupaku).

The North Island variety was found only in very young plants of *Nothopanax Sinclairii*, generally within a foot or so of the ground.

The Mine.

The egg is laid on the under-surface of the leaf, but otherwise in no more favoured position. The mine is entirely on the under-surface of the leaf; no signs whatever of it on the upper surface. Throughout its whole course it is a simple gallery, and very tortuous in its direction. Commencing with a width of a little under 1 mm., it has a width of 3–4 mm. in its later parts. The chief direction is in the long axis of the leaf, and the outer portions of the leaf are more mined than the centre—in fact, nearly three-quarters of the entire margin of the leaf forms the external margin of the

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mine. The gallery twists and turns, and in its course follows so close against the

earlier portions that the partition between them is broken down, and finally the entire mine appears to form a huge blotch occupying about one half the leaf-surface. Though thus closely following its former track, it rarely crosses it except under direct need. The midrib forms a barrier, except in its upper and thinner part, where it is invariably crossed. The final length of the mine may average as much as 26 in. Colour in the early stages white with a fine brown central line occupied by the frass;



Fig. 7.—Mine of *P. panactitorsens* in a leaf of *Nothopanax arboreum*. The dotted line shows the course taken by the larva; the heavily dotted line is the earliest part of the mine. (Two-thirds natural size.)

the remainder of the mine, however, is only a shade paler green than the rest of the leaf, and so is most inconspicuous. The track can be made out by the fine black frass granules strewn in close convex lines across the gallery; these are quite plain on the under-surface of the leaf if looked for, thus demonstrating the extreme thinness of the covering cuticle. There is a narrow portion of the gallery on either side not occupied by frass, so this outer margin is somewhat lighter in colour. The margins of the gallery are regular and even.



Fig. 8.—Part of track of *P. panacitatorsens* on underside of leaf of *Nothopanax Sinclairii*.

Fig. 9.—The same leaf showing part of mine visible on upper surface. (Natural size.)

In the case of *Nothopanax Sinclairii* the whole leaf is so mined that the entire under-cuticle can be lifted off. The mine is not conspicuous, but a trained eye can detect the paler colour of the under-cuticle, its

freedom from attachment to the surface of the leaf, and faint frass lines. The only evidence on the upper surface of the leaf is an unusual crinkled appearance, and sometimes short lengths of the later stages of the mine where the larva has eaten deeper into the substance of the leaf and reached the upper cuticle; the pale-green portion of the mine so exposed is readily noticed. Frass is finely granular, very scanty, and offers no characteristic features. Very rarely, and then only in the larger leaves, were two larvae found working in the same leaf.

The Cocoon.

The cocoon is constructed within the terminal part of the gallery, and invariably close against the outer margin of the leaf, and usually on that side opposite the one in which the mine commenced. Shape ovoid, slightly broader at head end, 7 mm. by 3 mm.; its long axis parallel to the leaf-margin. It consists only of a very thin covering of white silk. Its presence is quite conspicuous, due to the infolding and puckering-up of the leaf round about it, and the small area of white transparent cuticle at the head end prepared for the pupal dehiscence. The pupa thrusts the fore part of its body through this window (which is, of course, on the under-surface of the leaf) at dehiscence.

In the North Island variety the cocoon is a small, flattened, oval structure of white silk within the mine, generally found near the base of the leaf. It can best be detected by holding the leaf up against the light, when the pupa may be seen within. Externally its presence may be detected on the upper surface by a slightly elevated portion of the leaf. Size, 6 mm. by 2.5 mm. There appears to be no prepared outlet for the pupa.

The Pupa.

The head as seen from the side is somewhat pointed, but rounded as seen ventrally, with a slight incision at base of antennae. Cephalic plate long and slender, three-bladed, sharply pointed, twice, as long as broad

Fig. 10.—Ventral view of head of pupa of *P. panacitoresens*. Fig. 11.—Lateral view.

at its base, slightly longer than length of eye. Lateral cornua well developed, incurved, in length about three-quarters that of the plate. Frontal tubercles and setae long and slender, situated just caudally to the base of the cephalic plate; bottom of labrum about the same level as base of

eyes; maxillary palpi obscure. Head, thoracic, and abdominal appendages as in type. Only a very narrow slip of the first femur is seen between the maxillae and first legs. Antennae slightly longer than body. There is a small dorso-lateral ridge on all abdominal segments. The meso- and meta-thoracic dorsal setae are long and slender, and directed upwards and outwards; only the dorsal setae found on segments 1 and 2; they exist on all the other abdominal segments except the last, and are directed caudally; the dorso-lateral setae in segments 3, 4, and 5 are characteristic, being extremely long and slender, those on segment 3 being the longest and as long as the width of the body at this part; they are all mounted on prominent tubercles at the cephalic end of the lateral ridges, and project upwards and outwards. The dorso-lateral setae on segments 6, 7, and 8 have a similar position, but are small and directed caudally; there is a minute lateral seta ventral to and below the spiracle close against the outer or dorsal margins of the wing, and is found in segments 3–7 inclusive. All other particulars as in type. Tenth abdominal segment bi-digitate.

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Chief Measurements of Pupa.

Measurement at	length from Tip of Cephalic Plate.	Transverse Diameter.	Ventro-dorsal Diameter.
	Mm.	Mm.	Mm.
Base of eyes	0.76	0.76	0.55
End of labial palpi	1.55	0.83	0.79
End of first legs	2.48	0.72	0.79
End of maxillae	3.10	0.62	0.76
End of second legs	3.38	0.55	0.72
End of forewings	3.79	0.45	0.62
End of third legs	4.62	0.24	0.27
End of tenth	5.10		

Dehiscence.

A transverse split along the epicranial suture frees the frontal head piece, with its cephalic plate, antennae, labial palpi, and maxillae, all in one piece, and this is forced forward, but retained in its lower extremity by loose ships; the first and second legs form a separate piece on either side, but are retained more or less in position; a mid-dorsal splitting cleaves the vertex, prothorax, and upper two-thirds of the mesothorax.

(4.) *Parectopa panacivermiforma* n. sp. (The Panax Vermiform Moth). (Plate XXX, figs. 4 and 9.)***The Imago.***

10 mm. Head white; palpi white, with a few black scales on outer side of apex of second joint and a distinct black subapical ring on terminal joint; antennae grey-whitish. Thorax white, with a narrow central line of light fuscous branching caudally into a small V-shaped marking around metathorax; legs white with black rings. Abdomen grey-whitish. Forewings light bronze-brown, suffusely irrorated with black; markings white; base of wing to about $\frac{1}{4}$ white with a fine streak of dark fuscous along costa, and a small outwardly-oblique spot of dark fuscous about the middle; three short outwardly-oblique white markings on costa in middle , the

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outermost being the smallest, the interspaces densely irrorated with black; three rather obscure lines of white in outer ; cilia whitish with distinct band of black internally and a second indistinct one externally; a small triangular spot of white on dorsum at about $\frac{1}{2}$; two rather less distinct white spots at $\frac{3}{4}$. Hindwings dark-

grey; cilia grey on costa, grey with bronzy reflections on dorsum.

Distribution.

Found plentifully on Mount Egmont in the vicinity of North Egmont House and Dawson's Falls (3,000 ft.). Many larvae were found here in April of 1917. The pupae may be obtained about the end of December, and emerge during January and February. Also found at Dunedin, on Flagstaff Hill, chiefly around the margin of the bush. The pupae are to be obtained in November; larvae are plentiful in the early part of the month. The first images emerged on the 16th December.

Food-plant.

***Nothopanax Sinclairii*; *Nothopanax simplex* (haumakoroa), in South Island.**

Egg-laying.

The egg itself has not yet been found, but the following few particulars have been gleaned from observations on young mines. The eggs are laid singly, rarely more than one or two on any one leaf, upon the upper surface, and near but rarely touching the midrib, and generally in the lower part of the leaf towards the stem.

The Mine.

The mine is a very characteristic one. It is a simple gallery throughout, and vermiform in character, the loops being very closely applied to one another, never anastomosing or crossing. As a rule the gallery at first



Figs. 12, 13.—Mines of *P. panacivermiforma* in *Nothopanax Sinclairii*. (Natural size.)

winds backwards and forwards in slightly increasing distances, closely applied to itself, and in a direction more or less parallel to the long axis of the leaf; then with an almost remarkable abruptness it changes its

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direction for one almost at right angles to the earlier one, now crossing the leaf in curved sweeps from edge to midrib, this latter forming a certain obstacle to trespass on the other half of the leaf. The spot where the general change of direction takes place no doubt marks the situation where the larva underwent its first moult. On reaching the upper region of the leaf the mine becomes less vermiform in character and becomes rather tortuous in its direction, crossing the midrib in its upper and thinner part, and continuing down the other half of the leaf in more or less close proximity to the midrib or outer margin. This latter portion of the mine is often deeper in the leaf than the earlier vermiform part, and consequently is more difficult to detect. In this final part the width of the gallery is about 3/32 in. The entire mine is in the upper surface of the leaf, and no trace of it can be seen beneath. Colour of mine a paler green than other portions of the leaf, but even so the mine is not a very conspicuous object at a little distance. The terminal portion of the gallery may be slightly enlarged, and within it the cocoon is constructed, a small area of the upper cuticle of the leaf at the extreme end of the mine being first prepared to a transparent thinness for the exit of the pupa later. The frass is finely granular, pale in colour, not very abundant, and occupies a rather broad band in the central third of the gallery.

The South Island type differs from the above. In the earlier part the mine is a simple vermiform gallery very similar to that of *P. panaxvermiformella* both in size and character; later, however, instead of ending in a somewhat tortuous and widened gallery, it expands into a



Figs. 14, 15.—Mines of *P. panacivermiforma* (South Island) in leaves of *Nothopanax simplex*. (Natural size.)

relatively large blotch, which may occupy the entire leaf in small ones, or all or the greater part of one half of the leaf in larger ones. The entire mine is on the upper surface of the leaf, and is pale green in colour, and not very conspicuous at a distance. The final blotch may occupy about

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1 square inch; it is generally more closely applied to the outer margin of the leaf, where there is plenty of room. The midrib forms a barrier in its basal two-thirds. The blotch is irregular in shape, but all irregularities are rounded. Frass is finely granular, black, scanty. Old mines soon become white and conspicuous.

I have not yet been able to study the larva.

The Cocoon.

This is a small oval structure of thin white silk within the terminal part of the mine. The roof of cuticle protecting it above is slightly thicker than elsewhere in the mine. The position of the cocoon is not a constant one, but is generally alongside the midrib or outer margin of the leaf; sometimes, however, it occupies a position between these, lying more or less at right angles to their general direction. It is most generally found about the middle third of the leaf. Dimensions, 7 mm. by 3 mm. Quite frequently the cocoon causes a slight infolding of the leaf in its immediate vicinity, but this is not so constant as in some of the other *Panax* moths; most generally a small hump on the upper surface of the leaf is all that reveals its existence.

In the South Island form the cocoon is constructed in a small narrow extension of the terminal part of the blotch, close to the upper cuticle of the leaf. It is usually near the outer margin of the leaf, about its middle or in its upper half. The white silken lining is very thin and frail, and causes a slight local puckering of the leaf. The small white window at the end of the cocoon is similar to that of *P. panacifinens* and others. Size, 6 mm. by 2 mm.

The Pupa.

All the essential characteristics are the same as in the other *Panax* moths. The cephalic plate is about as long as wide at its base, and the lateral cornua are short and of about half the length of the plate; the labrum is slightly above the lower

margin of the eyes; mandibles prominent. Prothorax wide laterally against the antenna, but almost obliterated

Fig. 16.—Head of pupa of *P. panacivermiforma*, ventral view.

Fig. 17.—Lateral view.

in the mid-dorsal region. Antennae reach to the eighth abdominal segment. Regarding the setae, these are the same as in *P. panacitorns*; in the tenth segment the dorsal setae are replaced by a pair of short pointed tubercles; segment 8 bears all three pairs of setae; segment 9 bears the dorsal pair only. The two caudal appendages are well developed. The

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pupa is very active if disturbed, twirling its abdomen vigorously; two distinct movements are made, a circular twirling and a side-to-side movement. Movement takes place between segments 4–5, 5–6, 6–7, also very slightly between 2–3, 3–4. Colour at first pure crystal-white, later changing to light yellow. Just prior to emergence the wings and frontal parts become speckled grey, eyes black, upper half of antennae and legs speckled grey, lower half light yellow except for the tips. Headpiece and abdominal segments light yellow, except dorsally, where they are darker in colour.

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Chief Measurements of Pupa.

Measurement at	Length from Tip of Cephalic Plate.	Transverse Diameter.	Ventro-dorsal Diameter.
	Mm.	Mm.	Mm.
Base of eyes	0.23	0.52	0.42
End of labial			

palpi	0.86	0.69	0.65
End of first legs	1.55	0.65	0.62
End of maxillae	1.89	0.62	0.59
End of second legs	2.24	0.52	0.59
End of forewings	2.52	0.45	0.55
End of third legs	3.08	0.31	0.31
End of antennae	3.28	0.24	0.21
Extreme length	3.45		

In the South Island form the antennae are as long as the body. The setal plan is identical with that of *P. panacitoresens*. Colour at first pearly



Fig. 18.—Pupa of *P. panacivermiforma* (South Island form), ventral view.

Fig. 19.—Dorsal view.

white with a faint tinge of green; later the eyes become black, and the appendages mottled grey and white. The abdominal segments 3–6 inclusive become black dorsally, and this pigmentation remains in the cast skin.

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Chief Measurements of Pupa.

Measurement at	Length from Tip of Cephalic Plate.	Transverse Diameter.	Ventro-dorsal Diameter.
	Mm.	Mm.	Mm.
Base of eyes	0.51	0.65	0.48
End of labial palpi	1.21	0.76	0.72
End of first legs	2.06	0.69	0.69
End of maxillae	2.76	0.62	0.69
End of second legs	2.83	0.55	0.65
End of forewings	3.17	0.48	0.62
End of third legs	3.90	0.27	0.27
End of antennae	4.27		
Extreme length	4.30		

Dehiscence.

The pupa pierces the prepared window at the head of the cocoon on the upper surface of the leaf. All details as to splitting are identical with those of *P. panacitoresens*, and so need not be repeated.

(5.) Parectopa panacicorticis n. sp. (The Panax Bark Moth). ([Plate XXX, fig. 5.](#))

The Imago.

. 7–8 mm. Head and thorax dark grey irrorated with white; palpi white with apex of second joint and subapical ring of terminal joint black; antennae grey-blackish, whitish towards apex; abdomen dark grey above, white beneath; legs white with black rings. Forewings dark grey to black, densely irrorated with white; a series of short, outwardly-oblique white marks on costa, three before $\frac{1}{2}$; at $\frac{1}{2}$, , and $\frac{3}{4}$ a larger wedge-shaped spot of white with a smaller one on its outer side; a narrow line of black separates the white apical spot from an indistinct band of white on its inner side; a small conspicuous white triangular area on dorsum at $\frac{1}{2}$, a small white spot at and another at ; cilia white at apex, elsewhere grey. Hindwings and

cilia dark grey.

In male the wing-expanses are shorter, about 6 mm.; the white markings are more conspicuous, those on costa at $\frac{1}{2}$ and especially so; the ventral surface of the abdomen is whitish tinged with grey.

This species approaches *P. aethalota* Meyr. very closely. I have never seen it on the wing, all my specimens being reared from pupae.

Distribution.

It is quite common on Mount Egmont at an altitude of 3,000 ft., and is plentiful in the vicinity of the Mountain House and down the mountain track. I have also found it at Dunedin in the bush behind the Botanical Gardens, and more plentifully in the Bush Reserve on Flagstaff Hill. Several old mines have been found at Aberfeldy, in the Wanganui district. The following dates give some idea as to the time of its appearance, &c.: Egmont 10/1/17, pupae found; 21/4/17, young larva; 23/12/17, many pupae obtained. Dunedin—20/17/19, a few young larvae found (these

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pupated about the middle of November); 2/12/17, many pupae found (these all emerged during January).

This little moth is attacked a great deal by a hymenopterous parasite at present unidentified.

Food-plant.

Nothopanax arboreum (whauwhaupaku).

Egg-laying.

The eggs are laid singly on the bark of the young stems of the food plant. There appears to be no especially favoured position, except that it has been noticed that the region about the expanded bases of the leaves is rarely chosen, some more or less exposed position on the internode being utilized. A description of the ovum must wait until fresh unhatched ova can be obtained. They should be looked for during the months of January and February.

The Mine.

The mine is a simple gallery throughout. At first about 0.5 mm. in width, it increases gradually to about 3 mm. The general direction is along the young stem in the internodes in its long axis. On reaching a node where the large expanded base of the leaf-stalk closely embraces the greater part of the stem the mine follows the obstruction a varying distance, eventually turning down into the next internode or retracing its way back in its old internode, turning again in a similar manner on reaching the other extremity. In this way the internodes become more or less occupied by long galleries, while at the nodes the mine may enlarge and quite envelop the stem. Blind branches are rarely found. The



Fig. 20.—Mine of *P. panacicorticis* in stem of *Nothopanax arboreum*. (Two-thirds natural size.)

mine may at times become somewhat tortuous, and in places more or less expanded owing to several parts intercommunicating. As a general rule but one internode will be occupied by any one mine, though sometimes a mine may extend into two. Where two mines are occupying the rather small area offered by a single internode, their galleries may intermingle indiscriminately without any attempt at mutual avoidance. Such crowding is rarely found. The colour of the mine at first is white, and later white or a very pale brown; it is most conspicuous. The frass is scanty, and in the earlier portions of the mine occupies a narrow central line in the gallery. Details of the larva are reserved for a future monograph.

The Cocoon.

This structure is built in the terminal portion of the mine somewhere in the internode, very rarely against the base of the leaf-stalk. It is constructed of white silk, but is very thin, almost transparent, and is

covered externally by the thin outer cuticle of the stem. It is somewhat cylindrical in shape, with rounded ends; average size about 10 mm. by 2.5 mm. It forms quite a conspicuous little bulge on the side of the stem, its long axis parallel to that of the stem.

The Pupa.

Of the head-parts, the cephalic plate is about twice as long as broad at its base; the lateral cornua are represented by two extremely small tubercles, only slightly elevated; labrum slightly above lower margin of the eyes. All the chief characteristics are the same as in *P. panacitoresens*. Individual characteristics in the *Panax* moths are hard to find. The forewings normally extend to the lower border of the fifth abdominal segment, while the third legs reach to the lower border of the seventh, and the antennae to that of the eighth or ninth. Regarding the setae,



Fig. 21.—Head of pupa of *P. panacicorticis*, ventral view.

Fig. 22.—Lateral view.

these are the same as *P. panacitoresens*, with the exception that the dorso-lateral seta was present in the second segment; all three pairs were found in 8 and 9, and 10 bore a small dorsal pair and a larger dorso-lateral seta at the base of each caudal appendage. The lateral ridges are very rudimentary. The dorso-lateral setae in 2–6 inclusive are directed upwards and outwards, that on segment 3 being the longest, and in length about equal to two-thirds the width of the body at that point. Colour golden brown, darker on dorsum of head and thorax and segments 3–6 inclusive.

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Chief Measurements of Pupa.

Measurement	Length from Tip of	Transverse	Ventro-lateral
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at	Cephalic Plate. Mm.	Diameter. Mm.	Diameter. Mm.
Base of eyes	0.76	0.69	0.51
End of labial palpi	1.41	0.79	0.72
End of first legs	2.24	0.79	0.76
End of maxillae	2.65	0.76	0.72
End of second legs	2.97	0.69	0.72
End of forewings	3.28	0.66	0.63
End of third legs	3.97	0.38	0.48
End of antennae	4.41		
Extreme length	4.89		

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Dehiscence.

Exactly the same as in *P. panacitoresens* and all the other *Panax* Parectopas. There is here no external evidence of any prepared exit from the cocoon, but the pupa always emerges at the uppermost end, and here also with its ventral appendages outermost.

This moth is a favourite prey to parasites, two species having been reared but not yet identified—in fact, quite 90 per cent. of all the *Panax* Parectopas are destroyed by these parasitic Hymenoptera. Usually there is but a single parasite to each post; this parasite constructs its small cylindrical cocoon within that of its host,

and later emerges through a circular outlet gnawed in the upper end of the latter structure.

(6.) **Parectopa panacifinens n. sp. (The *Panax* Marginal and Central Moth). (Plate XXX, fig. 6.)**

The Imago.

, 10 mm.; , 8 mm. Head whitish with a dorsal streak of fuscous; palpi whitish, with apex of second Joint and a well-defined subapical ring on terminal joint black; antennae fuscous. Thorax light fuscous with a fairly broad central line of darker fuscous, and on either side a narrow, rather obscure dorso-lateral line of dark fuscous. Abdomen grey-black; legs whitish ringed with black. Forewings brown irrorated with black; markings white, the black irrorations being somewhat denser on their margins; a narrow slightly wavy streak of white along dorsum from near base to $\frac{3}{4}$, interrupted by a small patch of brown about (this white streak is more pronounced in the male); three distinct short outwardly-oblique white lines from costa at , $\frac{1}{2}$, , the outermost one being the narrowest and longest, the centre one the most conspicuous and almost square; a narrow outwardly-concave transverse bar of white near apex, broadest against the costa; cilia fuscous with a distinct black line. Hindwings and cilia fuscous.

Distribution.

Numerous on Mount Egmont at 3,000 ft. Pupae are to be obtained during November and December, the imagos appearing in January. Also found in the Bush Reserve on Flagstaff Hill, Dunedin, in November, the imagos emerging early in December.

Food-plant.

Nothopanax arboreum (whauwhaupaku).

The Mine.

The egg is laid on the upper surface of the leaf, generally near the midrib. The mine is a simple gallery, white in colour, on the upper surface of the leaf; increases in width very gradually to about 2 mm.; its total length is about 16 in.; its character is very constant, and altogether it is a most conspicuous object. The larva on hatching burrows immediately into the leaf, and heads in in more or less of a straight line till the margin or midrib of the leaf is encountered, after which this obstacle is closely followed. Out of several hundred examined, no cases showed any tendency on the part of the newly hatched larva to mine in a spiral, as in the case of *P. aellomacha*. Its course invariably takes it close around the greater portion or entire margin of the leaf, closely following the digitations and

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any incursions made by other insects, and also along one or both of the sides of the midrib, this forming a barrier only in its basal three-quarters. The gallery then follows a more or less tortuous course within these boundaries; if the leaf be large it will rarely cross earlier parts of its own track, and will wander in a vermiform manner along one half of the leaf, generally that half opposite the one on which the egg was laid; in smaller leaves almost the entire upper surface will be mined in a very complicated manner, but there is never any tendency to blotch formation as in *P. panacitorsens*. Loops may be thrown out from the straight central portion of the gallery against the midrib, but never blind branches; this is characteristic. The way in which the gallery closely follows the margin of the leaf nearly all the way round was very characteristic of the Egmont

Figs. 23, 24, 25.—Typical mines of *P. panacifinens* in leaves of *Nothopanax arboreum*. (Two-thirds natural size.)

mines, but was not so constant in the Dunedin ones. Perhaps the chief characteristic of the mine is the absence of blind branches. Frass is almost negligible, black, very finely granular, and is irregularly distributed. As a rule it is deposited at the margins of the mine, alternately on either side in the early parts, but later is arranged in close curved lines, convex forwards, transversely across the gallery. In the final stages it tends to become somewhat fluid in character.

The Cocoon.

The cocoon is constructed in the slightly expanded terminal part of the mine, somewhat deeper in the leaf than the rest of the gallery. Its position may be alongside the midrib, the outer margin, or one of the coarser veins of the leaf. The small cylindrical structure of white silk pulls in the cuticle of the leaf in its vicinity and causes the leaf here to become slightly elevated, puckered, and infolded, affording it greater protection. A small, thin, almost transparent white window is constructed in the upper surface of the leaf at the end of the cocoon by the larva

just prior to pupation Size, about 8 mm. by 3 mm.

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The Pupa.

The pupa differs hardly at all from the other *Panax* moths. The cephalic plate is rather short, and about as long as wide at its base; the lateral cornua are well developed, and are about equal in length to that of the plate; in some of the Dunedin specimens, however, they were not free, but soldered down to the headpiece around the front of the base of the cephalic plate. There is a strongly marked middorsal ridge on vertex, meso-and meta-thorax, and extending slightly on to the first abdominal segment. The prothorax is narrow. Antennae variable in length, sometimes slightly longer than the body. Setae exactly as in *P. panacivermiforma*.

Fig. 26.—Head of pupa of *P. panacifinens*, ventral view.

Fig. 27.—Lateral view.

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Chief Measurements of Pupa.

Measurement at	Length from Tip of Cephalic Plate	Transverse Diameter	Ventro-dorsal Diameter.
	Mm.	Mm.	Mm.
Base of eyes	0.72	0.79	0.55
End of labial palpi	1.51	0.96	0.90
End of first legs	2.53	0.90	0.86

End of maxillae	2.86	0.86	0.86
End of second legs	3.51	0.72	0.86
End of forewings	3.90	0.69	0.83
End of third legs	4.89	0.48	0.51
End of antennae	5.45		
Extreme length	5.65		

Dehiscence.

Exactly as in P. panacivermiforma.

**(7.) Parectopa aellomacha Meyr. (The *Panax* Branching Moth).
(Plate XXX, fig. 8.)**

Gracilaria aellomacha Meyr., *Trans. N.Z. Inst.*, vol. 21, p. 184, 1889.
Parectopa aellomacha Meyr., *Trans. N.Z. Inst.*, vol. 47, p. 228, 1915.

Meyrick's Original Description.

“ . 7–9 mm. Head and palpi snow-white, palpi with apex of second joint and a subapical ring of terminal joint black. Thorax snow-white, with a small black spot on shoulder. Forewings snow-white; markings fuscous, irrorated with dark fuscous; a cloudy central longitudinal streak from near base to disc above anal angle, more or less obsolete towards base, connecting obscurely with about seven oblique costal and about four

oblique dorsal streaks (these vary somewhat); costal streaks usually alternately slender and thick; a fuscous apical spot: cilia grey, round apex white, with two dark fuscous lines and a black apical hook. Hindwings fuscous-grey, cilia paler."

Distribution.

I have so far found this species only on Mount Egmont, about 3,000–4,000 ft., where it is quite plentiful. Pupae were obtained during December and January, emerging in February. Young larvae were found in April of 1917. Meyrick records it from "Wellington and Christchurch, in September, January, and February; four specimens.

Food-plant.

Nothopanax arboreum (whauwhaupaku).

The Mine.

The mine is a most characteristic one. It is rare to find more than one mine in a leaf. The egg is invariably laid upon the upper surface near the midrib, and generally in the basal portion of the leaf. The larva on hatching at once mines into the leaf through the shell of the egg, and as a general rule takes several spiral turns before mining in any definite direction. This spiral nature of the earliest portion of the mine is characteristic. The mine throughout is a very gradually widening gallery, never becoming blotched, and rarely do portions cross each other except in the smaller leaves. The final width is about 2 mm. Its direction invariably takes it

Figs. 28, 29.—Mines of *P. aellomacha* in leaves of *Nothopanax arboreum*. (Two-thirds natural size.)

along both sides of the midrib, this obstacle being crossed in its upper and thinner part; from these long straight portions a varying number of blind arms or

branches of varying lengths, mostly straight but sometimes slightly curved, sprout out into the leaf. As a rule the greater number will be confined to one half of the leaf. These blind branches sometimes follow the course of the veins of the leaf, but most often do not, generally treating these as no obstacle; they do not often reach as far as the outer margin of the leaf, but may do so, and may follow it a short distance; the result is, however, always the same—a single blind-ended branch, never loops as in the case of *P. panacifinens*; and rarely is any of the margin of the leaf so mined. The branches are all more or less parallel to one another, and rarely cross; they are all more or less equal in width, about 2 mm. The mine is found only in the younger leaves, and is pale green in colour, the tips of the branches often being white, showing where the larva came close against the upper cuticle. No evidence of the mine is to be found on the underside of the leaf, and in its natural state the mine is not a very conspicuous

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object, though so very striking when seen in picked leaves. Old mines become white, but otherwise do not discolour the leaf; they are consequently far more conspicuous objects than the fresh ones. The mine is slightly deeper in the leaf than that of *P. panacifinens*. The total length of the mine may reach to 12 in. or 16 in. Frass is very finely granular; negligible.

The Cocoon.

The cocoon is a somewhat cylindrical structure of thin white silk, with all the characteristics of *P. panacifinens*. It is within the mine in the upper part of the leaf, and is protected by a somewhat thicker covering than the rest of the mine. It is slightly elevated, and as a rule causes a local pinching of the leaf. It is invariably found alongside the midrib in the basal third of the leaf. Size, 7 mm. by 2 mm. Its small white window is quite conspicuous at the head end of the structure; it is fan-shaped, with its broadest part upon the surface of the leaf. Old cocoons soon become discoloured brown.

The Pupa.

The pupa of this moth is practically identical with that of *P. panacifinens*; on the average it may be slightly smaller; its lateral cornua are relatively more developed, and are about one-half the length of the cephalic plate. The arrangement of the setae is the same in both, but in *aellomacha* the dorsal setae are short and fine, the dorso-lateral ones rather stout and long. The following measurements were taken from a typical specimen:—

Chief Measurements of Pupa.

Measurement at	Length from Tip of Cephalic Plate.	Transverse Diameter.	Ventro-dorsal Diameter.
	Mm.	Mm.	Mm.
Base of eyes	0.69	0.76	0.63
End of labial palpi	1.44	0.86	0.79
End of first legs	2.76	0.79	0.76
End of maxillae	3.03	0.69	0.76
End of second legs	3.28	0.63	0.69
End of forewings	3.65	0.51	0.60
End of third legs	4.55	0.38	0.35
End of antennae	5.03		
Extreme length	5.59		

Dehiscence.

This takes place on the upper surface of the leaf, and is identical with that of *P. panacifinens*.

**(8.) *Parectopa panacivagans* n. sp. (The Lancewood *Parectopa*).
(Plate XXX, fig. 10.)**

The Imago.

8 mm. Head white at the sides, black above and against thorax; palpi white with two black rings; antennae black suffused with white below and towards base. Thorax white, black against the head, and caudally a small black V-shaped mark;

legs white with black rings. Abdomen blackish grey. Forewings black, slightly irrorated with white; markings white; from base to $\frac{1}{4}$ white with a small central spot of black; a short narrow outwardly-oblique line of white on costa at , another slightly larger and triangular spot a little beyond $\frac{1}{2}$ reaching half across wing; a short narrow oblique line of white at $\frac{3}{4}$; an indistinct inwardly-curved

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[View Image](#)

transverse line of white near apex; a small white apical spot; a broad outwardly-oblique line of white on dorsum at $\frac{1}{2}$, and a small white spot at $\frac{3}{4}$; cilia grey-black. Hindwings dark grey; cilia grey-black.

Distribution.

This appears to be a rather rare moth. It was found first at Aberfeldy, in the Wanganui district, in 1917. The larvae are to be found in December, the pupae in January, and the imagos emerge in February. Old mines were found in Dunedin in May and July.

Food-plant.

Found mining in the long tough leaves of the young lancewood, *Pseudopanax crassifolium* (horoeka), but more commonly in the young succulent leaves of the mature tree.

Egg-laying.

The egg is laid singly on the upper surface of the leaf, generally close to the midrib.

The Mine.

The mine throughout is a simple gallery, more or less straight in its direction. It is made entirely in the upper surface of the leaf, and there is no trace of it to be seen below. The mine starts in a more or less oblique direction till it reaches the midrib

or margin of the leaf; this it follows till it reaches the end of the leaf, and it then either turns back alongside its former track or continues back along the barrier on the other half of the leaf. It never crosses the midrib except in its upper part. On the margin of the leaf the mine closely follows all the irregularities of outline, and extends into the bases of the serrations of the leaf. Portions of the earlier mine may be enveloped by the later broader



Fig. 30.—Mine of *P. panacivagans* in the lancewood-leaf. (Two-thirds natural size.)

gallery. The average length may be about 10 in.; commencing with a width of 0.5 mm., the terminal part of the gallery measures about 4 mm. across. Colour light green in fresh mines. There is no tendency to branch. Margins of the mine fairly regular and white. Mines are not very conspicuous at a short distance. Frass is almost fluid in nature, and occupies a fairly broad brown band in the centre of the early gallery, but in the wider part is dark green or black, and often forms an unbroken line on one side of the gallery; it is sometimes deposited in short curved transverse lines with the concavity directed forwards. It appears to be deposited chiefly on the upper cuticle of the leaf.

The Larva.

Flattened, moniliform; colour yellowish with broad green dorsal stripe. About 6 mm. in length. A detailed description is kept for a future paper on the *Parectopa* larvae.

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The Cocoon.

The cocoon is constructed within the terminal part of the mine, either close alongside the midrib or on the outer margin of the leaf. It is slightly deeper in the substance of the leaf than the rest of the mine. It is cylindrical in shape and

slightly curved. The scanty silken lining causes a local pinching and puckering of the leaf, and raises the cuticle above the surface of the leaf. It bears a small white almost transparent window at one end, prepared for the pupal emergence. Its position is generally in the basal half of the leaf. Size, 12 mm. by 3 mm.

The Pupa.

Closely resembles the pupa of the *Panax* moths in all particulars. The cephalic plate is moderate in length, but fairly massive; the lateral



Fig. 31.—Pupa of *P. panacivagans*, ventral view.

Fig. 32.—Dorsal view.

Fig. 33.—Lateral view.

cornua are about equal in length to the plate. Prothorax broad against the antennae, but is lost in the mid-dorsal region. Setae exactly as in *P. panacitornsens*; the lateral setae are relatively long.

[The section below cannot be correctly rendered as it contains complex formatting. See the [image of the page](#) for a more accurate rendering.]

Chief Measurements of Pupa.

Measurement at	Length from Tip of Cephalic Plate.	Transverse Diameter.	Ventro-dorsal Diameter.
	Mm.	Mm.	Mm.
Base of eyes	0.53	0.70	0.53
End of labial palpi	1.29	0.82	0.76
End of first legs	2.12	0.76	0.76
End of maxillae	2.65	0.70	0.76
End of second legs	2.82	0.70	0.76
End of forewings	3.18	0.65	0.53
End of third legs	3.88	0.41	0.35
End of antennae	4.65		
Extreme	4.65		

length

Dehiscence.

This takes place on the upper surface of the leaf and is identical in all respects with that of the *Panax* moths.

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