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J. H. ...

# TRANSACTIONS

AND

# PROCEEDINGS

OF THE

# NEW ZEALAND INSTITUTE

FOR THE YEAR 1916

VOL. XLIX

(New Issue)

EDITED AND PUBLISHED UNDER THE AUTHORITY OF THE BOARD OF GOVERNORS OF THE INSTITUTE

**ISSUED 20th DECEMBER, 1917**

Wellington, N.Z.
MARCUS F. MARKS, GOVERNMENT PRINTING OFFICE
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NEW ZEALAND INSTITUTE.

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Benham, W. B., 1915. Oligochaeta from the Kermadec Islands, *Trans. N.Z. Inst.*, vol. 47, pp. 174–85.

Park, J., 1910. *The Geology of New Zealand*, Christchurch, Whitcombe and Tombs.

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# OBITUARY.

## CAPTAIN L. S. JENNINGS.

Captain Lancelot S. Jennings, who was killed in action at the front on the 15th September, 1916, as born at Takaka, Nelson Province, in the year 1888. He was the second son of the Rev. Charles Jennings, sometime incumbent of Takaka Parish, and a grandnephew of the late Sir John Jennings, England. His mother was the second daughter of the late Rev. T. S. Grace, who for many years in the earlier history of New Zealand, before the Maori War, was the Church of England missionary resident at Pukawa, Lake Taupo.

Captain Jennings was educated at Nelson College and Canterbury College. He distinguished himself at both places, taking his B.Sc. degree in 1910, M.Sc. in 1911, B.A. in 1912, and was the Canterbury College candidate for the Rhodes Scholarship in 1912. During that year he acted as Professor of Biology at Canterbury College while Dr. Chilton was absent on leave in Europe. After that he served for some time on the staff of the Wanganui Collegiate School, and at the time of his enlistment he was Science Master at Waitaki High School. He was a keen soldier always, and put in his full time in the Senior Cadets and Territorials. He embarked on the 14th August, 1915, with the Sixth Reinforcements as senior lieutenant in the Otago Infantry Battalion, and after the Gallipoli campaign got his captaincy in Egypt, prior to departure for the western front in France.

He was a first-class cricketer, having represented both Nelson College and Canterbury College, and was one of the most brilliant lawn-tennis players in the country. He was New Zealand University champion from 1908 to 1912 (inclusive), and in the last year he and Miss B. D. M. Cross (now Mrs. Jennings) won all five championships between them.

Before the end of his college course he had joined the Philosophical Institute of Canterbury, of which he continued to be an active member. He took up specially the study of the New Zealand Cirripedia, a group which has been very much neglected, and had already published a paper dealing with the species of the pedunculate Cirripedia, while his revision of the sessile forms was well advanced when he left New Zealand for the front.

## THOMAS KING.

Thomas King was born in Glasgow in 1858, and was brought to Auckland in infancy by his parents. He was educated at the Auckland College and Grammar School, and afterwards by private tutors in Wellington. He joined the staff of Messrs. W. and G. Turnbull and Co., and afterwards entered the service of Messrs. Levin and Co.

Mr. King was on the staff of the Colonial Observatory as transit observer under the directorship of the late Sir James Hector, and from 1887 to 1911 he was responsible for the time service. At the latter date he resigned from the Observatory.

In December, 1903, and January, 1904, as part of the programme carried out by the Dominion Observatory, Ottawa, Canada, under the charge of Dr. Otto Klotz, to determine trans-Pacific longitudes, Mr. King observed at Wellington, in conjunction with Dr. Klotz at Doubtless Bay, to ascertain the difference of longitude between these two places.

Mr. King took great interest in the Wellington Philosophical Society, of which he was President at the time of his death. He was elected as a member of the Council of the Society for 1881–85; Auditor, 1891–1904; Secretary and Treasurer, 1904–9; Vice-President, 1910–14; and President, 1914–16. In 1910 he was elected an honorary life member in recognition of his services to the society.

Mr. King was the author of a valuable paper, "On New Zealand Mean Time, and on the Longitude of the Colonial Observatory, Wellington; with a Note on the Universal Time Question" (*Trans. N.Z. Inst.*, vol. 35, 1903, pp. 428–51). He was elected a Fellow of the Royal Astronomical Society in 1910, and was also a member of the Société Astronomique de France.

He died on Thursday, the 16th March, 1916, at Wellington.

C. E. A.

# CONTENTS.

## I. BOTANY.



## II. ZOOLOGY.

## III. GEOLOGY.



## IV. MISCELLANEOUS.

## PROCEEDINGS.



## APPENDIX.

# LIST OF PLATES.

*(Text figures not included.)*

# TRANSACTIONS.

# TRANSACTIONS

OF THE

# NEW ZEALAND INSTITUTE, 1916.

ART. I.—*Notes from the Canterbury College Mountain Biological Station, Cass.*

## No. 5.—THE MAT-PLANTS, CUSHION-PLANTS, AND ALLIED FORMS OF THE CASS RIVER BED (EASTERN BOTANICAL DISTRICT, NEW ZEALAND).

By C. E. FOWERAKER, M.A., Assistant, Biological Laboratory, Canterbury College.

[*Read before the Philosophical Institute of Canterbury, 4th October, 1916; received by Editors, 30th December, 1916; issued separately, 28th June, 1917.*]

Plates I–VI.

### I. INTRODUCTION.

#### (A.) *General.*

IN the following pages an account is given of certain mat- or cushion-plants which occur in the valley of the River Cass, Canterbury, South Island of New Zealand.* Their environmental conditions and general morphology are described, and certain conclusions are drawn from the observations made. The locality is somewhat out of the way, and the visits made to it were short and at wide intervals. Most of the observations were conducted in the field, though a considerable amount of laboratory work was done in the investigation of structure, and a few experiments were made in growing certain plants under different conditions.

Of the publications which deal with the neighbourhood of Cass or of other parts of the South Island with a close ecological resemblance, the first to be mentioned is that by L. Cockayne (1900), who gave a general account of the conditions for plant-life in the Waimakariri River basin, together with certain details regarding the response of the plants to these conditions, and a brief account of the plant-formations. Later, the above ecologist, in collaboration with Laing (Speight, Cockayne, and Laing, 1911), gave a much fuller account of the very similar vegetation of the Rakaia Valley and neighbouring mountains. Cockayne (1911) supplemented this by a more detailed account of the vegetation of the Rakaia near its source, dealing with the vegetation-dynamics, the *Raoulia*-form, and publishing a synopsis of all the species of the habitat in terms of their growth-forms. Finally, Cockayne and the author (1916) dealt with the plant-associations of the area under consideration, but their treatment is not by any means exhaustive.

* For a map showing the exact locality of the area see Chilton, 1915, p. 332; and for a more detailed map see Speight, 1916, p. 146.

The following studies deal with cushion-plants in general. Lazniewski (1896) published a short account of the leaf-anatomy of *Haastia pulvinaris*, and Miss Low (1899) gave a detailed account of the structure of the same cushion-plant. Laing and Blackwell (1906, pp. 424, 426, 428) have a brief popular account of certain forms of *Raoulia* and *Haastia*, and call attention to the growth-form being due to "environment and not to relationship" (*l.c.*, p. 430). Cockayne (1909, pp. 196–97) dealt with the cushion-form in certain subantarctic plants, and the same author (1912, pp. 20–21) shows the relation between the mat- and cushion-forms, and discusses the question of epharmony and epharmonic convergence in the latter. More important by far than any of the above is the work of Schröter and Hauri (1914), which defines and classifies the various types of cushion-plants, gives a systematic list of the cushion-plants of the world, and concludes with an examination of the relation between habitat and the cushion-form with regard to its being a xerophytic adaptation or the contrary.

It may be noted that no part of the present paper is devoted to the synecology of the area dealt with. This arises from the fact that the author had no additional material for a closer description of the associations than that given by Cockayne and himself in the paper cited above, to which the reader who desires further information may refer.

In concluding these brief general remarks I must thank most sincerely Professor C. Chilton, C.M.Z.S., and Dr. L. Cockayne, F.R.S., from both of whom I have received much valuable assistance and advice.

### (B.) *Terminology and Definition of Term "Cushion-plant."*

As the various growth-forms dealt with merge into one another, so that exact classification is difficult, the term "cushion-plant" is here used as a generalization to include cushion-plants proper, mat-plants, and similar growth-forms. It is rather difficult at the outset to frame an exact definition of the term "cushion-plant" as applied to the types considered. The exact significance of the term will appear after consideration of several types.

Warming (1909, p. 11) defines cushion-plants thus: "Shoot-system richly ramified, often with the branches densely packed to form hemispherical cushions. Foliage leaves usually small, more or less evergreen, remaining attached for a long time in a faded condition, and decaying slowly. Buds open."

Schröter and Hauri (1914, p. 618) give this definition: "Polsterpflanzen sind perennierende, krautige oder verholzende, meist immergrüne Chamaephyten von kugeligem, halbkugeligem oder flach-deckenförmigem, kompaktem Wuchs. Die Zweige sind zahlreich, kurzgliedrig, bis weit herab dicht und ununterbrochen von kleinen, mehr oder weniger unbeweglichen, sitzenden, in mannigfaltiger Weise verwitternden Blättern bedeckt; die Zweige endigen in kontinuierlicher Fläche und sind entweder dicht aneinander gepresst oder bei lockerer Stellung durch Füllmaterial verbunden. So entsteht eine gewisse Festigkeit, Kompaktheit und Geschlossenheit des ganzen Individuums, das aus einer lebenden, dichten Decke über einer selbstgebildeten, verwitternden Füllmasse mit Schwammwirkung besteht."

These definitions are certainly comprehensive, but for the present purpose provisional definitions may be framed thus: A "mat-plant" is one whose main branches lie prostrate on the ground and, as a rule, radiate in all directions from a centre of growth; the vertical branches are very short and compacted together so that the plant forms a close mat of little depth: while a "cushion-plant" has the same general form of growth as a mat-plant, but the vertical branches are longer, so that the whole growth is deeper and tends to assume a hemispherical form.

All the types considered consist, in their early stages, of a long vertical tap-root, crowned by a disc of horizontally-spread radial branches closely appressed to the soil. At first no adventitious roots are produced by these branches, but in many types these appear later. The horizontal stems branch frequently, so as to produce a mass of stems forming a mat or disc, with the primary tap-root in the centre. Many vertical branches are given off from these horizontal stems, and it is chiefly these vertical branches that are clothed with the leaves, which are small. The ultimate branches are compacted together in varying degrees of closeness, and this compactness determines the density of the mat or cushion. These ultimate branches will be termed for brevity "branchlets." Each branchlet is clothed with leaves, which are always small and frequently closely appressed to the main axis. The leaves die away towards the proximal portion of the branchlet. The distal end of the branchlet terminates in a bud, below which are several more or less expanded leaves with a close spiral phyllotaxy. This grouping of the terminal bud and leaves makes the end of the branchlet, when viewed from above, appear as a rosette. This term "rosette" will be used to denote the distal leafy portion of the branchlet. It will be easily seen that the rosettes form the "surface" ("Fläche," Schröter and Hauri) of the cushion, and the more compact and equal in length are the branchlets the more even will be the surface. Neglecting the character of the surface, the cushion itself may not present a flat or evenly convex exterior, but may, owing to the unevenness of its substratum, be thrown into various mounds and hollows. This will constitute the "contour" of the cushion.

Lastly, as the leaves die away on the branches, and as sand, silt, and other debris are blown or washed upon and into the cushion, the central portion of it — *i.e.*, the spaces between the main stems, branches, and branchlets—becomes filled with a kind of humus. This will be referred to as "filling-material" ("Füllmaterial," Schröter and Hauri). It plays a most important rôle in the economy of many cushions.

### (C.) *List of Species dealt with.*

(*a.*) CUSHION-PLANTS :—

1. *Raoulia lutescens* (T. Kirk) Beauverd. (Compositae.)
2. *Raoulia Haastii* Hook. f. (Compositae.)
3. *Scleranthus biflorus* (Forst.) Hook. f. var. (Caryophyllaceae.)

(*b.*) MAT-PLANTS :—

4. *Raoulia tenuicaulis* Hook. f. (Compositae.)
5. *Raoulia australis* Hook. f.: several distinct forms. (Compositae.)
6. *Raoulia glabra* Hook. f. (Compositae.)
7. *Raoulia subsericea* Hook. f. (Compositae.)
8. *Raoulia Monroi* Hook. f. (Compositae.)
9. *Acaena microphylla* Hook. f., in a wide sense. (Rosaceae.)
10. *Coprosma Petriei* Cheesem.: two varieties. (Rubiaceae.)
11. *Muehlenbeckia axillaris* Hook. f. (Polygonaceae.)
12. *Pimelea prostrata* (Forst. f.) Willd. var. *repens* Cheesem.* (Thymelaeaceae.)

* Whether the plant here dealt with is really var. *repens* Cheesem. the writer does not know. Cheeseman (1906, p. 613) gives no localities for any of his three varieties. Var. *repens* is evidently identical with Hooker's var. β, which he states is "abundant, especially in hilly districts" (*Handbook of the New Zealand Flora*, Part I, 1864, p. 244), which distribution fits in admirably with the Cass plant.

## II. Physiographical.*

### (A.) *General.*

The lower portion of the Cass Valley alone concerns us here. This area consists of a flood-plain about 7 km. long by 2·5 km. wide. The actual river occupies a comparatively small strip in the centre of the plain, while on either side there extend, east and west, a series of low, flat terraces.

Strictly speaking, the term "bed" is applicable only to that part of the valley actually covered by the flowing water. But the Cass, like most New Zealand rivers, is continually liable to flood, at which time the river covers a much wider strip than usual. The river, moreover, even normally, flows as a network of anastomosing streams, and in time of flood these channels become wider and meet, until there is a considerable breadth of running water. In this paper the term "river-bed," following the colloquial usage, is used to include that part of the valley liable to be covered with water in times of severe floods. This "river-bed" is bounded on either side by a broad expanse of flat land, chiefly tussock-covered, termed colloquially "river-flat," but in this paper "terrace." This area is at no time subject to complete inundation, and probably only in times of very severe floods will the lower-lying portions of it be slightly submerged.

Now, it is the whole flood-plain which supports the cushion- and mat-plants dealt with, but the chief area, the richest and the most interesting, is the river-bed itself, only a few species of the cushion types growing on the terraces.

The river-bed consists of various areas varying from bare shingle to a well-defined plant-association. These areas merge into one another, but certain well-defined stages occur, and for purposes of comparison and reference it has seemed advisable to adopt some scheme of classification of the various portions of the river-bed. The lowest grade may be termed "bed proper." Above this are various grades which, becoming more and more consolidated and more and more peopled by plants, finally merge into the mature "terrace." These grades are termed "transition terrace," and are placed in three grades, called respectively transition terrace 1, 2, and 3. It must be clearly understood that these grades merge into one another.

### (B.) *The Bed Proper, and the Terraces.* (Plate I, figs. 1 and 2.)

The bed proper is obviously the simplest grade to define; it is not necessarily the lowest part of the valley at any cross-section. It consists of a mass of water-worn greywacke rock the constituents of which vary from fine sand to boulders 0·25 m. and more in diameter, the larger ones projecting strikingly above the general surface. It is through such shingle that the river flows, being confined to various channels which are continually changing. An old channel may be deserted for a new one; and the older one, if not used considerably during frequent floods, soon commences to merge into transition terrace. The chief point about the bed proper is its absolute freedom from a plant-covering.

The transition terrace, grade 1, is the first stage after the unpeopled bed; it is sparsely covered with plants. It is that part of the river-bed no longer liable to be used as a channel except in case of moderate floods. It has a

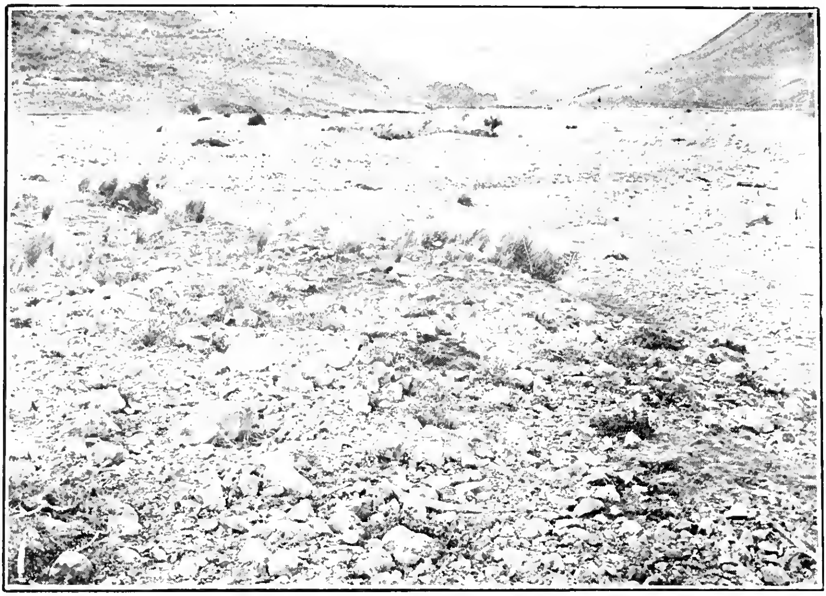
* For a detailed account of the physiography of the area adjacent to the River Cass, see Speight, 1916.

[C. E. Foweraker, photo.

Fig. 1.—Recently vacated stream-bed and stream towards centre showing dry channels, looking north-east towards mouth of Cass River. Higher plant-life absent.

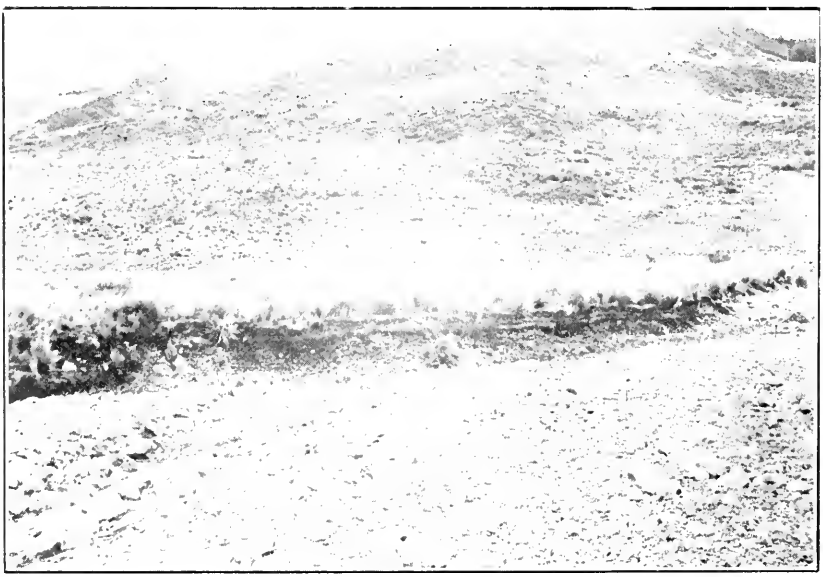
[C. E. Foweraker, photo.

Fig. 2.—View similar to fig. 1, but showing deposits of sand and fine shingle. Terrace with *Festuca* tussocks and *Discaria* thicket in background.



[C. E. Foweraker, photo.

Fig. 1.—Transition terrace, grade 2, with mats and cushions of *Raoulia tenuicaulis* and *R. lutescens*, prostrate *Discaria toumatou*, tussocks of *Festuca novae-zealandiae*, and towards the centre a cushion (black) of *Raoulia Haastii*.



[C. E. Foweraker, photo.

Fig. 2.—Edge of old terrace covered with tussocks of *Festuca novae-zealandiae*, looking north from river-bed. Slopes with low tussock grassland in background.

more consolidated appearance than the bed proper, the interstices between the larger boulders being well filled up with small gravel and sand. Such transition terrace forms not only the banks of the bed proper in some places, but also small islands between streams.

The transition terrace, grade 2 (Plate II, fig. 1), has the boulders and the shingle well consolidated. There is much sand, and the plants thereon have already commenced to form humus. The whole surface is by no means covered with vegetation, but the cushion- and mat-plants already there serve to assist other plants in gaining a footing. This grade is covered with water only in times of great flood.

The transition terrace, grade 3, is reached when the whole shingle area has a distinct plant-covering. There is much humus, which is interrupted only where the boulders and shingle-patches project above the surface.

The terrace proper (Plate II, fig. 2) is the type which forms the greater part of the flood-plain; it is entirely covered with plants. As it stretches away to the bases of the surrounding hills its character changes—it becomes more consolidated, the depth of humus becomes greater, and it supports a more varied vegetation, which merges into low tussock grassland. (Cockayne and Foweraker, 1916, pp. 172–73).

## III. THE ECOLOGICAL CONDITIONS.

### (A.) *Edaphic.*

It will be seen from the above descriptions of the various grades of terraces that the substratum in which the plants grow is composed in the three lowest grades largely of stones of various sizes mixed with small quantities of sand and silt. "Such a soil," writes Cockayne (1911, p. 111), "is deficient in available nutritive salts, and in itself provides merely desert conditions for plant-life no matter how frequent the downpour." As the terraces merge from bed proper to higher grades the proportion of sand and silt to stones becomes greater until there is "a thin coating of light silky loam which, though far from being a fertile soil, is quite sufficient to support, with the addition of the self-supplied humus, a closed formation of those plants which are provided with certain 'adaptations'" (*l.c.*). This stony soil is necessarily extremely porous, and after rain it rapidly dries, so that ordinarily its water-content is quite small. Still, there is always a small amount of moisture in all but those parts composed solely of huge boulders. The large stones on the surface assist in checking evaporation. There is always plenty of underground water; indeed, many of the New Zealand shingle-bed rivers flow to a certain extent underground. The depth of the water-table varies, but it is always nearer to the surface in the lower grades.

"How far," to quote from Cockayne again, "the heat from the sun can penetrate into the soil I cannot say, but probably to no noticeable depth, except between the chinks of the stones. These latter become so strongly heated during a period of insolation that one can hardly bear to touch them with the hand, and the reflected heat must be very considerable so far as the ground plants are concerned. On the other hand, the stones rapidly lose their heat when the sun's rays are obscured" (*l.c.*, p. 112). "As for aeration of the soil, that will be abundant. From the above it is evident that a river-bed is a strongly xerophytic station, and that, notwithstanding an abundant rainfall, the conditions primarily resemble those of a desert" (*l.c.*).

### (B.) *Climatic.**

As explained by Cockayne and Foweraker (1916, pp. 166–67), the Cass Valley has a critical climatic situation, since it lies just beyond the influence of the excessive western rainfall. What the actual rainfall, &c., of the area is cannot be stated, since no statistics are available, but by observations made at various times and comparison with similar localities in Canterbury whose meteorological conditions are known a fair idea of its climate may be obtained.

At Bealey, distant from Cass about 11 km., but somewhat similarly situated as regards the limit of the western rain, the average annual rainfall is 145 cm. At Cass the rain is often considerable, and it frequently rains heavily at intervals for days at a time. There are many low-lying areas which are more or less constantly boggy; but on the "river-bed" and shingle-slips (talus slopes) the rain rapidly soaks away, and these latter areas are then subject to desert conditions. This is a point of considerable importance, as this desert condition is a great ecological factor in the life of the plants dealt with.

The prevailing wind is from the north-west. This comes from over the Tasman Sea, and is heavily moisture-laden when it strikes the dividing-range. Here much precipitation occurs, the rainfall on the west coast of New Zealand being excessive (350 cm.). On the eastern side of the dividing-range the rainfall is rather heavy at the foot, being 175 cm. at Arthur's Pass, but gradually diminishing towards the east coast, where it is about 65 cm. The wind on approaching the east coast becomes very dry and warm, and sweeps over the Canterbury Plains as the well-known "nor'-wester" (see Cockayne, 1900, pp. 110–11). This wind in the Cass Valley is moderately dry, usually cold, and blows with very considerable force. It blows more frequently during the spring, summer, and autumn months, it being rare from late spring to early autumn to have a day or night without wind. During the winter, however, a calm may prevail sometimes for over a week. The wind sweeps over the Cass Saddle and other low saddles farther west, and blows pitilessly over the flood-plain of the Cass Valley. This severe cold wind sweeping over the broad expanse of the flat "river-bed" is a factor of great ecological importance.

Snow falls frequently during the winter, and has been observed as much as 7 cm. deep on the flood-plain and other low-lying places. Snow occurs much more frequently at higher altitudes on the surrounding ridges It does not lie on the lower levels for longer than a few days or a week.

As regards temperature, extensive statistics are not available, but during the midwinter of 1915 the temperature of the air at midday during one week varied from 6° to 15° Centigrade.

Comparatively severe frosts occur during the winter, the ground being frozen to the depth of several centimetres. This is especially noticeable on the old terrace, where the upper layer of soil is frozen hard for days at a time, thawing only slightly on the surface during the daytime. Slight frosts may occur at any time during the summer months.

The air is clear, and on a fine day the insolation is considerable. The effect of this heat on the "river-bed" is of importance, as the shingle in the

* For the most detailed account of the climate of the Waimakariri River basin yet published see Cockayne, 1900, pp. 104–16, which treats not only of the usual climatic factors, but of the behaviour of certain introduced plants and of phenology.

lower grades of transition terrace has not the power of retaining much moisture, and the area becomes practically a desert for the time being.

From the matter of the preceding paragraphs it may be concluded that the climate varies from hygrophytic to xerophytic. Though considerable rain falls, still there are periods, as mentioned above, when the "river-bed" especially experiences desert conditions; hence the need for the plants to have a xerophytic structure—a character illustrated in nearly all the species dealt with.

## IV. AUTECOLOGY OF THE CUSHION-PLANTS.

### (A.) *Raoulia tenuicaulis.* (Plate III, fig. 1.)

(*α*.) HABITAT.

This is the dominant plant of the transition terrace in its earlier stages. It is one of the first plants to establish itself on the first grade of terrace, and its greenish or greyish mats, perhaps 1 m. in diameter, form the chief element of the scanty plant-covering found thereon. The mats, later on, frequently run together so that large patches, 25 square metres in area, become covered with this plant.

On the second or third grade of transition terrace *R. tenuicaulis* frequently grows on the margins or the "banks" of the terrace, and hangs down over the edge, thus helping to consolidate the latter and to resist the effects of weathering and river erosion. (Plate III, fig. 2.) It frequently forms the chief covering of various "islands" that stand up above the level of the general shingle of the lower grades of terrace. In these cases it is evident that the plant has had a consolidating effect, and holds together the area of which it forms the covering. But, as Cockayne and Foweraker have stated, these areas are larger than on many river-beds, owing to the width of that of the Cass in relation to the flow of water (1916, p. 176). Owing to the slight difference in coloration of the various mats on such an area (see "Coloration" below), the individual outline of each mat can be made out. Besides river-bed, *R. tenuicaulis* frequently colonizes other bare shingle —*e.g.*, railway embankments and shingle laid bare by denudation. Also, it can occupy denuded clayey soil and rock.

($\beta$.) LIFE-FORM.

(1.) *General.*—This species forms a bright-green flat mat, roughly circular or ellipsoid (Plate III, fig. 1), compact in the centre, but very loose and open at the margin. The surface is rough; it has a "bristly" appearance, owing to the numerous acute leaves, but owing to the laxness of growth and the flexibility of the leaves and stems the general "feel" of the mat is soft. The general appearance of the surface of the mat is not quite uniform, owing to the laxness of the marginal growth; moreover, the leaves of the new growth are often larger and more hairy than the older ones, and this aids in the contrast. There is a considerable resemblance between the leaves on new growth and those on young plants, except that the new leaves are not quite so large as those on the juvenile form. This species is of much more rapid growth than the other cushion-plants. The marginal branches spread rapidly over the shingle and are closely applied to it, their tips being slightly ascending. The mats differ greatly in size. Three that were measured had the following dimensions: 15 cm. by 12 cm., 70 cm. by 70 cm., and 130 cm. by 55 cm. The growth is centrifugal. The stems lie close to the substratum, and give off copiously the terminal branchlets above and very numerous roots below.

(2.) *Filling-material.*—The filling-material in the case of this plant is very varied in quantity. In its usual condition *R. tenuicaulis* forms a shallow mat of branchlets, so short that there is a very little depth below the rosettes. The black dead leaves clothe the branchlets below the rosette, and except these leaves and a modicum of wind-blown sand there is no other filling-matter.

But, growing as this plant usually does on the lowest grades of the terrace, it is frequently subjected to inundation, and when this occurs its mat is liable to be covered wholly or partially with sand. The rapid growth of this plant during the spring and summer soon counteracts the effects of being sand-covered. Several large mats were noted which had been completely covered with sand during a flood some time near the end of August, but in the first week in September the majority of the rosettes were vigorously uplifting themselves above the sand-level. Many old mats were of considerable depth (relatively speaking for *R. tenuicaulis*), being about 4 cm. deep. Such mats have a filling-material composed chiefly of sand, but the whole has a blackish-brown appearance, due to the colour of the stems and dead leaves. Most of the filling-sand is due to flood deposits; very little is wind-blown. Sandy areas are not so frequent in the Cass Valley as in that of the Waimakariri, consequently miniature sandstorms, such as often occur in the latter, are almost entirely absent at Cass.

(3.) *Coloration.*—As regards coloration this plant is most variable. Typical mats during the summer and early autumn are a bright sap-green. The hairy forms have a greyish tint. During the winter the variety of colours is most remarkable. Very few of the plants are of a greenish tinge; none of them have the deep-green colour so evident in the spring; those that do exhibit green are of a yellowish-green tint.

Many of the plants are densely hairy during the winter, and this aids in giving a general greyish colour. This appearance is aided by the lower leaves dying away, and their greyish colour shows here and there between the rosettes. The edges of the leaves are yellowish or brownish, and the whole of the plant at this stage is a greenish grey (this is the case with that form which is green in summer). The greyish form does not alter during the winter, for the leaves and colour seem the same as at other seasons.

In the upper part of the Lower Valley, where large areas are covered with mats which run into one another, each plant is of a different colour, so that the original individual mats can be distinguished. The colours are most varied—pale yellow-green to a fawny brown, and various shades of a pinkish grey; really the colours are indescribable. During the winter the colours are rich. On one "island," amid river-bed proper, having an area of 15 square metres, the whole surface, save for large projecting boulders, was covered with *R. tenuicaulis*. The separate mats had run into one another, but their individual outlines could be made out owing to their colours—all shades from sap-green to chocolate-brown through various yellow-browns. Also, the hairy variety showed all colours from a pinkish grey to a brownish grey.

(4.) *Morphology.*—(*a.*) *Stem.*—The main stems are prostrate, closely appressed to the ground, and above give off secondary branches, but below root copiously. They are wiry, thin (main stem 2 mm. diameter, ultimate branchlets 0·5 mm. diameter), and brownish or blackish in colour. The branchlets vary in length according to the amount of filling-material—*e.g.*, 0·5 cm. in shallow mats to 1·75 cm. where filling-material is considerable.

Below the rosette the branchlets are clothed with the brown or blackish remains of the leaves which are not closely appressed to the stem.

A transverse section of a young stem shows the following structure: Epidermis well marked, with a cuticle of moderate thickness and frequent hairs as described below. Cortex of about six layers of thin-walled polygonal cells with few chloroplasts; middle layers composed of largest cells, innermost have small flat cells. Endodermis very regular, composed of barrel-shaped cells considerably larger than the inner cortical ones. Cells often contain anthocyan.

In older stems secondary thickening and general lignification soon commence. Transverse sections just behind the branchlets show the following structure (fig. 1):—Epidermis: In some sections this is still fairly evident with moderately thick cuticle. In others it appears dark, and the cells are flattened and appear to have lost their contents. Cortex: In younger

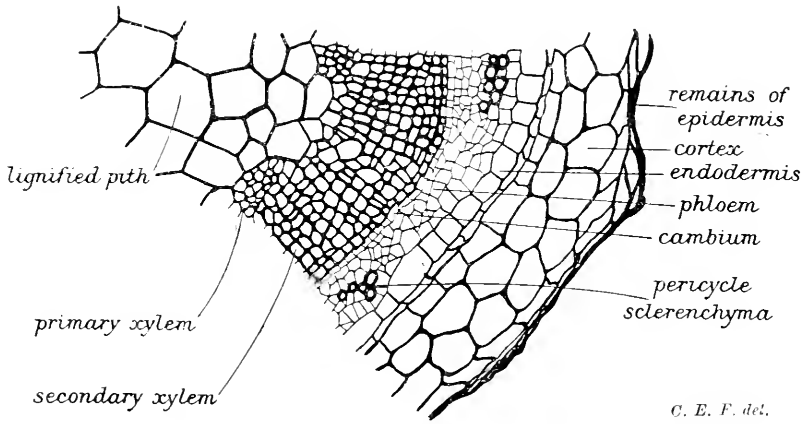



FIG. 1.—*Raoulia tenuicaulis.* Transverse section of an old stem.

parts consists of parenchymatous tissue of polygonal cells with thin cellulose walls. In older parts the whole cortex has become strongly suberized, giving a brownish-yellow colour with chlor-zinc-iodine. Cell-walls are thickened, but have a wavy outline: the cells have lost their contents, and the walls are commencing to "buckle up." * Endodermis: Same appearance as in young stems, save that the cells are larger and have thicker walls. Phloem: Several layers of nearly-equal-sized cells. Xylem and pith: Occupying whole centre of the stem is a strong lignified column of tissue. The pith has become lignified after commencement of secondary growth. Central cells (altered pith) large. Primary xylem masses visible, and zone of small squarish cells more or less arranged in radial rows marks secondary wood. Cambium: Outside wood cylinder cambium visible as a single layer. Pericycle sclerenchyma: At regular intervals near periphery of phloem isolated patches of lignified tissue occur; these are strands of bast fibres, but more abundant in older stems.

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* In one specimen the cortex became *lignified* with thick rigid walls, exhibiting clearly the central lamella, as well as pits. The only cells in this specimen which did not exhibit lignification were those forming the two layers just outside the endodermis. This cortical lignification, however, must be regarded as unusual.

Longitudinal sections of old stems show as follows: Pith of rectangular cells lignified, fairly regular, from two to three times as long as broad. Xylem mainly of fusiform tracheides with walls strongly lignified and pitted. A few large cylindrical pitted vessels or tracheae occur, the original transverse walls showing at intervals as an internal ring. Cambium: Single layer, thin-walled. Phloem composed mainly of elongated cylindrical cells and a few sieve-tubes. External to the phloem comes a rather confused mass of tissue, but in most cases in old stems the cortex has been shed, and the endodermis surrounded by one, or at the most two, layers of flattened cork forms the outer covering.

(*b*.) *Leaf*.—The leaf of this species is polymorphic. In old plants, what may be considered as the typical form is oblong-lanceolate or linear-lanceolate. The leaves have the margins on the lower half parallel, and a little past half-way they gradually taper to an acute apex, which has a distinct blunt papillose point of a pale-yellow colour. The blade is slightly folded inwards, and the tips are reflexed.

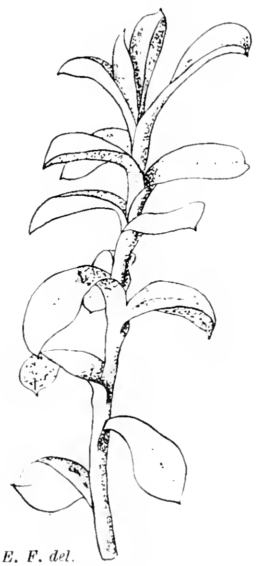

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FIG. 2.—*Raoulia tenuicaulis*. Young shoot from a shaded mat. (Hairs not shown.)

Typical leaves are very slightly hairy with long white silky hairs on both surfaces. Length of leaf, 3–4 mm.

In many cases the leaves are strongly conduplicated, so much so that the margins of the distal half of the blade meet towards the tip, and give a general subulate form to the whole leaf. The phyllotaxy is spiral.

This pseudo-subulate form may be regarded as the typical adult condition of the leaf, but younger ones do not exhibit this—they may be thus described: Broadly spathulate, tip almost truncate, minutely apiculate; whole leaf much recurved; margins incurved; narrowed to a broad sheathing base; total length, 6 mm.; broadest part, 2·5 mm. Whole leaf rather densely covered with a felt of silvery hairs lying more or less parallel to midrib, closely appressed to epidermis. Midrib and veins indistinct. This is the type of leaf found on seedlings and on terminal branches of young shoots (fig. 2).

The hairs, which are very long, arise from an epidermal cell which gives off a short branch near its junction with another cell at its distal end. On this branch or basal portion of hair the long, tapering, more or less twisted hair-cell is formed, separated by a septum from the basal portion. The hair-cell is not septate; it is not easily wetted. The epidermal cells are polygonal, and their lateral walls are not wavy, but smooth.

The rosettes are from 3 mm. to 4 mm. across. About six leaves are visible from above in each rosette. Owing to the leaves being linear, and their not being closely appressed to the axis of the branchlet, leaves of adjacent rosettes interlock somewhat, so that the surface of the mat is not marked out into very distinct rosette-areas.

A transverse section of a young leaf is as follows (fig. 3): Epidermis same on both surfaces; weak cuticle; cells barrel-shaped in transverse section. Stomata on *both* surfaces; normal. Air-cavities (substomatal) small. Chlorenchyma peculiar: on upper surface a single layer of cylindrical cells and on lower surface a single layer of spheroid cells densely packed with chlorophyll grains. No spongy parenchyma of usual type, but between the chlorenchyma layers is a layer of large clear thin-walled polygonal cells with few chloroplasts, evidently a water-storage tissue. Lower epidermis easily separates from mesophyll, but it is difficult to remove upper epidermis. Vascular bundles have a large-celled sheath.

In a typical adult leaf the structure is but slightly different from that of the young form. The cuticle is slightly thicker. The chlorenchyma may be of two layers of cells on both surfaces of leaf. Aqueous tissue and vascular bundles, &c., are similar to those of young leaf.

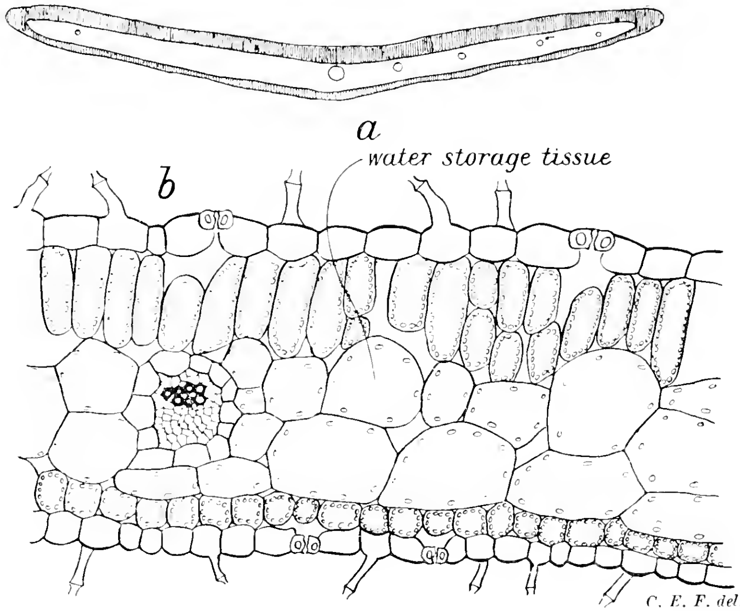


FIG. 3.—*Raoulia tenuicaulis.* Young leaf. (*a*) Diagram of transverse section: haded portion is chlorenchyma: (*b*) transverse section of lamina.

(*c*.) *Root*.—The roots are given off from the lower surface of the creeping stems. They are very fine and hair-like, copiously branched, and of a blackish-brown colour. A large quantity of roots is given off from all over the lower surface of the stems. The creeping marginal stems, not far behind their slightly upturned tips, soon commence to give off copious roots. In plants where filling-matter is in considerable quantity, roots are also given off into this by the erect branches.

Regarding their anatomical structure, sections of older roots show structure not much unlike stem. There is a central column of lignified elements surrounded by phloem. External to this comes the endodermis, and finally the cortex, which becomes either lignified or suberized, and is gradually thrown off from the exterior.

(*d*.) *Flower and Fruit*.—The flower-heads, of the usual Composite type, are borne at the ends of the branchlets. In an adult mat about half the branchlets produce a head. This is cylindrical, about 5 mm. long, and contained by an involucre of three series of bracts The florets are about eight in number, the outer ones pistillate, the inner hermaphrodite. All are tubular. The pappus-hairs are long, almost equalling the corolla. The fruit is an oblong cypsela, slightly hairy. The flowers are very sweetly scented, and the scent given off from a large mat area is very noticeable.

(γ.) Mode of Growth of Mat.

The seedling is at first erect and unbranched. The tap-root is long in proportion to the size of the plant, and the leaves are very broad and hairy. As growth proceeds, branches appear in the axils of the leaves, which rapidly elongate, but their growth is obliquely upwards. Subsidiary branches are given off, which are more horizontal than the primary laterals. Soon the proximal portions of the lowest branches come to rest on the ground, owing possibly in part to root-shrinkage. As growth and branching proceed, more and more branches come to lie on the ground, until a disc of radiating stems is formed round the central root. As this centrifugal growth goes on, adventitious roots are given off from the ventral surfaces of the horizontal stems. Vertical branches are also given off, which end in the branchlets. All the horizontal branches have ascending tips. Occasionally one side of the mat may grow faster than another, but in most cases there is a growth of practically uniform rate all round the periphery. Mats often spread over large boulders, though the extending branchlets seem to prefer running *round* a stone to running *over* it. When branchlets come to a tussock they run up through it and become erect.

(δ.) Epharmonic Variations.*

The growth-form and morphology given above are those taken from what may be called the "typical" form, but very many variants of the "type" occur. As regards the growth-form itself, there is not much departure from the usual type. The chief variations occur in the branchlets and leaves, and may be arranged thus: (i) As in the typical form, but very hairy, so that the general appearance is grey; (ii) a form with much broader leaves and laxer growth, though not hairy; (iii) a broad-leaved hairy form.

(ε.) Growth Experiments.

Plants of different types were taken from their habitat in March and planted in sandy soil in an unheated greenhouse at sea-level. They were abundantly supplied with moisture. The results were: (i) No change in colour during the winter—*i.e.*, no production of anthocyan; (ii) very rapid

* In my usage of the term "epharmonic" I have followed L. Cockayne, whose most recent definition (in Cockayne and Foweraker, 1916, p. 169, as footnote) is as follows: "The term 'epharmonic' is here used as in my former writings—*e.g.*, 'Observations concerning Evolution, derived from Ecological Studies in New Zealand' (Trans. N.Z. Inst., vol. 44 (1912), pp. 13–30)—with a somewhat different significance to that of Vesque and Warming (see 'Oecology of Plants' (1909), pp. 2 and 369). According to my usage, an epharmonic variation is a change in its form or physiological behaviour *beneficial* to an organism evoked by the operation of some environmental stimulus. Such a change may be called an epharmonic adaptation, as distinguished from such adaptations as cannot be traced to any direct action of the environment. To the neo-Darwinian no permanent adaptation according to the above definition would be 'epharmonic,' whereas to the neo-Lamarckian all would be so considered."

growth in the spring, particularly in September; (iii) this new growth much greener and decidedly less hairy than that in the Cass Valley; (iv) general softness, succulence, and laxness of growth.

(ζ.) CONCLUSIONS.

*R. tenuicaulis* appears to be a plant fitted for a shingly or sandy substratum, where the water-supply is not too deficient. The structure of the plant shows that it is not so strongly xerophytic as the other species of *Raoulia* described in this paper.

The structure of the stems is perfectly adapted to the habit of the plant. They are thin and wiry, and the central column of strongly lignified tissue lends strength. The stems can creep through sand, can withstand floods, the dashing against them of sand and shingle, and the crushing effect of boulders. Their wiriness imparts a springy effect to the whole mat, so that it is not easily flattened or crushed by flood-sand or flood-shingle.

The leaves show several xerophytic features, but the xerophytic characters of the leaves of cushion-plants as a whole are dealt with further on.

The rapid growth of this plant, where energy is put into horizontal rather than into vertical extension, enables it rapidly to clothe a barren area with its mats. Its copious seed-production and the plentiful distribution of the seeds enables its seedlings to establish themselves in the most diverse places where a little moisture is available; hence its early appearance on embankments, cuttings, and other bare places. Further, its rapid growth enables it easily to overtop any sand or silt that has covered its mats during a flood.

Its early peopling of the recently vacated bed proper does not mean that it is suited to absolute desert conditions. This lowest grade of terrace is also that nearest to the underground water-table, and consequently the first to be benefited by a rise of the water-table. Where it grows on rocks and railway cuttings it is found in those places which are exposed to a trickle of water, due to a spring or other form of soakage. It does not occur on the higher parts of the second-grade terrace, and not at all on the third grade. Its non-appearance on terrace proper may be explained by the fact that it cannot long brook competition with other plants. It readily succumbs before the hosts of invading species, and then serves but to provide a bed of humus.

## (B.) *Raoulia australis.**

(*a.*) HABITAT.

Along with *R. tenuicaulis*, several forms of this species are found on the lowest grades of terrace. It may be said that *R. tenuicaulis* appears first on grade 1 terrace, and *R. australis* next. It is to be understood, however, that *R. tenuicaulis* and *R. australis* are not the only plants which invade the newly exposed shingle. *Epilobium melanocaulon* and *E. pedunculare* vars. are quite as frequent inhabitants of the lowest grade, but they do not concern this paper.†

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* The above name as applied here refers only to the "species" as it occurs at Cass, and even there it is fairly polymorphic.

† By Cockayne and Foweraker this association is called the "*Epilobium* association" (1916, p. 176).

*R. australis* is of fairly wide distribution on the river-bed, and may be found on all the grades except the old terrace. Indeed, it so resembles young hairy forms of *R. tenuicaulis* that the latter could easily be mistaken for it. As it does not form a distinct cushion, and is extremely prostrate, it is unable to combat with taller plants; hence its disappearance on terraces above grade 3.

($\beta$.) Life-form.

(1.) *General.*—The growth-form of this species is a low, very flat mat, much resembling that of *R. tenuicaulis*, with the usual centrifugal growth, but with its main stems somewhat thicker than are those of *R. tenuicaulis.* They are straggling, and do not produce a copious growth of intermediate branches so as to form a close mat; in young forms much shingle and sand is visible between the branches. The contour is rather flat, but the surface is very rough and uneven, due to the inequality of the branchlets and their lack of compactness.

Its rate of growth is rather rapid, though less so than in *R. tenuicaulis;* hence its margins are uneven and lax. A noticeable feature of this species is its copious flower-production. Copiously flowered heads terminate nearly all the branchlets in the flowering season, and when the fruits are mature the whole surface of the mat is covered with the tufted pappus-hairs crowning the fruits.

(2.) *Filling-material.*—Owing to the thinness and looseness of the mat this is practically non-existent. The branches and stems are clothed with the light-brown remains of the dead leaves. A certain amount of coarse debris is entangled among the stems in the centre of the mat, giving this portion a darker appearance than the periphery.

(3.) *Coloration.*—The general colour of the mat is greyish, due to the copious white silky hairs on the leaves. In winter the edges of the leaves develop anthocyan, which gives a slight brownish tinge to these parts, so that the whole greyish appearance of the mat is modified by an elusive pink hue.

(4.) *Morphology.*—(*a.*) *Stem.*—The stems have much the same appearance as in *R. tenuicaulis.* They are prostrate, terete, wiry, and of a light brown. Copious roots are given off from the lower surface, thus producing a distinct dorso-ventral appearance.

The branchlets are short (0·3 cm. to 0·7 cm. long), and clothed throughout their whole length with leaves, which die away only at the very base.

The young stem has its general anatomical structure much the same as in *R. tenuicaulis*, except that the pith has not so great a proportional diameter.

The old stem is much the same as in *R. tenuicaulis*, except in the following features: (i) Less pith in proportion. (ii) Greater growth of secondary wood; the elements are arranged in more regular radial rows; the walls are thicker, and there are more numerous pitted vessels, which also have a greater lumen. (iii) More sclerenchymatous fibres on the periphery of the phloem opposite the primary vascular bundles; these are probably pericycle fibres. (iv) The endodermis has thicker walls, and the cells are shorter tangentially.

In other respects the secondary growth of the stem is the same as in *R. tenuicaulis*, both as regards lignification of the pith and suberized cortex, which is cast off as far as the endodermis.

(*b.*) *Leaf.*—The leaves are obovate-spathulate or linear-spathulate, about 2 mm. long and 1·25 mm. broad. The lamina is broadly spathulate, folded inwards in a conduplicate manner, thick, densely woolly on both surfaces, especially the inner, and most so at the junction of sheath and lamina. Apex truncate, obscurely emarginate, with a minute papilla at the extremity. The sheath is not broader than the lamina. During the winter the leaf-margins have a brownish tinge, due to anthocyan, which gives a faint pinkish-brown tinge to the whole mat.

The rosettes are small (about 2 mm. across), and on an average four leaves are visible from above. There is no compactness of growth, so the rosettes do not enter as a factor into forming a surface. A transverse section of the rosette shows the large space occupied in the terminal bud by the tomentum (fig. 4), which almost equals the leaf in thickness. This

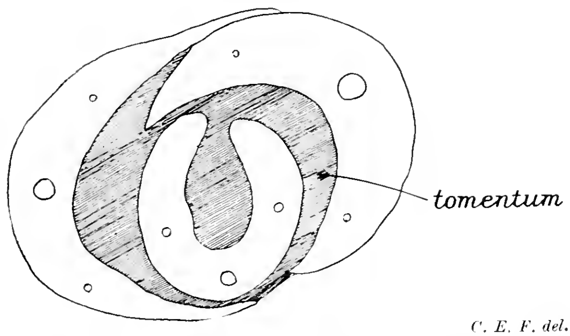



FIG. 4.—*Raoulia australis.* Diagram of transverse section of rosette: shaded portion represents tomentum.

layer of tomentum plays an important rôle in protection during frosts. It should function as the tomentum in the large rosettes of *Celmisia spectabilis*, dealt with later.

The leaf-anatomy differs from that of the leaf of *R. tenuicaulis* only in the slightly thicker cuticle, greater density of hairs, and chlorenchyma more closely packed.

(*c.*) *Root.*—This species forms its mat somewhat more slowly than does *R. tenuicaulis.* The primary tap-root remains in evidence longer, and the prostrate branches are slower in putting forth adventitious roots. As no filling-material exists, no roots can be given off from the branchlets into the central mass.

The root-anatomy is as in *R. tenuicaulis,* except for a more general lignification of the tissues.

(*d.*) *Flower and Fruit.*—The flower-heads are cylindrical, 0·5 mm. to 0·75 mm. long, with involucral bracts in about three series. The florets are ten to twenty, about half of which are female florets on the exterior. The cypsela is oblong, minutely pubescent, and crowned with a dense pappus tuft.

(γ.) EPHARMONIC VARIATIONS.

In its natural habitat this plant varies mainly in the size of the leaves and their degree of hairiness. Plants grown in a greenhouse at sea-level for six months developed elongated branchlets, with larger, flatter, less hairy and consequently greener leaves. Indeed, the branchlets under these conditions resemble the hairy greyish forms of *R. tenuicaulis,* but can be distinguished from these by the leaf-apices, which are not apiculate, and by the thicker lamina.

(δ.) Conclusions.

This plant may be ranked with *R. tenuicaulis* as a denizen of the open shingle, but its much more xerophytic nature, as shown by its small, thick, hairy leaves, and its rigid stem-structure allows it to exist longer than the latter on the ascending grades of terrace. Its copious seed-production and the long pappus-hairs permit of rapid seed-dispersal.

## (C.) *Raoulia lutescens.**

(*a.*) Habitat.

*R. lutescens* is a plant of definitely restricted habitat. It occurs only on transition-terrace grades 2 and 3. Its comparative slowness of growth prevents its gaining an early footing on the lower grades, and before the grades on which it grows pass into the highest stages it dies out. Essentially a plant of open shingle where the plant-covering is widely scattered, it dies away when encroached upon by other plants. Careful search of the old terrace revealed no trace of this plant save at the margins where the change to the lower grades began.

It frequently occurs on the edges of the terraces of intermediate grade, where these form a "bank" to a stream or an old watercourse. The cushions curve over the edge, forming a thick bulging "beading," and, where the bank is deeply undermined, assist in holding the soil together. The growth in such situations is very compact, and will easily bear the weight of one's body on the edge; whereas on portions of the undermined bank where no such growth exists the slightest pressure will cause the edge to fall down. *R. tenuicaulis* grows in similar situations on the lower grades, but has not so great a consolidating effect. (*Cf.* Plate III, fig. 2.)

(β.) Life-form.

(1.) *General.*—Next to *Raoulia Haastii* this species ranks as a true cushion-plant. It is the most even and the most uniform of all the raoulias dealt with in this paper. The cushions are more or less circular or elliptical raised in the centre and gently sloping away to the margins. Geometrically speaking, the cushion tends to take the form of the minor segment of a sphere. (Plate IV, fig. 1.) The general contour is smooth. The surface is the smoothest of all raoulias. The margin is well defined, as there is practically no difference between the branchlets, rosettes, and leaves of the margin and those of the centre. The cushions are of various sizes, four measurements being 20 cm. by 15 cm., 40 cm. by 18 cm., 50 cm. by 50 cm., 100 cm. by 100 cm. A section through the cushion shows a layer-formation due to the successive growth of branchlets, and it is possible that each layer represents a season's growth (fig. 5). Some branchlets do not branch at the tips to produce the ultimate ones of the new growth, but remain short at their old level, and thus help to fill up the spaces between the stems.

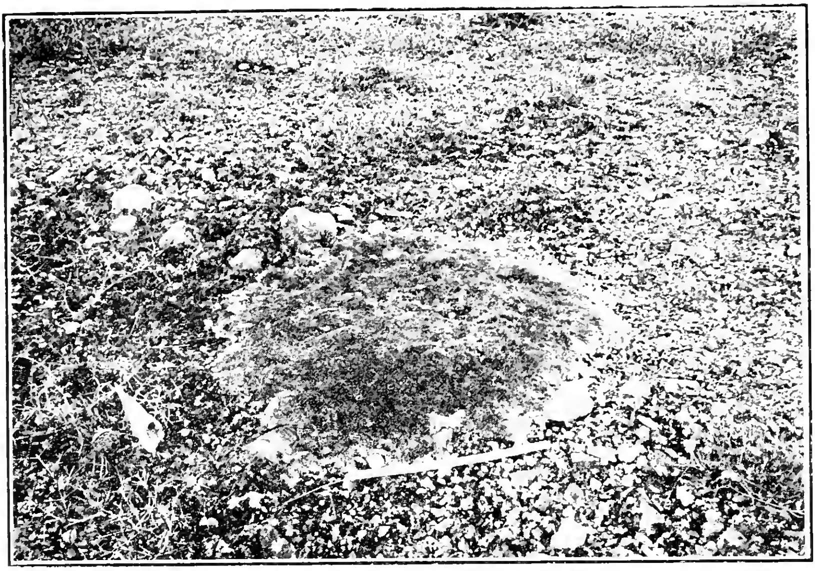
* The plant referred to in this paper as *Raoulia lutescens* is described in Cheeseman (1906) as a variety of *R. australis;* but Beauverd (1910, p. 221) rightly considers the divergence between the two is enough to constitute a specific difference.

[C. E. Foweraker, photo.

Fig. 1.—Transition terrace, grade 1, with mats of *Raoulia tenuicaulis*.

[C. E. Foweraker, photo.

Fig. 2.—Mats of *Raoulia tenuicaulis* growing over stream-edge of a grade 2 terrace which is being undermined.



[C. E. Foweraker, photo.

Fig. 1.—*Raoulia lutescens* cushion on grade 2 terrace. (30 cm. rule in front of cushion; *Discaria toumatou* in background.)

[C. E. Foweraker, photo.

Fig. 2.—Cushion of *Raoulia Haastii* on grade 2. (Note invasion of cushion by other plants, especially tussocks of *Festuca novae-zealandiae*.)

As the successive layers of branchlets are added, and consequently the depth of this cushion increases, adventitious roots are given out into the filling-material. The cushions, when uninjured, are very compact, and offer considerable resistance to mechanical force; but when once commencing to die away in parts, or when a portion of the cushion has been cut out, separation of the stems and branchlets is rendered easy. Older cushions are very "crumbly" in this respect—much more so than young flat ones. In some positions, where the mat grows over a flat boulder, the lower roots and stems die away and serve merely as a humus basis for the upper part, which in such cases is very easily disintegrated.

(2.) *Filling-material.*—The filling-material is not plentiful, its scantiness being due to the very compact growth of the cushion. The branchlets are so closely compacted together that not much space is left for foreign material to collect. The humus formed by the plant from its own leaves is scanty; the leaves are very small, and form, when dead, but a slight

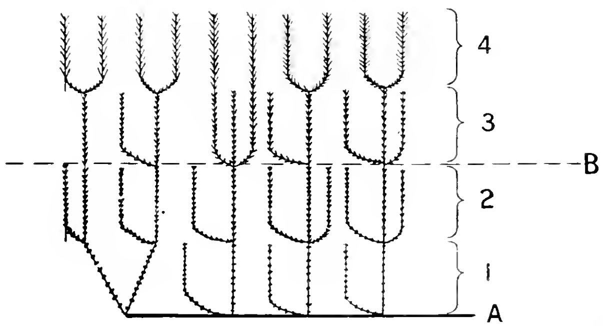



FIG. 5.—*Raoulia lutescens.* Diagram of stems and branchlets in a cushion. A, horizontal stem: 1, 2, 3, 4, successive tiers of branchlets; 4, tier of terminal branchlets. B, plane below which adventitious rootlets arise.

blackish-brown coating round the branchlets. The greater part of the filling-material consists of sand, which is most abundant when the plant grows on the lower grades, where it is more exposed not only to wind-blown sand, but also more especially to occasional inundation and its consequent sand deposit. On the higher grades of terrace the sandy constituent of the filling-material is not quite so predominant, and more humus is apparent. Still, in no case is there any considerable amount of free humus: it consists merely of a brownish coating formed by the dead leaves round each branchlet. Lower down in these old cushions the filling-material becomes blacker. The filling-material is always of a porous consistency, and, as the spaces between the branchlets are small, the total capillarity ("Schwammwirkung," Schröter and Hauri) of such a growth-form as *R. lutescens* must be considerable.

(3.) *Coloration.*—During the summer the colour is glaucous, due to greyish tomentum of the leaves. In winter the coloration is different, but difficult to describe. The anthocyan at the edges of the greyish-green leaves gives a slight brownish tint to these parts, and this, in conjunction with the greyish tomentum, makes the general effect a grey with a tinge of pink. The cushions often die away in the centre, these dead parts becoming black. Such cushions during the winter, with their black centre and pinkish-grey periphery, have a peculiar appearance, quite unlike an ordinary plant.

(4.) *Morphology.*—(*a.*) *Stem.*—The main stems are prostrate, thin (2 mm. diameter) and wiry, and rather difficult to trace. The secondary branches all tend to take a vertical direction, even at the margins, and in young plants the general trend of all the smaller branches is vertical. The colour of the stem is brownish—rather lighter than in the other species. Owing to the smallness of the leaves not much humus is formed, hence there is no dense coating of dead leaves round the stems. The branchlets vary in length, but compared with those in other species of *Raoulia* are short (0·4 cm. to 1 cm. long), and, with the leaves, about 1·5 mm. diameter. The leaves are very small, and to the naked eye appear almost like scales or leaf-bases. Lower down the branchlet, and on the lower branches, the dead leaves cling tenaciously, and have still more the appearance of scales; they are brownish, not blackish as in *R. tenuicaulis.* The branchlets, taken as a whole, are remarkably equal in length, and so arranged that their rosettes form a very even surface. As stated above, the surface of *R. lutescens* is the smoothest of all the cushion-plants in the Cass Valley. Owing to the smallness of the leaves the branchlets are able to be very closely compacted, so that one cannot insert a finger into the cushion without using considerable force.

The anatomy of the stem is practically the same as in *R. australis.*

(*b.*) *Leaf.*—The leaf is much the same as in *R. australis,* only smaller (1·25 mm. long) in every respect. Sheath and lamina edges have anthocyan, which gives a brownish tinge to the cushion. The rosette is very minute (1·75 mm. across); about nine leaves are visible from above. The inner leaves are closely crowded together and short, but become larger as the periphery is approached, so that the top of the rosette is more or less flat. These rosettes, forming as it were the units of the surface, and being flat themselves and very closely compacted, form the flat surface so characteristic of this species.

The leaf-anatomy is practically the same as in *R. australis,* with the whole structural features just slightly smaller.

(*c.*) *Root.*—This is practically the same as in *R. australis;* it is fine and wiry. The original tap-root cannot be made out, its place being taken by hosts of adventitious roots which spring from the prostrate stems. Adventitious roots arise in the body of the cushion in older plants, and seem to come from all parts of the upper stems below the first two tiers of branchlets. (See fig. 5.)

(*d.*) *Flower and Fruit.*—These are much as in *R. australis,* but slightly smaller.

### (γ.) Mode of Formation of Cushion.

No very young seedling stages were seen, but several young plants, already commencing to branch, were observed. They had a considerable number of rather closely compacted branchlets of equal length, and their terminal rosettes were already massed into a small surface. This mode of growth is well in accord with the marginal growth of the mature cushion. Compactness, indeed, is the chief feature of this plant throughout all its stages.

(δ.) EPHARMONIC VARIATIONS.

*Raoulia lutescens* is an exceedingly stable type. In the Cass Valley careful examination of many cushions on grades 2 and 3 terrace showed no perceptible difference so long as they were well exposed. In a few instances cushions were found growing in the shade of large *Discaria* bushes and of *Festuca* tussocks; these showed a laxity of growth, with longer branchlets and greener leaves than usual. Such cushions were dead in many places, and the remaining portion appeared to be having a losing struggle with the quicker-growing herbaceous plants in its neighbourhood. Plants grown for six months in a moist greenhouse at sea-level showed a great elongation of the branchlets, a laxity of growth, and a production of larger, thinner, less hairy and consequently greener leaves.

(ε.) RELATION TO OTHER PLANTS.

As stated already, the typical habitat is on terrace grades 2 and 3; but as this form of terrace merges into more consolidated forms different edaphic and environmental conditions arise. *R. lutescens* is accustomed to creep over stones and sand, but plants have been observed among tussocks and *Discaria toumatou*, when the branchlets, more especially the marginal ones, elongate and become greener. The same occurs where a tussock grows up through the middle of a cushion. These branchlets in contact with the tussock elongate considerably, but soon die off. On the other hand, the marginal branches can climb up the face of a boulder and live. It would seem that a solid substratum is necessary for the establishment of the cushion.

Few cushions of *R. lutescens* exist on the margins of the old terrace, for there the plant rapidly succumbs before the advance of other vegetation. Its cushion, which in the older plants is of considerable depth (5 cm. in some instances), affords a convenient growth-bed for other plants. Foreign roots can penetrate among its branchlets and make use of the nutrient filling-material. Surrounding plants encroach on its margins, and a whole plant-community takes possession of the cushion. Such invaders rapidly spread. Their growth deprives the cushion of air and light; and though in some places it makes a strenuous effort to lengthen its branchlets, nevertheless it is doomed, and sooner or later dies completely away, its sole remnant being a rich mass of humus at the feet of its conquerors.

One cushion (area, 0·5 square metre) growing at the exterior edge of grade 3 transition terrace had a large plant-community upon it.

But it is not alone with non-cushion plants that our types have to strive. They often intermingle with one another, and an interesting piece of work would be to watch the struggle for supremacy.

Seldom does *R. lutescens* occur on the higher terrace grades in large pure patches; it is usually broken up and divided. One of its chief enemies is the xerophytic moss *Racromitrium lanuginosum*, which rapidly encroaches on its margins and reduces its cushions to a bed of humus.

(ζ.) CONCLUSIONS.

*R. lutescens* exhibits in its growth-form and structure all the characteristics of a xerophyte—*e.g.*, very compact, low-growing cushion; small, coriaceous, densely hairy leaves with aqueous tissue; extreme capillarity of cushion; well-developed endodermis of stems; and capacity for growing in a habitat devoid of surface humus.

### (D.) *Raoulia Haastii.*

(*a*.) Habitat.

*Raoulia Haastii* occurs only on terrace grades 2 and 3. Its comparative slowness of growth prevents its gaining a footing on grade 1. Its cushions grow either among the boulders on the surface of the terrace or else at the edges or banks, where it grows down over the edges, forming huge pulvinate masses (Plate IV, fig. 2). This plant does not occur at all on terrace proper. It does not encroach even on the edges of old terrace, as does *R. lutescens*, but appears to die away before even the external limit of grade 3 terrace is reached.

(*β*.) Life-form.

(1.) *General.*—This species is the most conspicuous of all the cushion-plants on the river-bed; it is the cushion-plant *par excellence* of this area. Its large cushions, bright-green in summer and chocolate-brown in winter, are very conspicuous objects. The cushions are large, in some cases over 1 m. across, and 12 cm. deep. Its periphery and surface are irregular. The surface is thrown into numerous mounds and hollows, which were formed primarily by the plant covering, when young, obstacles of various kinds, such as boulders and driftwood. These irregularities have been retained in the adult condition, and give the cushion its characteristic irregular contour.

Though the general contour is irregular, the actual surface is smooth, due to the compactness and uniformity of the branchlets. The cushion is of the many-rooted type. In adult plants there is no dominant central root, but a multitude of adventitious roots arise from the creeping stems.

The arrangement of the upper branches in tiers, such as was noted in the case of *R. lutescens*, is apparent here also. In some cases six tiers can be made out before a considerable deposit of humus appears in the centre of the cushion. The cushion is as compact and as difficult of penetration as that of *R. lustescens.*

(2.) *Filling-material.*—This varies with the age of the cushion. When young the growth-form is really a mat. In young flat mats it consists chiefly of sand, but as the mats increase in depth more and more humus makes its appearence. In old cushions there is a very marked amount of filling-material in the centre of the cushion, consisting of a rich humus mixed with sand. The general colour of the filling-material is black. The leaves die away rapidly behind the terminal rosette, and become black.

(3.) *Coloration.*—The summer colour of *R. Haastii* is a sap-green. But the most conspicuous coloration is in the winter, when the whole cushion becomes a rich chocolate-brown with a tinge of red. As the winter coloration of this species was so remarkable it received special attention. Close inspection of the rosette showed that the tips and edges of the leaves were a reddish brown, but where central leaves showed they were a yellowish green. Behind the rosette the leaves die away and become brown, and the tips of these dead leaves showing here and there on the surface assist in giving the general brownish colour to the cushion.

Microscopic examination showed that the epidermal cells are filled with anthocyan, which is densest at the angular edges and tips of the leaves. Beneath the epidermis is the chlorenchyma. The yellow-green of the chlorophyll, covered with the pinkish-red of the anthocyan, gives the brownish effect so characteristic of the winter habit of the plant. That the brownish hue is due to the blending of the green and red may be illustrated by mixing two water-colours, sap-green and crimson-lake. By varying the proportions suitably a reddish chocolate-brown colour, similar to that of *R. Haastii*, may be obtained.

A small cushion of *R. Haastii* was removed in March, 1915, from the Cass River bed, and planted in a pot in a greenhouse near the east coast, at sea-level. When removed from the Cass it was bright green, and it retained its green colour throughout the winter. Practically no anthocyan whatever was formed. Careful examination showed a tinge of yellow at the angles, and a faint brown at the extreme tips of the leaves—an effect due to the weak development of the anthocyan.

(4.) *Morphology.*—(*a.*) *Stem.*—The stems are thin, wiry, brownish, and much wrinkled. The lower ones are prostrate, but the finer branches are more upright, the uppermost ones bearing the terminal branchlets. Rootlets are given off from most of the lower branches. The average diameter of the upper branches is 1·5 mm.

The branchlets vary in length from 0·5 cm. to 1 cm.; their axes are straight and radially disposed in relation to the hemispherical cushion; they are as closely compacted together as in *R. lutescens*, but the coherence to each other is not so great as in the latter, this being due to the glabrous and more coriaceous leaves, so that when they dry the outer boundaries of the whole branchlet are rather smooth. Hence the branchlets do not interlock and adhere together so firmly as in *R. lutescens*. They are of quite as uniform a length as in *R. lutescens*, so that the general surface is as even as in the latter species.

Transverse sections of stems from the centre of the cushion show the following structure: Epidermis apparent only in the younger stems, but soon thrown off with the outer cortical layers. Cortex of rounded thick-walled cells, early becoming suberized and empty. Endodermis very distinct, though not so thick-walled as in *R. australis*. Phloem a very thin layer; pericycle-fibres appear in the periphery. Cambium single layer. Xylem ring of dense tissue; closely packed tracheides and vessels. Pith a narrow column, early becomes lignified. In the very old stem the only external covering is a layer or two of the remaining suberized cortex-cells outside the endodermis.

(*b.*) *Leaf* (fig. 6).—The leaves are stiff and rigid, minute, 2 mm. long, approximately triangular in form, with a broad, spathulate, deeply hollowed base (1·25 mm. wide), which sheathes the stem and edges of the neighbouring leaf-bases. It narrows rather abruptly into a short subulate tip, the real "lamina," which is semicircular in section, the flat surface facing the axis of the branchlet. The tip is slightly curved inwards. On the convex surface on both sides there is a longitudinal depression, and the epidermis at these areas usually gives off a small patch of short silky hairs.

The rosettes are minute (diameter on a surface view 2–3 mm.). The leaves do not tend to come to the same level as in *R. lutescens*, so that a side view of the rosette shows an elliptical contour. The average number of leaves visible from above is twelve.

A cross-section of the leaf (fig. 7) shows the following structure:—Epidermis: Small roundish cells, many of which contain anthocyan. Cuticle very thick towards the tip of leaf, but thins out towards basal sheath. Stomata on both surfaces of leaf, but mostly on the outer convex surface; sunk below cuticle-level. Mesophyll: Near tip a band of about two layers of cylindrical chlorenchymatous cells surrounds leaf. Between

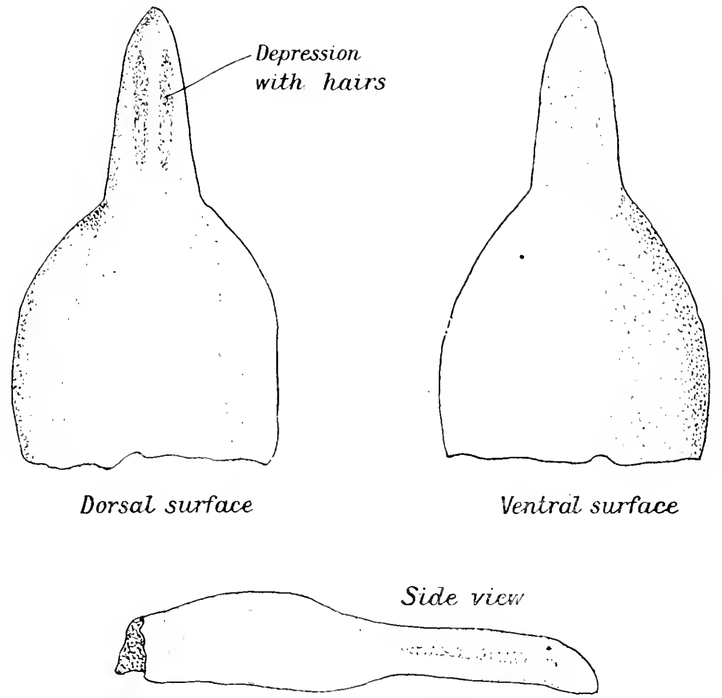



FIG. 6.—Leaf of *Raoulia Haastii.*

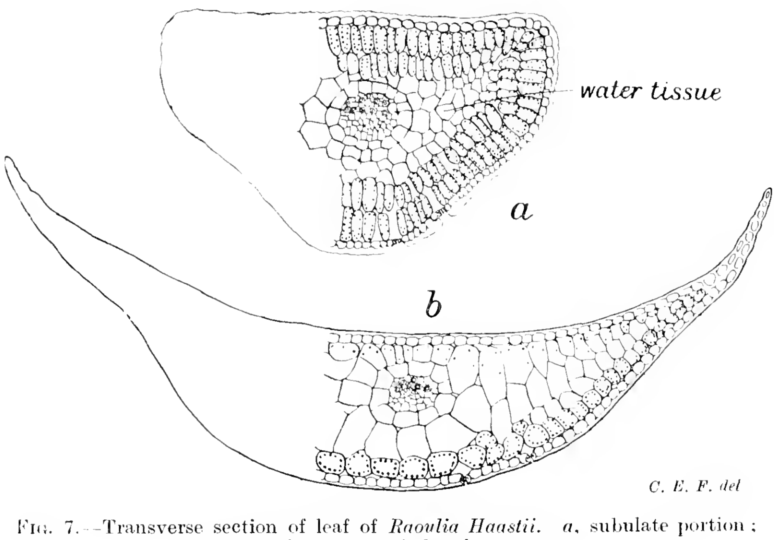



FIG. 7.—Transverse section of leaf of *Raoulia Haastii.* *a*, subulate portion; *b*, near basal sheath.

the single central vascular bundle and the chlorenchyma is an aqueous tissue of roundish or polygonal clear cells containing but few chloroplasts. Vascular strand: Sheath of large clear cells. Xylem has a few scattered vessels. Lateral branching bundles terminate in spiral tracheides among the chlorenchyma. Phloem composed of normal sieve-tubes and companion cells.

Towards the sheathing base the character of the tissues changes. The cuticle becomes thinner; the stomata are not sunken; the chlorenchyma changes to ovoid and finally to rounded cells, and becomes ultimately confined to a single layer just beneath the epidermis on the outer convex surface, while the lower layer of chlorenchyma changes to tissue similar to the water-tissue. The leaf-sheath consists of two layers of epidermal cells near the thin margin, but its extreme outer edges consist of a single layer. The epidermal cells all contain anthocyan (in winter). Behind the leaf-apex on either side is a shallow depression lined with fine twisted hairs, silvery white, and covered more or less with a mealy substance, possibly a glandular secretion. In these depressions the cuticle is thin, and the hairs arise from single epidermal cells.

(*c.*) *Root.*—The roots are very long, wiry, dark brown or blackish in colour, and rather free from tortuous twistings; they are straighter than in the previous species. From the branches below the third tier of branchlets copious adventitious roots are given off into the filling-material.

The anatomy is much as in the previous species, but there is a greater development of lignified tissue.

(*d.*) *Flower and Fruit.*—The capitula are short (3 mm. long). Involucral bracts scarious, especially at edges; obtuse at tips. Very few florets (four to eight), about half the number being female. Achene slightly hairy, with a long bunch of pappus-hairs, which are slender and not thickened above. The capitula soon disappear, the involucre becoming detached early, so that the surface of the cushion does not show any sign of flowering later than February. In this respect it differs from the other species, especially *R. australis* and *R. subsericea*, on which the involucres persist throughout the winter.

### (γ.) FORMATION OF CUSHION.

The earliest stages have not been observed, but small plants forming mats from 2 cm. to 5 cm. across occur on grade 2 and 3 terrace. The growth is compact from the commencement, and the young mats are miniatures of the mature plants. The marginal growth is slow and even. There are no long runners as in *R. tenuicaulis*, and no difference between the branchlets and rosettes of the periphery and centre. The only difference is that the marginal branchlets are less closely packed.

### (δ.) EPHARMONIC VARIATIONS.

In the Cass Valley this plant showed absolutely no variation whatever. Growth-form, filling-material, branchlets, rosettes—all were alike in every plant examined. Plants grown in a greenhouse at sea-level from March to October showed a difference from those in the Cass Valley as follows: Laxer growth; more succulent stems and branchlets; less compact rosettes; less xerophytic leaves—viz., thinner cuticle, leaves larger and more flexible.

### (ε.) CONCLUSIONS.

*Raoulia Haastii* illustrates in several ways the suitability of the cushion-form to its habitat. Its rounded convex surface and densely packed branchlets can offer unlimited resistance to the wind. Its firm margin and general robustness of growth; its small leaves with thick cuticle and sunken stomata; its densely packed branchlets; its filling-material with adventitious rootlets entering it—these structural features all point to a plant of xerophytic habit.

### (E.) *Raoulia subsericea.*

(*a*.) HABITAT.

This species is essentially a plant of the old stable terrace: it is found only there and on the lower slopes of the bordering hills; it does not approach the edge of the terrace which borders on the river, but usually is well away from the bank. Large quantities of this species grow among the *Festuca* tussocks on the terrace, and also in the low tussock grassland generally.

(*β*.) LIFE-FORM.

(1.) *General.*—*R. subsericea* forms large, very flat mats. It has trailing stems like *R. tenuicaulis,* but is much stouter. The horizontal stems root copiously, and give off very short vertical branches, which end in the branchlets. The general contour is flat; the surface is rather rough, owing to the breadth and large size of the rosettes, these being larger than in any of the raoulias considered above. The mats are of irregular outline, and their margins are closely interwoven with the surrounding herbage. Indeed, it is difficult to find a "pure" mat, as so many other plants grow up through the middle of it. In spite of this, however, the mats as a whole often occupy a considerable area, some of them being at least 1·5 m. across. The depth varies from 2·5 cm. to 4 cm. There is a general lack of compactness, and there are very large spaces between the branchlets as compared with the two previous species.

(2.) *Filling-material.*—There is practically no filling-material. The leaves die away behind the rosette, but remain attached to the branchlet. Dead grass leaves and other plant debris may collect among the branchlets and stems, but owing to their comparatively wide distances apart there can be no "sponge" effect produced, and consequently no growth of adventitious rootlets into the centre of the mat.

(3.) *Coloration.*—In summer the general effect is a sage-green, due to the green leaves edged and tipped with grey tomentum. In winter the edges and tips of the leaves develop anthocyan, and the general colour effect of the mat is a very light brown.

(4.) *Morphology.*—(*a*.) *Stem.*—The stem is much stouter than in the other species, some of the main stems being 2·5 mm. in diameter. It is usually buried in the humus which here forms the common covering of the old terrace—the common growth-bed, indeed, for all the plants thereon. Hence *R. subsericea*, whose branches ramify through this surface-soil, cannot be said to have a filling-material of its own.

The branchlets are all free, not closely compacted, and form the only part of the plant which comes above the surface of the substratum. They vary in length from 0·75 cm. to 2 cm., and their average breadth (including leaves) is 0·6 cm. They are densely clothed with leaves, which die away and hang down on the lower two-thirds of the axis. Their anatomy need hardly be described. The whole stem-structure is very similar to that of *Raoulia tenuicaulis,* except as regards the rather larger size.

(*b.*) *Leaf.*—The general shape is oblong-spathulate, but the lateral edges are almost parallel, and widen out but little towards the tip. The length is about 4 mm., and greatest width 1 mm. The lamina is concave upwards, more so towards the tip, which is subacute with a blunt terminal papilla. The upper surface is covered with short glandular hairs; so, too, the under-surface, except over the upper half, which has long sticky white hairs, which reach round and lap over the edge of tip. The sheath is no wider than the lamina.

The rosettes are spreading. As the branchlets are not closely compacted together, each rosette stands out well, and, although most of them touch some barely do so, while others are free and solitary. The leaves are spreading and more or less recurved, and from twelve to twenty leaves are visible from above. This rosette is the largest among the raoulias considered.

Generally the leaf-anatomy is much as in *R. tenuicaulis*, but the structure is more xerophytic—*e.g.*, cuticle thicker, especially on the upper surface; chlorenchyma a double row of cylindrical cells on the upper surface, and a single row below; water-tissue, hairs, stomata, &c., are similar to those in *R. tenuicaulis*.

(*c.*) *Root.*—The roots are rather straight, very wiry, and dark brown in colour. In many respects they resemble those of *R. Haastii*.

The older roots are strongly lignified. There is a central cylinder of xylem, with numerous very large vessels scattered irregularly through it. The phloem consists of a very thin zone, and external to this is a strongly lignified pericycle. The endodermis is conspicuous, and external to this is the suberized and rapidly disappearing cortex.

(*d.*) *Flower and Fruit.*—Capitula large, 0·8 cm. diameter. Involucral bracts in about three series, the inner with conspicuous white radiating tips. Florets about twenty, outer series female. Cypsela glabrous. Pappus-hairs copious, soft, slightly thickened at the tips.

### ($\gamma$.) EPHARMONIC VARIATIONS.

When this plant grows in dry exposed situations its growth tends to be more compact—the branchlets are shorter and the rosettes smaller. In moist situations the growth tends to become lax and luxuriant. Greenhouse cultures showed an elongation of the branchlets and an increase in the size of the leaf.

### ($\delta$.) EFFECT OF FROST.

Growing, as this plant does, in a usually moist humus substratum, the effects of freezing during the winter can be studied better than in the "river-bed" species, which grow on the usually dry shingle. In July, at noon, on a day after a severe frost, a few temperature observations were made on mats of *R. subsericea* growing on a moist slope of a low spur. The meteorological conditions were as follows: Sun obscured by drifting clouds; slight drizzling rain; north-west wind; snow falling on high ridges; temperature of air 6·25° C. The soil had been frozen hard during the night, and had thawed but little by noon. The temperature of the soil at the base of the mat was 0° C., while among the branchlets it was 4° to 5° C. It is quite evident that the rosettes were exposed to the full influence of the frost, but owing to the thick cuticle, the tomentum, and the terminal bud structure they could withstand it. The smallness of the rosettes in *R. subsericea* prevents temperature readings being taken in the field of the interior of the bud, but another Composite, *Celmisia spectabilis*, which grows on the low slopes of the spurs above the old terrace, shows in an interesting manner how terminal branchlets may behave during frost.

*Celmisia spectabilis* forms large clumps, often over 1 m. across. It has a mass of stout creeping stems, and the leaves, which average 15 cm. in length, are arranged on the short branchlets to form rosettes about 15 cm. across. The lower part of the branchlet, which is composed of the ensheathing leaf-bases surrounded by the dead and decaying old leaves, is about 4 cm. in diameter. These branchlets are embedded in a coarse filling-material of dead leaves and other organic debris, which during the winter is more or less saturated with moisture. During a severe frost the whole of this filling-material freezes solid. On chopping out a cube from the centre of a frozen clump a complete branchlet can be separated out with some difficulty. All that portion of the branchlet below the large rosette appears frozen hard, but on chopping it through transversely it is seen that only an external shell, about 1 cm. thick, is frozen. This shell consists chiefly of the *dead* leaf-bases. Within this frozen shell comes the central portion, which consists of numerous young leaves closely packed in tomentum, and quite normal and unfrozen. It is quite obvious from an analogy with *Celmisia spectabilis* that the central leaves of the *Raoulia* rosette, closely packed together with tomentum, are eminently adapted to resist such cold as they are likely to experience in the New Zealand mountains.

(ε.) Conclusions.

It is difficult to understand why this plant should be restricted to the moist old terrace, and *R. tenuicaulis*, an apparently more herbaceous form, to the lowest grades. An explanation may lie in the behaviour of the stems, which are always buried in the soil. This plant seems to require humus in which to grow. Its large leaves and total lack of filling-material are also mesophytic features.

## (F.) *Raoulia glabra.*

(α.) Habitat.

As far as the Cass Valley is concerned, this is a plant of ubiquitous habitat. Though its principal station is on the higher grades of terrace, yet occasional plants are found on the first grade. As will be seen later, its structure is less xerophytic than that of most of the other species of *Raoulia* dealt with, and its growing-place seems to account for this. It is not in the wide, open spaces of the valley that it is at its best, but in the lateral secondary gullies. Beside the creeks in the bottoms of these gullies occur large mats of this species growing luxuriantly. Specimens have also been observed at an altitude of 1,000 m.* It appears to have wide powers of adaptation, and no definite set of conditions limits its habitat.

(β.) Life-form.

(1.) *General.*—A "lax mat" best describes the growth-form taken by this species. It is easily the laxest of all the raoulias dealt with. The branches are prostrate, laxly intermingled, and the terminal branchlets are more or less distant from each other. The leaves of some rosettes barely

* Cheeseman (1906, p. 331) gives 4,000 ft. as its extreme altitudinal limit.

touch those of neighbouring ones, while in other cases the leaves of the branchlet are not in contact with anything. The contour is flat, but the surface is most uneven, due to the unequal length of the branchlets.

(2.) *Filling-material.*—In this species filling-material is practically non-existent. A small amount of decayed leaves forms a loose humus at the bases of the main branches.

(3.) *Coloration.*—This plant shows greater stability in colour than other members of the genus. During the summer the mat is of a light-green colour, and this changes but little during the winter. The edges of the leaves become very slightly tinged with anthocyan, and this is just sufficient to give the slightest suggestion of brown to the mat.

(4.) *Morphology.*—(*a.*) *Stem.*—The stems are wiry, creeping, brownish in colour, more or less covered with remains of the dead leaves, much more slender than in *R. subsericea*, being from 0·75 mm. to 1·5 mm. in diameter. Whereas in the latter species the stems are more or less buried in the humus, in *R. glabra* they merely trail on the surface and interlace with each other in the mat. Adventitious rootlets are given off as usual, but there is not such a firm hold of the ground obtained as in other species. It is quite easy to pull up large areas of the mat by grasping any portion of it, whereas in most of the other species any such attempt removes only a small local tuft.

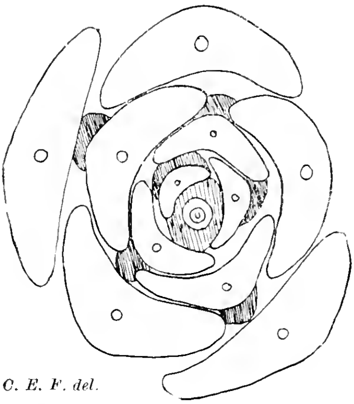
The branchlets greatly resemble those of *R. subsericea*; they vary in length from 1 cm. to 3 cm., and, including the leaves, are 7·5 mm. in diameter. Their axis tends generally to take up a vertical position, but is not as strictly so as in the previous forms. Being much more lax and but loosely in contact with neighbouring branchlets, they are capable of much movement, and when a mat grows in the shelter of a dense bush or a large stone the branches show strong positive heliotropism.

The anatomy of a young stem, on transverse section, shows the following structure: Epidermis very regular. Cortex of about four layers of parenchymatous cells, with chloroplasts. Endodermis not so clearly marked as in other species. Vascular bundles, about eight primary bundles. Pith, thin-walled parenchyma.

The anatomy of an old stem as growth proceeds exhibits the following changes: The cortical cells lose their contents and become flattened and suberized. In old stems the cortex falls away as far as the endodermis, or a layer or two outside it. The endodermis becomes much more strongly developed and conspicuous. In the early stages it is not too clearly defined from the cortical tissues, but as growth proceeds its cells enlarge, become barrel-shaped, and stand out distinctly from the roundish cells of pericycle and cortex. Secondary thickening commences early, and small strands of lignified fibres appear in the pericycle opposite the primary vascular bundles. The pith commences to lignify at the initiation of secondary thickening.

(*b.*) *Leaf.*—The leaves have very much the same shape as those of *R. subsericea*, though somewhat narrower. Their length is about 3 mm., and their breadth 0·75 mm. They have parallel edges, tapering for the last quarter of the length to an acute tip. The base is slightly broadened and clasps the stem. The midrib is visible as a groove on the upper surface, but obscure on the lower. The leaf is glabrous, save for a small area of white silky hairs on the dorsal surface, extending from the apex along the midrib for a third of the length.

The terminal rosette resembles that of *R. subsericea*, but is much smaller. In forms growing in dry situations the leaves are erect, but in forms from moist places the leaves are reflexed. The rosette of this species differs from that of *R. subsericea* in the amount of tomentum apparent in a transverse section. Fig. 8 represents diagrammatically the relative area taken up by the hairs in the terminal bud, there being about four times as much tomentum in the terminal bud of *R. subsericea*.



C. E. F. del.

Fig. 8.—Diagram of transverse section of rosette of *Raoulia glabra*.

A cross-section of a leaf shows the following structure (fig. 9): Epidermis, very regular cells; cuticle rather thin; stomata level with cuticle and found on both surfaces. The cells are elongated in the direction of the long axis of the leaf. Hairs as in *R. tenuicaulis*, arising from distal end of epidermal cell and leaning forward towards leaf-apex. At the leaf-base the lateral walls of the epidermal cells are straight, but become wavy towards leaf-tip. There is very little production of anthocyan in the epidermal cells. Chlorenchyma continuous round periphery of leaf. On the upper surface there are about three layers of cylindric or elliptical cells. On the lower surface there is a single layer of spheroidal cells. Water-tissue,

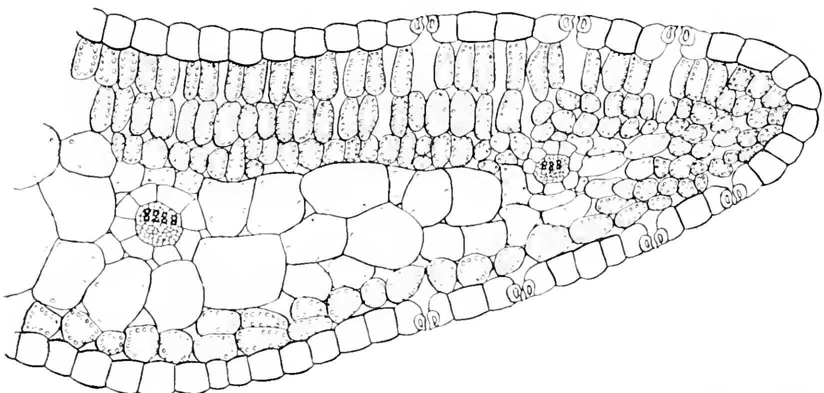


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Fig. 9.—Transverse section of leaf of *Raoulia glabra*.

a central tissue from one to three layers deep of large clear polygonal or spheroidal cells with scanty chlorophyll.

(*c*.) *Root*.—Fine and wiry; not so deeply penetrating as in other species.

(*d*.) *Flower and Fruit*.—The flower-heads are very large in comparison with the other raoulias. They are 6 mm. or 7 mm. long, and about 6 mm. in diameter. The involucral bracts are in three or four series. The florets are very numerous, varying from thirty to fifty. Female florets occupy the periphery, and are rather less in number than the hermaphrodite ones. The cypsela is oblong, slightly hairy, and crowned with a dense tuft of soft pappus-hairs.

(γ.) EPHARMONIC VARIATIONS.

Growing, as this plant does, in all portions of the Cass Valley upon grade 1 terrace, and on moist hillsides, in damp gullies, and on barren mountain-tops, it is but natural that much epharmonic variation should be exhibited. Those mats growing on the bare river-bed or on dry exposed mountain-ridges have a more compact growth-form, shorter branchlets, smaller rosettes, smaller, less membranous, and more hairy leaves than those forms which grow in the moist shady gullies. Plants grown in the greenhouse at sea-level developed an extraordinary length in branchlets and in leaves, which were almost glabrous.

(δ.) CONCLUSIONS.

Considering the various habitats of this plant as a whole, in the majority of cases it is found in moist and more or less shady situations. The forms found in drier and more exposed spots have shorter branchlets, smaller and less membranous leaves. But such exposed plants have the appearance of strangers to their habitat: they have a straggling and unhealthy appearance. Still, the fact that the plant does appear in these drier situations seems to point to considerable powers of adaptation.

## (G.) *Raoulia Monroi.*

(*a.*) HABITAT.

This plant occurs only on old terrace, and, from the positions in which it grows, appears to require a soil rich in humus and other water-holding material. Occasionally it is found near the edge of the old terrace, and often on the lowest parts of this, bordering on grade 3, but it is totally absent from the various grades of the transition terrace. Its mats seem to be able to grow on any part of the old terrace, and are found in open and exposed situations, as well as in the shelter of tussocks and *Discaria.*

(β.) LIFE-FORM.

(1.) *General.*—An "irregular mat" best describes the growth-form taken by this species. It seldom forms a "pure mat"—*i.e.*, a mat consisting entirely of its own vegetative growth—but grows on old consolidated terrace where many plants thrive, some of which are introduced species—*e.g.*, *Trifolium repens*, *Sagina procumbens*, *Hypochoeris radicata*, *Holcus lanatus*, *Cerastium glomeratum*. Indigenous plants occurring among its mat are, amongst others, *Hydrocotyle novae-zelandiae* var., *Anisotome aromatica* var., *Geranium sessiliflorum* var. *glabrum*, *Gnaphalium collinum*, *Plantago spathulata*, and several small species of *Carex* and *Luzula*, together with various mosses. When other plants occur to any extent among the mat it is difficult to distinguish the *Raoulia* itself; in such cases it does not strike the observer as a distinct individual mat, but its erect branchlets, often widely separated, appear as separate plants struggling with their neighbours.

The appearance presented by the mat is that of a number of short, erect, greyish-white branchlets, each with two opposite rows of leaves. These branchlets are all that can be seen of the plant, and they grow vertically upwards among the mosses and other low-growing vegetation of the terrace. *R. Monroi* can hardly be said to exist as a separate mat—certainly not as an entity, as in the case of, say, *R. Haastii;* but it, along with various other small plants, forms a thick plant-covering to various parts of the old terrace.

(2.) *Filling-material.*—This plant resembles *R. subsericea* in that its stems do not merely trail over the surface of the substratum, but are well buried beneath it. In no case are any main stems visible on the surface: they creep among the humus-laden soil at a depth of from 0·5 cm. to 2 cm. or 3 cm. Hence it can be seen that this plant cannot possess any true

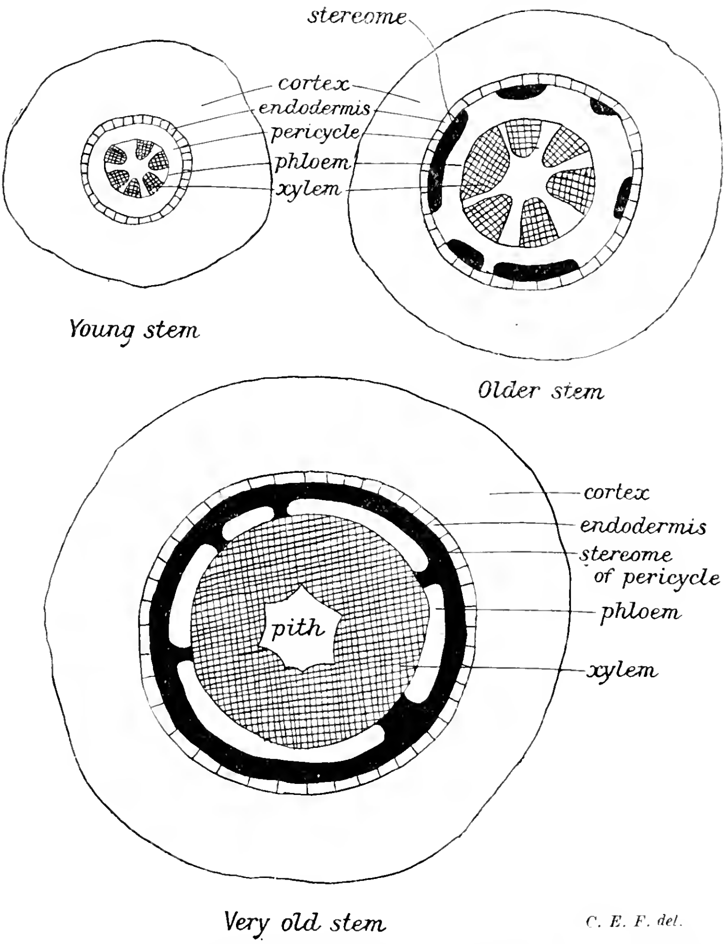


Fig. 10.—Diagrams of transverse section of stem of *Raoulia Monroi*, showing formation of stereome in pericycle.

filling-material. *R. Monroi* is really a plant with creeping and rooting underground stems, such as is found in *Cotula perpusilla* and certain other plants.

(3.) *Coloration.*—The general colour effect of the mat is a silvery grey. This is most obvious in a mat with the branchlets fairly close together and predominating over the intermingled moss and other low herbage. The greyness is due to the dense tomentum on the leaves. In winter the greyish colour is slightly suppressed, owing to a development of anthocyan in the leaf-margins.

(4.) *Morphology.*—(*a.*) *Stem.*—The stem is wiry, creeping and rooting. The main stems are horizontal and covered more or less with humus. The colour is a light brown, and the exterior is smooth, as the cortex does not fall away from this species so early as in the various species already described.

The branchlets have a flabellate form, with distinctly distichous leaves In this respect they stand alone among the types considered, and, indeed, among the whole genus. They average about 1 cm. in length and 0·4 cm. in breadth. At least half the branchlet is clothed with the strongly conduplicate leaves. The branchlets are by no means compacted together, so that the mat hardly presents a "surface" in the ordinary sense. The flabellate form of the branchlets is accentuated by the recurving exhibited by the leaves.

Transverse sections of a young stem show the same appearance as in the other species of *Raoulia*; indeed, the differences between the young stems of all the species are but slight.

In an old stem secondary growth soon commences, and, as in the other Raoulias, the pith soon becomes lignified.

A peculiar feature of the stem is the mode of growth of the bands of stereome-fibres in the pericycle. As soon as secondary thickening has well begun certain groups of cells in the pericycle begin to lignify, and this lignification extends tangentially until it forms a complete cylinder (fig. 10). The stereome groups commence opposite the primary vascular bundles. This stereome-cylinder connects on to the secondary wood at certain points. These points number from four to six, and are opposite the primary medullary rays. The cortex suberizes from the exterior inwards and falls away gradually.

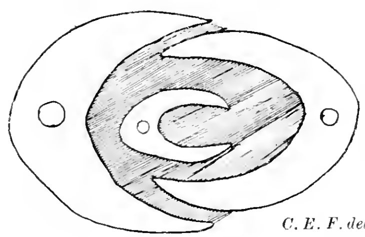

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Fig. 11.—Diagram of transverse section of rosette of *Raoulia Monroi*.

(*b.*) *Leaf.*—The leaves are oblong, with parallel edges and bluntly rounded tip, and arranged in two rows on the branchlets. The basal portion sheathes a part of the stem and the base of the leaf next above it. Both surfaces are covered with a dense white silky tomentum, especially the inner (upper) surface. The leaves are folded inwards along the midrib, and the dense mass of tomentum on the upper surface entirely fills the groove formed by the folding of the leaf. Owing to the apparent distichous arrangement of the leaves, there is no terminal rosette, as is so characteristic of the other Raoulias.

The proportionate amount of tomentum in the terminal bud is shown in fig. 11.

The contour of the leaf in transverse section is V-shaped, with the space between the arms densely filled with tomentum.

The leaf-anatomy is as follows:—Epidermis: Cells on upper surface flatter than below. Cuticle thinnish, same on both surfaces. Stomata on both surfaces; normal; sunken on lower surface, raised on upper. Hairs usual *Raoulia* type. Anthocyan in a few isolated cells in some leaves; in others it fills all cells. Chlorenchyma: Cylindric cells right round leaf; very dense at margins; two cells deep, except at midrib, where layer is single. Nearly every cell contains a large oil-drop. Water-tissue: About three layers of roundish cells; very few intercellular spaces; scanty chlorophyll. Vascular bundles normal.

(*c.*) *Root.*—Much as in *R. subsericea.*

(*d.*) *Flower and Fruit.*—Capitula 3 mm. long and about 1·5 mm. wide. Involucral bracts in three to four series. Florets from fifteen to twenty, the peripheral females the most numerous. Cypsela oblong, puberulous; pappus-hairs copious and slender.

($\gamma$.) Epharmonic Variations.

No epharmonic variations were observed in the Cass Valley, save that some mats had shorter branchlets closer together than others. Greenhouse cultures of six months' growth demonstrated a peculiar fact. The leaves on the ordinary branchlet are decidedly distichous as far as appearance goes, but the spring growths in the moist greenhouse produced branchlets with an *alternate* phyllotaxy. The writer was unable to obtain young plants or to make seeds germinate, but it is likely that the juvenile form has alternate leaves. This assumption is based on an analogy with the seedling forms of *R. tenuicaulis*, which have the same appearance as some of the new growth in older mats when these for some reason or other form a luxurious growth.

($\delta$.) Conclusions.

This species is rather a remarkable one, and although growing on old terrace it has so many xerophytic characters that it is probable that its habitat is of comparatively recent adoption. Its small densely hairy leaves are compacted into two opposite rows on the branchlets, thus giving as compact a branchlet as in the rosette-forms like *R. lutescens;* its upper stomata are covered by the tomentum, and the lower ones are sunken; its stems are strongly lignified, the pericycle-cylinder adding to the rigidity, though this stem-solidification may be an adaptation to the "burrowing" habit of the stem in the old terrace.

On the other hand, its reversion in a moist culture to an alternate leaf-arrangement like the other raoulias seems to point to a primitive mesophytic habit. The seedling forms of *R. tenuicaulis* and *R. australis* have a much more mesophytic appearance than the adult, and possibly the seedling form of *R. Monroi* shows similar features.

Again, *R. Monroi*, by its "scattered" mat, intermingled with other plants, illustrates the transition from the mat-form to that growth-form where an underground stem sends up tufts of leaves at intervals.

Now, this plant is much more compacted in drier situations, and in some places in the Lower Waimakariri Valley the writer has observed it forming a comparatively close mat. In the Cass Valley it appears to be adopting a mesophytic habitat and growth-form. It has been suggested above that its seedling form is probably of mesophytic structure. Does this bear out Cockayne's theory (1910, p. 62) that the ontogeny of some of the indigenous plants affords a clue to the former climate of New Zealand?

(H.) *Scleranthus biflorus* var.*

($\alpha$.) Habitat.

*Scleranthus biflorus* is found chiefly on old terrace, and to a less extent on grade 3. It is totally absent from grade 1, and occurs occasionally on grade 2 where this merges into grade 3.

* This variety of the species is *not* the type, since it is only one-flowered and of somewhat different growth-form.

(β.) Life-form.

(1.) *General.*—This plant forms a true cushion, especially when growing on a substratum with a very open plant-covering, where it forms convex cushions of varying sizes, and depths up to 12 cm. The contour is regular; the surface is rough owing to the subulate leaves. This plant differs from those previously considered in possessing a very conspicuous long, stout, central tap-root, and on a sandy or shingly substratum the adventitious rootlets put forth from the horizontal stems are very few. In such situations the whole cushion is remarkably loose when uprooted, and its branchlets do not adhere together as, for example, in *Raoulia Haastii* or *R. lutescens.* The cushion is not tightly compacted, and is easy of penetration. On moist parts of the terrace, however, the cushions are flatter, there are copious adventitious roots, and the margin of the cushion gradually merges into the surrounding low herbage. In fact, its growth-form in such situations is almost a mat.

(2.) *Filling-material.*—Visible filling-material does not appear till about half-way down the cushion. The leaves on the branchlets below the rosettes die and become a straw colour, but are slow to decay, and for at least the depth of the branchlets no free filling-material occurs. Lower down, among the older branches, appears humus, which is dark-coloured on the old terrace, but lighter and containing much sand on the river-bed. As stated above, the whole cushion is remarkably loose, and the single-rooted river-bed forms of this plant can be uprooted, inverted, and have all their filling-material shaken out. On old terrace filling-material appears sooner, and quickly merges to a dense black humus, in which the lower stems are buried: indeed, in such situations the dividing-line between filling-humus and the actual soil of the terrace is indistinguishable.

(3.) *Coloration.*—The spring and summer colour of the cushion is a light green with a faint tinge of yellow. In late autumn and winter the colour is a brownish yellow. The causes of this coloration are discussed under "Leaf-anatomy."

(4.) *Morphology.*—(*a.*) *Stem.*—The main stems are prostrate, and radiate from the top of the large central tap-root; on river-bed substrata they lie on the surface, but on old terrace they are more or less buried in the surface soil. They have practically the same mode of growth and branching as in some *Raoulia* forms, but the stems lack the rigidity of the latter. They are perfectly supple, being in fact as supple as solid rubber: the cause of this is explained by their anatomy. They are of a pale-straw colour: the upper branches are clothed more or less with the remains of the dead leaves, which do not decay away so rapidly as in the raoulias.

The branchlets, with the leaves, are about 4 mm. in diameter, but the leaves (1 cm. long) are subulate and in opposite not very close pairs. The branchlets are lightly compacted in the cushion, but have no coherence.

Transverse sections of a young stem show the following anatomical structure: Regular epidermis with well-developed cuticle; cortex of spheroidal parenchyma bounded on the inner side by an endodermis with thick walls, giving a dark-brown reaction with chlor-zinc-iodine, and probably strongly suberized; pericycle of several layers of parenchymatous cells; vascular bundles of normal structure; and a small parenchymatous pith.

Regarding the anatomy of an old stem the following points of importance occur: A phellogen appears in the pericycle, which forms layers of tabular cork cells, with the result that the endodermis and cortex are thrown off. The walls of the pericycle cells within the phellogen become enormously thickened by depositions of cellulose.* The secondary xylem is not all lignified, but consists of strongly lignified spiral vessels, interspersed among prosenchymatous elements with thick cellulose walls.

(*b.*) *Leaf.*—The leaves are arranged decussately in opposite pairs. They are about 3 mm. long, subulate, pointed, slightly curving inwards towards the axis. In section they are semicircular, with broad sheathing membranous bases, and resemble very much the leaves of *Raoulia Haastii*. The general colour is a light yellowish-brown, and in winter a small amount of anthocyan occurs in the edges of the sheath near the commencement of the subulate part.

The rosettes much resemble those of *R. Haastii*, but the leaves are not so closely appressed to the axis, and the tips are more acute. About twelve leaves are visible from above.

Transverse sections of the subulate part of the leaf show the following anatomical structure:—Epidermis: There is a very thick cuticle, which is rather uneven and ragged on the exterior, and as thick as depth of epidermal

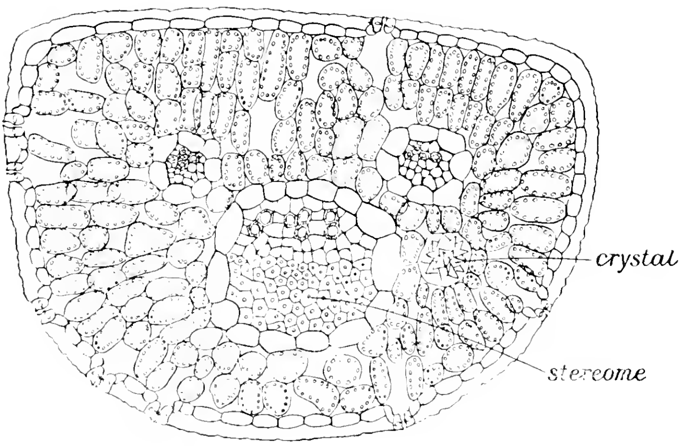



FIG. 12.—Transverse section of leaf of *Scleranthus biflorus*.

cells. Epidermal cells very regular. Stomata: Guard-cells as large as epidermal cells; walls thick; level with cuticular surface; on all surfaces of leaf. Chlorenchyma: Cells show practically no differentiation; ellipsoid or cylindrical, and rather loosely packed. Air-spaces fairly abundant, and many are large; a definite air-space below each stoma. Chromatophores in all cells save those of the bundle-sheath; large, ovoid, green to yellow, with many granules. The granules vary in number, are strongly refractive, and are apparently of a brownish or reddish colour, but are so minute that accurate observation is difficult; probably they are oil-drops. They are most numerous in older leaves: here the plastids are yellow; in young leaves the plastids are green. Most likely these globules, if oil-drops, may represent degeneration products of the chloroplast. Crystals: Large crystal aggregates of calcium oxalate occur in large cells close to midrib. These

* In old stems the cell lumina are almost obliterated. The cells are about twice as long as broad, and their walls take on a faint violet colour with chlor-zinc-iodine.

crystals are very large in proportion to the size of the midrib—in some cases they are half the size of the cross-section of central vein. Vascular bundle: Sheath very distinct, of large, clear, ovoid cells. Stereome: Two-thirds of the bundle consists of a rod of stereome below the phloem. Phloem of small parenchymatous cells and sieve-tubes. Xylem apparently weak; the large central bundle has five to ten vessels, between which is xylem parenchyma. Smaller bundles occur above the main one, but possess no stereome.

(*c*.) *Root*.—The tap-root is long, often attaining 30 cm. in shingly substrata. On old terrace it is much shorter. It is pale straw-colour, flexible like rubber, and has an internal anatomy very much like the adult stem. In deep cushions with much filling-material adventitious roots are given off into the interior.

(*d*.) *Flower and Fruit*.—The flowers were not observed, but Cheeseman (1906) describes them thus: "Flowers minute, in pairs, or more rarely solitary at the top of the peduncle, sessile within four minute concave bracts placed crosswise. Perianth 4-lobed. Stamen one, inserted on an annular membrane near the mouth of the perianth. Fruiting perianth about $\frac{1}{12}$ in. long, hard, ovoid at the base; lobes erect. Utricle membranous, included."

The fruit is a membranous utricle enclosed in the persistent and hardened perianth. Seed lenticular, smooth. The fruits easily break off, and many fall on the surface of the cushion.

### (γ.) EPHARMONIC VARIATIONS.

There are two growth-forms, as stated above—one a cushion with tap-root only, and the other almost a mat with adventitious rootlets. The habitats of these two forms have been already given. Greenhouse cultures produce a lax growth, which, save for the decussate phyllotaxy, much resembles that of *Raoulia tenuicaulis*.

### (δ.) CONCLUSIONS.

The outstanding feature of this plant is its xerophytic character. Its long flexible tap-root—very obvious in pure river-bed forms—enables it to exist among shingle when the water-table has been much lowered. Its thick sheath of cellulose-thickened pericycle serves as a protective pad against the crushing effects of moving shingle.

Its stems, which in the young stage have a well-marked endodermis, in adult forms have a coating of cork and cellulose. This shuts off connection between the central conducting cylinder and the exterior, and allows of maximum efficiency in water transport. The leaves show many xerophytic features—subulate erect form, thick cuticle, stereome-strand. On the other hand, their chlorenchyma is not closely packed, and water-tissue is absent.

Lastly, one of the growth-forms of the plant—a nearly hemispherical cushion—is a common xerophytic character.

## (I.) *Coprosma Petriei*.

### (α.) HABITAT.

*Coprosma Petriei* is confined to old terrace (terrace proper). It occurs on all portions of the terrace, and on the lower slopes of the bordering hills, especially on consolidated "shingle-fans." It grows densest, however, and in greater quantities near the edge of the terrace bordering on the river-bed, where it forms thick mats, curving over the terrace-edge, and forming a rounded "beading" often several metres long.

(*B*.) LIFE-FORM.

(1.) *General.*—The growth-form of adult plants is a dense, widely spreading flat mat. Occasionally the growth is so close as not to allow the establishment of other plants among it, but usually the creeping branches are matted in amongst a great variety of other plants. The contour is usually smooth, but the surface is very rough, being formed by the tips of the small coriaceous acute leaves, arranged more or less vertically. In late autumn numerous drupes, port-wine-coloured, or of various shades of translucent greenish-blue,* are very conspicuous, as they lie in vast quantities half-buried in the mat.

This plant, having a woody creeping stem, and short woody branchlets which project above the surface of the soil, cannot be said to have filling-material any more than has *Raoulia Monroi*.

(2.) *Coloration.*—The usual colour of the leaves is a dark green. During the winter, however, the upper surface, the margins, the lower midrib, and parts of the lower surface assume a dark-brownish tint, due to the formation of anthocyan in the subepidermal cells. The pigmented sap does not occur in the epidermal cells, but in certain cells and areas of cells in the outer layer of mesophyll, chiefly in the palisade.

(3.) *Morphology.*—(*a*.) *Stem.*—The main stems are woody, brittle, yellowish, and stout, being often as much as 0·5 cm. in diameter. They are horizontal, subterranean, root copiously, and give off secondary branches which end in branchlets as in the raoulias.

The branchlets vary in length from 0·5 cm. to 2 cm., and the axis averages 1 mm. in diameter. Towards their distal ends they are crowned with a small tuft of spreading leaves, arranged in opposite pairs on the axis.

The young stem shows the following anatomical structure:—Epidermis: Small oval cells; cuticle thin, wrinkled, yellowish. Cortex: Cells thin-walled, spheroidal, loosely packed; certain of the cells in the outer layers contain anthocyan—this causes the spots and streaks of red or purple on the young stem. There is a distinct large-celled endodermis. Stele: Phloem rather wide; four or five xylem masses. Pith: Polygonal cells containing much starch.

The anatomy of a mature stem is as follows: Secondary growth soon commences. Secondary xylem quickly forms a complete ring. The pith also soon becomes lignified. A cork-cambium forms in the inner layers of the cortex, and soon the tissues exterior to this are shed. The vessels of the secondary wood have very large lumina. The walls of the lignified pith in old stems are very thick and pitted.

(*b*.) *Leaf.*—The leaves are borne in opposite pairs on the branchlets. A peculiar feature, characteristic of the whole genus, is the form of the stipules, which are united at the sides of the node between the bases of the pairs of leaves, and are hence interpetiolar in position. The leaves are from 4 mm. to 7 mm. long, oblong-lanceolate, gradually narrowed into a short petiole, and with an acute apex; they are distinctly thick and coriaceous, with obscure venation. Both surfaces, but chiefly the upper, are

* There are apparently two well-marked varieties.

clothed with distant short white bristly hairs. The whole leaf is slightly incurved; its average position is vertical. There is no great difference between the marginal leaves and those nearer the centre of the mat.

This is the first of the types considered where the rosette ceases to become conspicuous. The branchlets are short, and bear from two to six leaves, which stand out stiffly, and do not form a distinct rosette.

A transverse section of a leaf shows the following anatomical structure:—Cuticle thick. Stomata on both surfaces, level with surface of cuticle. Hairs arising from a single epidermal cell, unicellular, short, tapering bluntly, slightly curved, shaped like a cow's horn, and covered with minute papillae. Mesophyll: Palisade three layers, upper two fairly regular and closely packed; upper layer has red anthocyan in winter; the palisade occupies approximately half the thickness of the leaf. Spongy tissue of rounded cells, rather closely packed for aerenchyma; air-spaces not large or numerous. Oil-globules plentiful; a large one occurs in each cell of mesophyll. Crystals abundant. Chloroplasts small and numerous.

(*c*.) *Root.*—In old mats it is difficult to distinguish any main root, because a mass of adventitious roots spring from the lower surfaces of the creeping stems. The larger roots are tough and woody, have large vessels, and show an internal structure much the same as the stem.

(*d*.) *Flower and Fruit.*—*Coprosma Petriei*, like the other members of the genus, is dioecious. The flowers are solitary, terminating the branchlets. The corolla is inconspicuous, a purplish grey, funnel-shaped, four-lobed, and about 8 mm. long. The female flowers have a minute four-toothed calyx, but this is wanting in the males. There are usually four exserted stamens, with long filaments, and large anthers, producing copious dry pollen. Styles two, long, papillose, sticky. Fruit an ovoid drupe, very succulent, containing two one-seeded plano-convex pyrenes. The red or greenish drupes are very attractive to birds, which are the agents of distribution for this species, as evidenced by bird-droppings containing masses of *C. Petriei* pyrenes.

(γ.) Relation to other Plants.

Seldom does this species occur as a "pure" mat, but is usually intermingled with other plants. Only on the "banks" of the old terrace are "pure" mats found. On old terrace one mat, having an area of 1 square metre, had the following plants mingled with it: *Festuca novae-zealandiae*, *Discaria toumatou*, *Raoulia subsericea*, *Hypochoeris radicata*, *Holcus lanatus*, *Geranium sessiliflorum* var. *glabrum*, *Rumex Acetosella*, *Gnaphalium collinum*, *Muehlenbeckia axillaris*, *Styphelia Fraseri*, *Cerastium glomeratum*.

(δ.) Conclusions.

This species, like the previous ones, shows complete adaptation to its environment. Its mat-form, its woody stems and tough roots, and the xerophytic nature of its leaves are all in harmony with its surroundings. The copious production of dry pollen, the pendulous papillate glutinous styles, and the small inconspicuous flowers point to wind-pollination; and, as wind is only too much in evidence in the Cass Valley, this means of pollination should be very efficient. Distribution of the seed by birds is well provided for. Another xerophytic character in common with the raoulias is the conspicuous endodermis. The oil in the mesophyll cells deserves notice, and may be perhaps explained by Haberlandt's suggestion of its providing a screening vapour (1914, p. 515).

### (J.) *Pimelea prostrata* var. *repens*.

This is not a true cushion-plant. *P. prostrata* has several varieties, ranging from suberect to prostrate, but as the plant I am calling var. *repens* has many characteristics in common with the true cushion-plants it is included here and briefly considered.

Its habitat is grades 2 and 3 and old terrace, but it is most abundant on the latter.

The growth-form is either a deep mat or a convex cushion (Plate V, fig. 1). There is one main central root, from the top of which radiate many branches, which trail horizontally over the shingle, and give off many secondary branches terminating in lax branchlets. The stems are woody, tough, and flexible. But few adventitious roots are given off from forms growing on a shingly substratum, though forms on the old terrace root copiously.

The plant in question is undoubtedly the loosest of all the plants considered; no filling-material exists. The main root (Plate V, fig. 2) is usually very long—in one case as much as 60 cm.; it penetrates more or less vertically. The leaves are quadrifariously imbricated on the branchlets; elliptic-oblong, coriaceous; length, 3 mm. During the winter anthocyan is developed at the leaf-edges. On old terrace this plant assumes a more spreading habit, with laxer stems and larger leaves.

The long root (for the size of the plant), small coriaceous leaves, and stunted form point to a plant adapted to a substratum where the water-table is liable to fall considerably. As far as this paper is concerned, the main point to note is the long tap-root and spreading (espalier) habit of the branches.

### (K.) *Muehlenbeckia axillaris* and *Acaena microphylla* (in its widest sense).*

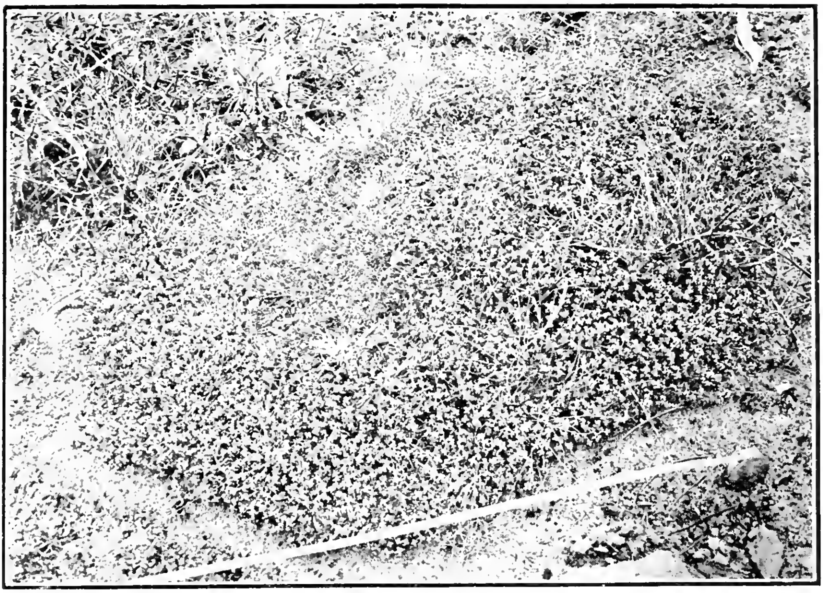
These two forms hardly fall within the category of "cushion-plants"; they are mat-plants in the widest sense. Both are woody, *Muehlenbeckia* most so. Both straggle unevenly over the surface of the shingle or hang down over "banks"; but as these two, especially *Acaena*, are among the most plentiful of the plants on the river-bed it is admissible to treat of them, however briefly.

*Muehlenbeckia axillaris* occurs on all grades of terrace above the second. It especially grows on the edges of the "banks" of the various terraces. Plants were also found at an altitude of 1,000 m. The growth-form is a loose mat of interwoven wiry branches sparsely covered with small leaves. The mats vary in depth from 3 cm. to 4 cm., and are of all diameters up to 50 cm. The leaves are more or less vertical, and to a certain extent form the surface of the mat.

The stems are wiry, tough, and black. The leaves are small, ovate-oblong, dark green, coriaceous, and about 4 mm. long. The roots are tough and wiry, and are produced abundantly from the stem. The flowers are dioecious. The fruit consists of a small black triangular nut, surrounded by the lobes of the perianth, which becomes white and succulent. There is no filling-material. In winter the leaves develop anthocyan.

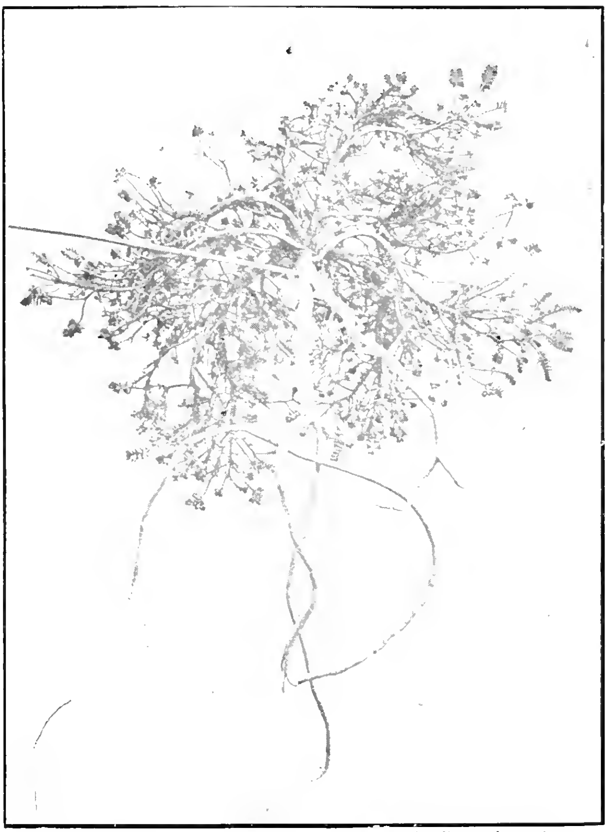
The succulent perianth should provide for distribution by birds, but the writer observed no seedlings. The plant is propagated chiefly by

* This is an aggregate species with two main divisions—perhaps species—which even in the limited area dealt with contain numerous well-marked forms.



[C. E. Foweraker, photo.

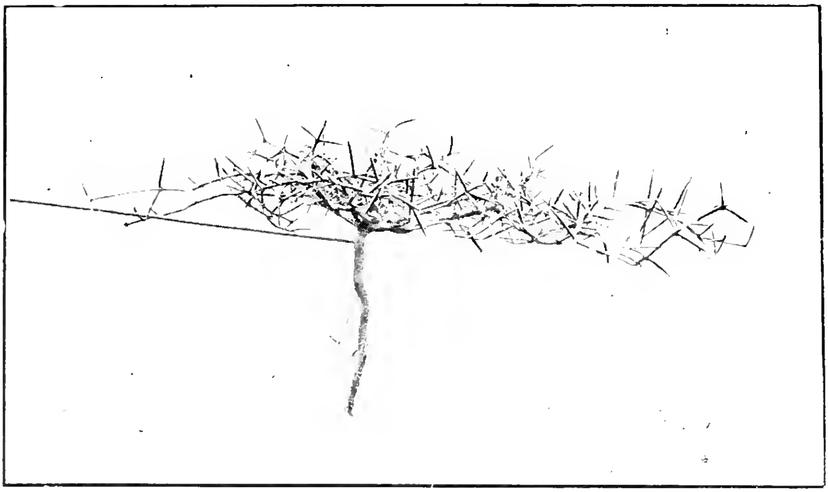
FIG. 1.—*Pimelea prostrata* var. *repens*, showing its cushion-form. (Tape 50 cm. long.)



C. E. Foweraker, photo.

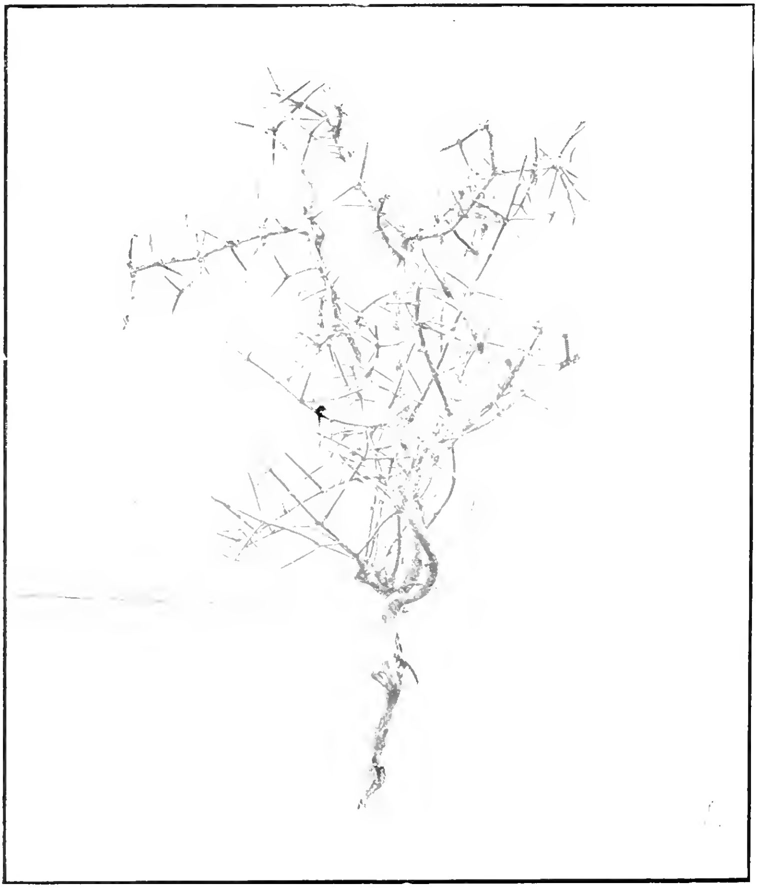
FIG. 2.—*Pimelea prostrata* var. *repens* of grade 2, showing its mat-form. (Note the long, thick, smooth roots.)

*Face p. 38.*]



[C. E. Foweraker, photo.

Fig. 1.—*Discaria toumatou* of grade 2 terrace, showing the "espalier-form."



[C. E. Foweraker, photo.

Fig. 2.—*Discaria toumatou* of old terrace, showing the erect form.

vegetative means. Small branches are broken off during floods and washed down-stream. Those which are stranded and partially covered with gravel soon take root and produce a new mat. The chief characteristic of the stems is their capacity to creep *round* and *under* stones; they rarely creep *over* large boulders.

*Aeaena microphylla*, in several varieties, is ubiquitous in the Cass Valley, and, growing well on bare spots, it naturally invades the river-bed. The stems are quite prostrate, branch copiously, sending up at intervals short vertical branches which bear the leaves and later the flower-heads. The stems are very tough and wiry, and creep with ease among the shingle. Roots are sent down frequently which hold the plant firmly, so that it is difficult to root up lengths of it. The leaves are about 4 cm. long, pinnate, with three to six pairs of leaflets, and have the usual *rosaceous* form. They have varying degrees of hairiness, and are usually membranous. They lie at varying angles, and form the uneven surface of the mat. The flowers are in heads, and the fruiting-calyx is pyramidal, four-angled, often with a bristle at each angle. Greenhouse cultures resulted in a form with longer, larger, more erect, and less hairy leaves.

The chief point to notice about the above two species is the fact that when growing on river-bed they become more wiry, more compact, have smaller leaves, and show anthocyan development—in a word, they assume xerophytic features. They have great capacity for spreading rapidly over the shingle, and to this end their stems can burrow among and thrust aside the shingle with ease.

## (V.) Chief Characteristics of the Cushion-plants.

The brief survey of the Cass cushion-plants just given brings out clearly certain points of ecological importance, such as their adaptations, the extreme convergence which they exhibit, their winter coloration, and their various habitats. In the descriptions of the different species certain general characters of cushion-plants have been brought out, which are discussed under the heads which immediately follow.

(*a*.) *The Cushion Growth-form*.—The fact of plants belonging to such diverse families as Polygonaceae, Caryophyllaceae, Rosaceae, Thymelaeaceae, Rubiaceae, and Compositae assuming the mat or cushion form illustrates in a striking way the principle of convergence.* Considering such forms as the raoulias, *Scleranthus biflorus*, and *Pimelea prostrata* var. *repens*, we find them all assuming the same growth-form. In all the above there is (primarily, at any rate) a main central root, from the top of which radiates a series of copiously branching prostrate stems whose vertical ramifications, becoming more and more closely packed together, finally end in the terminal branchlets. These, clothed with leaves, are compacted together in varying degrees of density, giving corresponding degrees of solidity to the cushion. Their terminal buds and leaves constitute rosettes, which together go to form the surface of the cushion.

Not only do these different plants resemble each other in their shoot-branching, but some possess filling-material into which penetrate a greater or smaller number of adventitious rootlets.

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* Were *all* the New Zealand cushion-plants being considered, the number of families would be much greater and the convergence far more pronounced.

This cushion-form is apparently well fitted to the environment. Wind, rain, frost, desiccation, and snow are the influences to which the above plants are variously subjected, and their particular growth-form is perfectly adapted to resist the harmful influences of these conditions.

(*b.*) *The long tap-root* is conspicuous only in *Scleranthus* and *Pimelea*. It exists in the other forms as well, but is so early reinforced by hosts of adventitious roots that it does not reach a high state of development. Similar tap-roots are characteristic of many plants growing among shingle. It is not difficult to see the advantage and importance of such an organ. On the lower grades of terrace the water-holding capacity of the shingle is low. As already noted, rain rapidly soaks away, and the moisture-content largely depends on the depth of the water-table. Hence the value of a long root is sufficiently obvious. Also the fact must be noted that both the *Pimelea* and the *Scleranthus*, the former especially, are rather of open growth: in fact, the former possesses no filling-material whatsoever, and has to depend upon the distant water-supply of the substratum.

(*c.*) *Filling-material*, as already described in detail, exists definitely in *Raoulia tenuicaulis*, *R. lutescens*, *R. Haastii*, and *Scleranthus biflorus*. This material, combined with the compactness of the cushion, forms a medium which has considerable water-absorbing and water-holding capacity—*i.e.*, the body of the cushion is really a sponge reservoir. The possession of such a mass of absorbent material renders the plant more or less independent of its substratum; indeed, it really has an ecological station different from its neighbours devoid of filling-material. The large cushions of *R. Haastii* are quite moist inside, even though the shingle all round them is practically devoid of water for a considerable distance below the surface. The branches of such a plant give out copiously adventitious roots into the filling-material, and it really is equivalent to a plant growing on a humus substratum.

(*d.*) *Stem-structure.*—The most striking feature in the stem-anatomy of the raoulias is the well-developed endodermis. Haberlandt (1914, p. 373), quoting Schwendener, explains that climatic and edaphic conditions react upon the structure of the endodermis, which is always specially strengthened in the roots of lithophytes and steppe-plants, the endodermis becoming thickened to quite an extraordinary extent, "evidently in adaptation to the alternation of periods of abundant water-supply with severe droughts." Further (p. 371), Haberlandt says, "By this means [*i.e.*, by the endodermis] the ventilating system of the cortex is permanently shut off from that of the central cylinder, with the result that considerable negative pressures can be maintained in the water-conducting channels." If this view be accepted, the strongly developed endodermis of many of the plants must be a structure of considerable importance in relation to the edaphic conditions. Certainly the above opinion of Haberlandt refers to the endodermis of roots, but the same should be true of stems.

Another adaptational feature of the stem is the early lignification of the whole central column of pith and wood. This would appear to be a structural arrangement favourable to the pushing of the stems forward over and amongst the shingle and sand. Haberlandt (*l.c.*, p. 184) says, "Those rhizomes which serve to fix the plant in the ground agree with roots in having their mechanical tissues united to form a stout axile tube or a solid central strand." Besides being able to force its way among the shingle, the stem also is adapted to resist the crushing influences of boulders and other debris which are washed on top of it in times of flood. Such apparently is the function of the pericycle stereome which forms a cylinder round the phloem.

(*e.*) *Leaf-xerophily.*—The xerophytic characters of the leaves are obvious in the many forms considered. As such features of a leaf are directed chiefly towards checking transpiration, it seems well to sum up the various methods of checking transpiration exhibited by the plants under consideration:—(i.) Reduction in transpiring-surfaces: All the species have small leaves, and, where the same species occupies different habitats, the more xerophytic the habitat the smaller the leaf. (ii.) Vertical position of leaves: Most of the leaves tend to assume a vertical position. (iii.) Compacting of leaves: These are often closely appressed to the axis of the branchlet, and the branchlets are closely compacted together. (iv.) Anatomical modifications of the epidermis: (*a*) Well-developed cuticle—*e.g.*, *Scleranthus;* (*b*) hairs—*e.g.*, raoulias; (*c*) position of stomata—sunken in some species. (v.) Water-storage tissue—*e.g.*, all the raoulias. (vi.) Presence of oil—*e.g.*, *Coprosma.* (vii.) Few intercellular spaces.

(*f.*) *Water-storage.*—One characteristic feature of the leaves of all the raoulias is their central mass of aqueous tissue. This tissue consists of large polygonal cells which exactly answer Haberlandt's description of water-tissue (1914, p. 398). During the heavy rainfalls water can be stored up in this central tissue, and during drought, when desert conditions prevail on the river-bed, the stored water can be gradually given up to the photosynthetic tissue.

(*g.*) *Coloration and the Rôle of Anthocyan.*—Haberlandt (1914, p. 117) explains how many evergreen leaves acquire a reddish colour in winter owing to the formation of anthocyanin, in which case the chloroplasts require special protection against the injurious action of light, because no appreciable regeneration of chlorophyll takes place at the low temperatures which prevail at that season. Again (*l.c.*, p. 42), he states, "Anthocyanin is also widely distributed as a constituent of the cell-sap in vegetative organs, especially in leaves, where it in many cases probably acts as a light-screen which prevents excessive illumination." The same author also states (*l.c.*, p. 118) that Stahl has shown that leaves with anthocyan became 1·5° to 1·82° C. warmer than leaves without it when placed 30 cm. from a bat's-wing gas-flame. Stahl considered that this increased temperature in the anthocyan-containing leaves would accelerate metabolism and translocation.

Both the screen and the heating theory would seem to fit the case in the cushion-plants of this paper. The plants are fully exposed; they grow where no shade is possible: thus the screening hypothesis is tenable. Further, the cold of the Cass Valley during the winter would seem to demand a heat-absorbing agent (anthocyan) in the leaves.

In support of these contentions the reader is referred to the experiment with *Raoulia Haastii* described on p. 21. No anythocyan to speak of was developed; the plant remained as green through the winter as when removed from its natural habitat, while the original cushion from which it was cut became, like it fellows on the river-bed, a deep chocolate-brown.

But Haberlandt concludes (*l.c.*, p. 118), "It must, in short, be admitted that, in spite of numerous interesting detailed observations, the general physiological and ecological significance of the presence of anthocyanin in vegetative organs is still very obscure." Cowles (1911, p. 529) ends his discussion of this subject in a still more disheartening manner: "Few of the theories here mentioned are more than guesses, and it may be that the red pigments are merely the indices of certain chemical activities that are quite without functional significance."

(*h.*) *The Effect of the Mat and Cushion Plants in Consolidating the Lower Terraces.*—An important rôle played by *Raoulia tenuicaulis, R. lutescens.* and *R. Haastii* is apt to be overlooked at first—viz., the formation of a humus layer and the consolidation of the terrace. *R. tenuicaulis,* as stated above (pp. 7, 8), covers large areas with a mass of contiguous mats which increase in depth, more and more filling-material collects, and sooner or later other plants begin to grow thereon. The rich humus-bed is an excellent germinating-ground for various seeds. and soon such *Raoulia* areas support a varied plant-community.* Later on the *Raoulia* commences to die out in patches. thus contributing further to the depth of humus, and so the surface of the shingle is consolidated, and becomes a fit habitation for other plants.

## VI. Evolution of the Cushion-plants.

Before concluding, some speculations regarding the evolution of cushion-plants seem allowable.

It is easy to see the suitability to the habitat of the cushion-form, with its surface composed of the rosettes terminating the branchlets. It can be seen, too, that the branchlet-rosette form is adopted by many foreign alpine plants, such as saxifrages and gentians. In New Zealand, on sub-alpine fell-field or herb-field, such plants as *Celmisia spectabilis. C. coriacea,* and *C. Armstrongii*, composed of a mass of large rosettes, are abundant. At higher altitudes are species having smaller rosettes and smaller leaves (*e.g., C. viscosa, C. Sinclairii,* and *C. Haastii*). At greater altitudes still occur species with still smaller leaves, still smaller rosettes, and still greater compactness of growth-form (*e.g., C. argentea, C. sessiliflora,* and *C. laricifolia*).

A similar gradation occurs in *Raoulia.* This genus has much the same growth-form as *Celmisia*, but the plants are generally smaller in every respect. We can trace a gradual transition from a large-leaved, lax. mesophytic form with large rosettes like *R. glabra* to a firmer form like *R. subsericea;* then to shingle-tolerating forms like *R. australis;* and upwards through such forms as *R. lutescens* and *R. Haastii*, until we arrive at a form like *R. eximia*, a denizen of dry alpine and subalpine rocks, one of the famous "vegetable sheep" of New Zealand. and one of the most remarkable cushion-plants in the world.

From a comparison of such forms we may conclude with Cockayne† (1912, pp. 21, 22, and 1911, p. 119) that the cushion-plants must have arisen from a mesophytic form with large leaves; from this form variants or mutants arose which were better adapted to dry habitats, and which survived while the others perished. This process of natural selection doubtless went on till now we have the numerous species before us.

If we accept the recapitulation hypothesis of certain evolutionists, the proof of the above course of events lies in the ontogeny of the various species. Let us recall the seedling stages of *Raoulia tenuicaulis.* The seedlings

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* See similar remarks by Cockayne regarding the "epiphytes," as he calls them, upon a cushion of *R. Haastii* (1911, pp. 121–22). On one cushion seven different species were noted.

† Cockayne, however, appears to attribute the change of growth-form entirely to the cumulative effect of xerophytic conditions, and allows nothing for mutations or Darwinian variation.

are erect, and have comparatively large broad leaves and rosettes. As growth proceeds their branches become prostrate, their branchlets become compacted together, and the true cushion or mat arises. May we not assume here that ontogeny recapitulates phylogeny? May we not suppose that our cushion-plants have arisen from lax, broad-leaved, mesophytic forms?

We can easily perceive how the leaves of our raoulias could become smaller and more closely appressed to the stem as xerophytic conditions increased, but the difficult point is how the *prostrate* form arose. Why do the main stems lie prostrate on the ground? This question is partially answered by observing some of the other plants on the river-bed. Let us consider *Discaria toumatou*. Plants of this species on the shingle have a stunted form with quite prostrate branches (Plate VI, fig. 1), the "espalier-shape" of Warming (1909, p. 26). On the moist old terrace, plants of apparently the same age are upright, this being the normal form (Plate VI, fig. 2). Similarly, gorse (*Ulex europaeus*) assumes the espalier-shape on shingle. Such forms as *Helichrysum depressum* are true espaliers. What causes this espalier shape? Wind? Insolation? Desiccation? It cannot be wind or the direct sun's heat—*i.e.*, insolation—because both river-bed and old terrace are subjected to equal amounts. It must be desiccation—the influence of the dry shingle. Just *how* the shingle affects the plants cannot be told. Warming (*l.c.*) says, "Probably the cause must be sought in the difference of temperature of the air and soil at the time when the shoots are developing." The writer has noticed the same habit among weeds in a gravel-pit. Here many of the ordinary introduced weeds that are more or less erect in normal situations take on the espalier habit. Further than this it does not seem wise to speculate.

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## APPENDIX.

Since the above article was received for publication, a paper entitled "Anatomische Untersuchungen an Polsterpflanzen nebst morphologischen und ökologischen Notizen" (*Beihefte zum Bot. Centralb.*, Bd. 33, pp. 275–93, 1916), dealing with a number of New Zealand cushion-plants, has been sent to me by its author, Dr. H. Hauri, of St. Gallen, Switzerland. As it concerns in no small degree the cushion-plants of New Zealand, in the absence of Mr. Foweraker, now bravely serving his country at the front, I am adding this brief appendix.

Hauri, by anatomical investigations, similar to those of Foweraker but far less detailed, endeavours to find the relationship in cushion-plants between anatomical structure and habitat, and also to determine if there is an anatomical as well as a morphological convergence. He deals with ninety-eight species, of which the following, forming no less than 24 per cent. of the plants treated of, are indigenous in New Zealand: *Oreobolus pumilio, O. pectinatus, Hectorella caespitosa, Colobanthus brevisepalus, C. muscoides, C. subulatus, C. Billardieri, Azorella Selago, Dracophyllum muscoides, Veronica pulvinaris, Phyllachne clavigera, Ph. Colensoi, Raoulia australis, R. bryoides, R. eximia, R. Goyeni, R. grandiflora, R. Haastii, R. lutescens, R. mammillaris, R. Parkii, R. Petriensis, R. rubra*, and *R. tenuicaulis*.

No full details of the structure of each plant are given, as by Foweraker, but certain important points (degree of hairiness, thickening of epidermis, number of rows of palisade, presence of bast in leaf and young stem respectively) are put in tabular form, and so the species can be readily compared.

Hauri comes to virtually the same conclusions as Foweraker, pointing out that there is a distinct anatomical convergence, so that, judged anatomically, cushion-plants are xerophytes. The author also points out that the presence of bast in the leaves is an example of mechanical convergence. This falls into two types—the one, where there is a peripheral strengthening of the leaf by bast or thickened epidermis; and the other, where there is, in addition, a central strengthening by strands of bast-fibre. Central bast without peripheral strengthening was not observed. A figure is given of the transverse section of a leaf of the New Zealand endemic *Dracophyllum muscoides*, showing its central bast development and thickened epidermis. Structure of this character the author considers as especially suitable for the more solid cushions.

L. COCKAYNE,
Joint Hon. Editor, New Zealand Institute.

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## ART. II.—*Notes on* Parsonsia capsularis *R. Br.*

By H. CARSE.

Communicated by Dr. L. Cockayne, F.R.S.

[*Received by Editors, 30th December, 1916; issued separately, 28th June, 1917.*]

FOR some years I have noted two very distinct forms of *Parsonsia capsularis* R. Br.—one, the small-flowered form described in the *Manual of the New Zealand Flora*, which appears to occur freely in the North Island, and perhaps in parts of the South Island, and another with much larger flowers, which appears to be much more restricted in its habitat.

When I heard of Dr. Cockayne's var. *rosea** I communicated with him, forwarding him specimens of the large-flowered variety for comparison.

* This is *Parsonsia rosea* Raoul reduced to a var. of *P. capsularis*: see L. Cockayne, Notes on the Plant Covering of Kennedy's Bush and other Scenic Reserves of the Port Hills, Canterbury, *Rep. on Scenery Preservation for 1915*, p. 14.

His opinion was that the two plants, while undoubtedly within the circumscription of *Parsonsia capsularis* R. Br., differ in certain respects, and that my northern plant should be accorded a varietal designation. He further suggested that the small-flowered form should also be named as a variety, the conception *Parsonsia capsularis* being evidently an aggregate of three, and probably more, distinct forms.

I take this opportunity of heartily thanking Dr. L. Cockayne, F.R.S., for the assistance he has afforded me in this connection.

**Parsonsia capsularis** R. Br. var. **parviflora** Carse var. nov.

Frutex tenuis ramosus scandens. Folia valde polymorpha, plantarum juvenilium 30–75 mm. longa, angusto-linearia, lanceolata, vel spathulata, integra, sinuato- vel inaequi-lobata; plantarum maturarum variabilia, angusto-linearia, 25–100 mm. longa, 2·5 mm. lata, oblonga vel oblongo-lanceolata, 25–75 mm. longa, 12·5–20 mm. lata, obtusa vel subacuta, coriacea, margine plerumque integerrima. Cymi pauci- vel multi-flori, axillari vel terminales. Flores parvi ± 3 mm. longi. Lobi calycis corollae tubum aequantes. Corolla campanulata, lobi revoluti. Antherae exsertae.

This is the slender climber, with small creamy flowers, which is not uncommon in the localities stated above. In the North Island, so far as I am acquainted with it, it usually occurs in open hilly woods. I take it to be the original *Periploca capsularis* Forst. f., but before this can be finally determined specimens must be examined from the neighbourhood of Queen Charlotte Sound.

**Parsonsia capsularis** R. Br. var. **grandiflora** Carse var. nov.

Frutex ramosus scandens, quam var. *parviflora* robustior. Folia similiter polymorpha. Cymi plerumque multiflori. Flores majores, rubri, vel luteo-rubri, nunquam rosei, 4–6 mm. longi. Corollae tubi lobos calycis equantes vel superantes.

North Island. Great Barrier Island: Colonel Boscawen, per Mr. Cheeseman! Whangarei district, Mangonui County: H. C. Usually in damp lowland situations.

A much more robust liane than var. *parviflora*. In most of my specimens the leaves are more or less ovate-lanceolate, but heterophyllous forms are not uncommon. At first glance this plant may easily be mistaken for *Parsonsia heterophylla* A. Cunn., but the exserted anthers at once place it under *P. capsularis*. The colour of the flowers varies from creamy-yellow to a red like the flesh of a pumpkin. Mr. Cheeseman describes Colonel Boscawen's specimen as having "orange-red flowers." It is undoubtedly the same plant as occurs from Whangarei northward. From var. *rosea* it differs in the more robust habit and larger differently coloured flowers.

It is quite possible that the above variety may be Colenso's *P. ochracea*, though from his description (*Trans. N.Z. Inst.*, vol. 22, 1890, pp. 480–81) I should say his was the small-flowered plant. His herbarium specimens appear to have been mislaid, so that at present it is not possible to compare them.

ART. III.—*On a New South Polynesian Palm, with Notes on the Genus* Rhopalostylis *Wendl. et Drude.*

By Dr. ODOARDO BECCARI (Florence, Italy).

Communicated by T. F. Cheeseman, F.L.S.

[*Read before the Auckland Institute, 13th December, 1916; received by Editors, 30th December, 1916; issued separately, 28th June, 1917.*]

IN a visit paid in August, 1887, by Mr. T. F. Cheeseman to the Kermadec Islands Group, lying in latitude 30° S. in the South Polynesian Sea, there was found growing very abundantly on Sunday Island, one of the group, a fine palm, which at the time of the visit was not bearing flowers, but was loaded with large bunches of nearly mature fruits. Specimens of this palm, supposed to belong to *Rhopalostylis Baueri*, or to a variety of it, were sent to Kew from the herbarium of the Auckland Museum, and transmitted to me in Florence some time ago. These specimens (wanting the flowers, and only a few detached fruits being available for study) were not sufficient for a rigorous specific identification. Quite recently, however, having received, also from Kew, portions of the flowering spadix of the same palm, its affinity to *Rhopalostylis Baueri* and *R. sapida* was rendered quite clear; but yet it proved to be a palm specifically distinct from either, on account especially of the shape and other peculiarities of its fruits. The flowers of the Kermadec palm were derived from a plant that, as Mr. Cheeseman informs me, flowered recently in Auckland from seeds originally collected in those islands.

It is for me a doubly pleasant task to distinguish with the name of its discoverer this new palm from the temperate Australian regions, as I hope that through Mr. Cheeseman's exertions it may soon become a new inmate in our Mediterranean gardens, as have the two already-known *Rhopalostylis*; and also in memory of the fine trip made on the 12th March, 1878, under Mr. Cheeseman's guidance, to the Titirangi Ranges, near Auckland, where I was able to admire *Rhopalostylis sapida*, the nearest ally of the Kermadec palm, in its native home.

RHOPALOSTYLIS CHEESEMANII Becc. n. sp.

A fine palm with a straight solitary stem, attaining 60 ft. (about 18 m.) in height, and producing large bunches of fruits 2 ft. (60 cm.) in diameter. The primordial leaves have the blade 12–20 cm. long, deeply bifid, or formed by two lanceolate slightly falcate leaflets, united by their bases; their petiolar part is elongate, and besprinkled with appressed rusty scales.

One leaf from a young plant is pinnate, and carries several leaflets on each side of the rhachis, upon which they are attached by means of a broad base; such leaflets are narrowly lanceolate-subfalcate, and very acuminate to a capillary tip; their lower surface is besprinkled with very minute brown scales, considerably smaller than those of the petiole and rhachis. The leaflets of the adult plant are ensiform, have the upper end gradually acuminate and very slightly falcate, and the lower end slightly narrowed and very slightly curved (sigmoid); the bases are relatively broad and the margins not reduplicate; are green above, subglaucescent beneath, and very distinctly 3-costulate; the costae are especially prominent on the lower surface, and slightly scaly-furfuraceous there, especially near the base; the side costae are not so strong as the middle one, and become feebler from the middle upwards; the secondary nerves are slender, and barely distinguishable from the tertiary ones, which are rather sharp, so as to render the two surfaces (in the dry specimens) distinctly striate; transverse veinlets obsolete: the margins acute. The single leaflet (from an adult plant) seen by me was 75 cm. long, and 4 cm. broad at about its middle. The spadix is large and much branched; its flowering branchlets are thickish, angular, and deeply and closely scrobiculate along 6 vertical series; the scrobiculi are shaped like a swallow's nest, and have their lower margins truncate, but with a small acute point at their middle. The flowers have their bases immersed in the scrobiculi, are arranged in glomerules of 3 (the central a female, and the side ones male, as usual) almost to the end of the flowering branchlets. At the time of the anthesis of the male flowers the female flowers are rather well evolute, but not yet ready for impollination. The male flowers are asymmetrical, 7 mm. long, lanceolate-acuminate, and somewhat falcate at apex; the calyx is formed by 3 free sepals, thinly membranous, lanceolate-acuminate, very briefly imbricate at the base; the corolla is divided down to the base into 3 concave ovate-lanceolate acuminate segments, one-third, or even less, longer than the sepals; are cartilaginous, strongly striately veined outside; the stamens are 6, have the filaments linear with the apex subulate and inflected; the anthers are erect when in the bud and versatile later, are attached about their middle, linear-sagittate, their apices and their auricles are obtuse, have the cells disjointed in their lower third part, and dehisce laterally. The rudimentary ovary is conspicuous, subclavate, almost as long as the stamens (in the unopened flower). The female flowers, at the time of the flowering of the male flowers, are broadly conical, acute, 4 mm. broad (probably slightly larger later); sepals thinly cartilaginous, very broadly imbricate, suborbicular, briefly apiculate; the corolla slightly longer than the calyx; petals similar to the sepals, broadly imbricate, having only the short apices valvate; sepals and petals minutely ciliolate; ovary oblong, conical above, terminated by 3 trigonous, acute, at first connivent, then spreading and recurved, stigmas; ovule relatively large, attached laterally in the highest part of the cell. Staminodes 3, dentiform.

Fruit globular: in the dry condition it is 11–13 mm. in diameter, and has a terminal discoid-mammillaeform apiculus, showing in its centre the minute remnants of the stigmas; the pericarp is in its totality 1 mm. in thickness; its epicarp is very thin, and very finely lineolate by very minute fibres (sclerostomes); the mesocarp is apparently very slightly fleshy in the fresh state, and contains 4–5 rows of flattened rigid fibres; the endocarp is very thin, pellicular-cartilaginous, tightly enveloping the seed.

Seed globose, 10·5–11 mm. in diameter, the outer coat is light-coloured and almost polished, and faintly marked by the nearly simple vascular branching of the raphe; several of the branches descend spirally and posticously from the summit, and only very few descend the sides. The hilum is conspicuous, broad and suborbicular on the vertex of the seed, it narrows gradually downward to its base, in close proximity to the embryo. Albumen very hard, homogeneous. Embryo exactly basal. Fruiting perianth very slightly concave, or almost explanate.

*Rhopalostylis Cheesemanii* appears to be more closely allied to *R. sapida*, the seed of which has, like that of *R. Cheesemanii*, a light-coloured and polished surface, than to *R. Baueri*, of which the seed has a brown and dull surface. *R. Cheesemanii* is, however, a much taller plant than *R. sapida*, and in that respect approximates more closely to *R. Baueri*. But this new species differs from both *R. sapida* and *R. Baueri* in the globular form of its fruit.

## Rhopalostylis Wendl. et Drude.

Wendl. et Drude in *Linnaea*, xxxi (1875), 180, t. 1, f. 2 (the ovary): Drude in *Bot. Zeit.*, 1877, t. 6, f. 18–21 (anatomy of the ovary); Benth. et Hook., *Gen. Pl.* iii, 890. *Kentia* and *Areca* of several authors.

Arboreous unarmed palms. Stem marked with annular rings or scars left by the dead fallen leaves. Leaves pinnate, furnished with a long basal sheathing part. Leaflets narrow and elongate, acuminate, slightly falcate at apex, 3-costulate, and with several distinct secondary nerves: their margins acute (not thickened by a marginal nerve). Spadix infrafoliar, briefly stalked, enveloped by 2 complete similar papyraceous or membranous deciduous spathes; the outermost 2-winged. Flowering branches thick, closely and deeply scrobiculate. Flowers in glomerules of 3 (one male between two females) from the base up nearly to the apices of the branches. Male flowers opening somewhat before the female ones, asymmetrical: sepals subulate, entirely free, slightly imbricate at the base; petals valvate, almost entirely free, more or less obliquely lanceolate, or ovate. Stamens 6, free, their filaments filiform, inflected at apex; anthers linear or linear-sagittate, versatile, dorsifixed. Rudimentary ovary conspicuous, columnar or subclavate. Female flowers globose-ovoid; sepals broadly imbricate; petals slightly longer than the sepals, convolutive-imbricate in their very broad basal part, and having very brief valvate apices; ovary ovoid, unicelled; ovule attached all along one side of the cell; stigmas triangular, short, at first connivent, later recurved; staminodes minute. Fruit small, globular-ovoid or elliptical, symmetrical, bearing the remains of the stigmas exactly on the apex. The whole pericarp thin; the epicarp furnished with very minute linear fibres (sclerosomes); the mesocarp very slightly fleshy and furnished with a few rows of rigid fibres; the endocarp very thin, cartilaginous. Seed globular, ovate, or ellipsoid, attached all along one side of the endocarpal cavity, and marked with a conspicuous hilum, running from the apical chalaza down to the base, in close proximity to the embryo; vascular branches of the raphe very slightly anastomosing, starting mostly from the chalaza, running down the ventral side of the seed, and only a very few starting from the sides of the raphe; albumen homogeneous. Embryo basal.

The generic name *Rhopalostylis* was proposed by H. Wendland and Oscar Drude for the two palms of the Southern Hemisphere known by the old names of *Areca sapida* and *A. Baueri*. The genus *Rhopalostylis* is now represented by three species, which form a small but well-characterized group: it is somewhat related to the true genus *Kentia*, as understood by me (see *Webbia*, iv, 1913, p. 143); but perhaps even more to the genus *Actinokentia* of U. Dammer (*Kentiopsis divaricata* A. Brongn., a palm indigenous to New Caledonia), on account of its ovule attached all along one side of its cell; of its symmetrical fruit, having the remains of the stigmata exactly on the apex; and of its seed being marked with a conspicuous hilum, running from apex to base, and with homogeneous albumen and basilar embryo.

*Rhopalostylis sapida* from New Zealand and *R. Baueri* from Norfolk Island are two palms very well characterized and distinct, but have a somewhat uncertain synonymy, and have been frequently confounded, or considered as representing one species only. Martius himself has apparently, in his description of *Areca sapida*, cumulated the characteristics of the palm of New Zealand with those of the Norfolk Island palm; but the fine plates 151 and 152 of his *Historia naturalis Palmarum*, reproduced from Bauer's drawings, represent only *Areca* (*Rhopalostylis*) *Baueri*.

The name of *Areca sapida* Solander appears for the first time, I believe, in the work of Georg Forster, *De Plantis esculentis insularum Oceani australis Commentatio botanica*, 1786, p. 66, n. 35; but apparently Solander has never given a description of that palm, and Forster evidently considers the New Zealand palm the same as that growing in Norfolk Island, as he writes of *A. sapida*, "Reperitur spontanea in Nova Zelandia usque ad aestuarium Charlottae reginae, et frequens in Norfolciae insula deserta."

H. Wendland, in the "Enumeration of all Known Palms," published in the work of Oswald de Kerchove de Denterghem, *Les Palmiers*, considers as *Rhopalostylis sapida* Wendl. et Drude only that which goes by the horticultural name of *Kentia sapida*, figured in the *Botanical Magazine* in plate 5139, under the name of *Areca sapida*. To *Rhopalostylis Baueri* he refers *A. Baueri* Hook. of the *Botanical Magazine* (plate 5735), *Areca sapida* Sol., *Kentia sapida* Mart., *A. Banksiia* A. Cunn., and *Seaforthia robusta* Hort.

I have not now the leisure to clear up the exact synonymy and to adduce the entire relative literature of these two palms. It is sufficient for me at present to establish the fact that these two palms are quite distinct, and that (1) *Rhopalostylis sapida* is now generally considered to be the species growing in New Zealand; (2) the palm indigenous to Norfolk Island is *R. Baueri*. Of the first I collected specimens myself in its native land; of the second I have examined fruiting specimens forwarded to me many years ago by my lamented friend Baron Ferdinand von Mueller, and collected in Norfolk Island by Mr. Isaac Robinson.

The three species of *Rhopalostylis* are characterized as follows:—

1. **Rhopalostylis sapida** Wendl. et Drude in Kerch., *Les Palmiers*, p. 255. *Areca sapida* (Sol.) Hook. f., *Fl. Nov. Zel.* i, 262, t. 59, 60; *Bot. Mag.* t. 5139.

A middle-sized palm, 5–6 m. high. Spadix 30–40 cm. long or less. Fruit ovoid or ovoid-elliptical, 12–14 mm. long, 7–8 mm. through. Seed ovoid, with light-coloured polished surface and marked with a broadly linear hilum. Fruiting perianth cupular-campanulate, 6–7 mm. high.

*Hab.*—New Zealand, from 35° to 38° S. latitude.

2. **Rhopalostylis Baueri** Wendl. et Drude in *Linnaea*, xxxix (1875), 180 et 234, t. 1, f. 2. *Areca Baueri* Hook. f. in *Fl. Nov. Zel.* i, 262, in obs.; *Bot. Mag.* t. 5735. *A. sapida* Mart., *Hist. Nat. Palm.* iii (partly, as to description), t. 151–52.

A tall palm. Spadix 60–90 cm. long. Fruit ovoid-elliptical, 15–17 mm. long, 12 mm. through. Seed with dull-brown surface; hilum linear but slightly narrowing towards the base. Fruiting perianth cupular-campanulate, 6–7 m. high.

*Hab.*—Norfolk Island.

3. **Rhopalostylis Cheesemanii** Becc. n. sp.

A tall palm, about 18 m. high. Spadix in fruit about 60 cm. in diameter. Fruit globose, 11–13 mm. in diameter. Seed globose, with light-coloured polished surface; hilum broad and suborbicular above, narrowing considerably towards the base. Fruiting perianth almost explanate.

*Hab.*—Kermadec Islands.

# ART. IV.—*Descriptions of New Native Flowering-plants, with some Notes on Known Species.*

By D. PETRIE, M.A., Ph.D.

[*Read before the Auckland Institute, 13th December, 1916; received by Editors, 30th December, 1916; issued separately, 28th June, 1917.*]

## 1. Wahlenbergia flexilis sp. nov.

Caules a summa radice complures gracillimi elongati flexuosi procumbentes teretes glabri parce ramosi. Folia ± conferta anguste lanceolato-spathulata integra acuta v. subacuta, inferiora opposita distantia, superiora alterna. Pedunculi terminales elongati 1-flori. Corolla infundibuliformis; stylus in ramos 2 recurvatos divisus.

Stems several from the top of a long slender root, very slender, usually with long internodes, flexuous terete glabrous, 4–8 in. long, more or less branched near the base and at the tops, the branches often loosely interlaced.

Leaves in opposite distant pairs on the lower part of the stem, alternate higher up and often more or less crowded at the tops, variable in size and outline, $\frac{3}{4}$–$1\frac{1}{2}$ in. long, $\frac{1}{4}$ in. in greatest width, narrow lanceolate-spathulate or almost linear, gradually narrowed to the base, acute (rarely subacute), entire, glabrous thin or slightly coriaceous, edges somewhat cartilaginous, when dried more or less recurved, midrib evident, veins oblique reticulate rather obscure.

Peduncles terminal, 4–6 in. long, filiform, glabrous, 1-flowered, with or without one or two short linear bracts.

Flowers ± $\frac{5}{6}$ in. long; calyx narrow, one-fifth as long as the corolla, cut half-way down into 5 linear-subulate lobes; corolla funnel-shaped, cut for one-third its length into 5 triangular acute lobes; style ending in 2 rather long arms that are recurved when mature; capsule obconic, $\frac{1}{4}$ in. long, usually 2-celled.

*Hab.*—Higher parts of Clarence Valley, Inland Kaikouras, Marlborough: end of December, 1915: B. C. Aston!

## 2. Gentiana tereticaulis sp. nov.

Annua: caules simplices erecti teretes 2·5 – 4·5 dcm. alti, internodiis elongatis. Folia pauca tenuia subacuta; radicalia longe petiolata, 4–5 cm. longa, laminis anguste ovatis, 3–5-nerviis; caulina perdistantia, supremis cuneato-ovatis sessilibus; pedunculi floribus $1\frac{1}{2}$–2 longiores graciles teretes. Flores albi 15–18 mm. longi, terminalibus umbellatim dispositis; pistilla matura corollam excedentia.

Annual: stems simple, erect, moderately slender, terete, 2·5–4·5 dcm. (10–18 in.) high, internodes several times longer than the cauline leaves.

Radical leaves few, thin, subacute, the blades narrow-ovate contracted into thin flattened petioles equalling or exceeding the blades, ± $1\frac{3}{4}$ in. long, 3-nerved or with an additional outer pair reaching half-way up the blade; cauline in few opposite widely distant pairs, the lower like the radical but shorter, the upper ovate-cuneate with a broad more or less decurrent base.

Inflorescence a terminal 4–7-flowered umbel, with or without a few long-pedunculate smaller umbels or solitary flowers from the axils of the uppermost cauline leaves.

Peduncles about twice as long as the flowers, slender, terete.

Calyx nearly half as long as the corolla, cut for two-thirds its length into linear-subulate 1-nerved lobes; corolla $\frac{5}{8}$ in. long, cut for three-quarters its length into obovate rounded lobes; stamens a little longer than the calyx; the mature pistil exserted beyond the corolla.

*Hab.*—Gentle grassy slopes at the foot of Lake Harris, Routeburn Valley, Lake County.

This plant is intermediate between *G. tenuifolia* (mihi) and *G. corymbifera* T. Kirk.

3. **Gentiana Gibbsii** sp. nov.

Annua: *G. lineatae* T. Kirk similis; differt foliis majoribus subcarnosis, scapis crassioribus rigidis numerosis, floribus majoribus (2–2·5 cm. longis), capsulis maturis multo longioribus (2·5 cm. longis).

Annual, not tufted: stems several from the top of a long slender root, more or less branched, ascending or erect, 3–4 in. high.

Leaves slightly coriaceous, radical few ovate-spathulate, $\frac{1}{2}$–$\frac{3}{4}$ in. long, cauline in opposite pairs sessile, broadly linear or narrow-ovate acute.

Flowers numerous, white, narrow, solitary, terminating the scapes or branches; peduncles slender, terete, three to four times as long as the flowers; calyx $\pm$ $\frac{3}{4}$ in. long, equalling the corolla or nearly so, cut almost to the base into linear acute lobes; corolla divided for four-fifths its length into narrow ovate-lanceolate acute and subapiculate conspicuously veined segments; stamens half as long as the corolla; ripe capsules $\pm$ 1 in. long, exceeding the corolla.

*Hab.*—Mount Anglem, Stewart Island: F. G. Gibbs!

The radical leaves are not well shown in the specimens I have been able to examine. I have to thank Mr. Gibbs for the gift of some of the specimens seen, and Dr. Cockayne, F.R.S., for the loan of the remainder.

4. **Veronica longiracemosa** sp. nov.

Frutex altus robustus ramosus: ramis ramulisque glaberrimis atrofuscis. Folia valde elongata $\pm$ 10 cm. longa 1 cm. lata, anguste lineari-lanceolata, apicibus acuminatis valde attenuatis. Racemi crassiores valde elongati $\pm$ 18 cm. longi 2 cm. lati, flores pernumerosos gerentes. Flores majusculi, corollae tubo lato calyce duplo longiore, limbi lobis tubum aequantibus ovatis acutis. Capsula glabra ovato-elliptica subacuta 4 mm. longa.

A tall stout much-branched shrub: branches and twigs stout, blackish-brown, quite glabrous.

Leaves moderately closely placed ($\pm$ 1·5 cm. apart), narrow-linear-lanceolate, $\pm$ 10 cm. (4 in.) long, 1 cm. ($\frac{3}{8}$ in.) broad, widest near the base, uniformly narrowed upwards to the finely acute or acuminate apex, sharply contracted at the base into a short broad petiole, glabrous, coriaceous, entire, flat, straight, spreading, midrib evident on both surfaces, paler below.

Racemes 1 or 2 in the axils of the upper leaves, very long up to 18 cm. (7 in.), 2 cm. ($\frac{3}{4}$ in.) broad, very many flowered. Rhachis naked below, stout, puberulous; bracts linear-subulate, short; peduncles short, puberulous or slightly pubescent. Flowers large, white (?); calyx deeply 4-partite, segments thin oblong obtuse (rarely subacute), ciliate along the pale margins; corolla-tube wide, fully twice as long as the calyx, limb cut into 4 ovate acute lobes about as long as the tube. Capsules glabrous, ovate-elliptic, 4 mm. ($\frac{3}{16}$ in.) long, subacute apiculate, about twice as long as the calyx.

*Hab.*—Awatere Valley, Marlborough: H. J. Matthews.

A very distinct species, allied, but not closely, to *V. salicifolia* Forst. f. and *V. rotundata* T. Kirk. My specimens came from a plant cultivated by Mr. Matthews, who informed me in letters of its native habitat. It shows no sign of being intermediate between any of the larger-leaved species of the genus, and it seems to me impossible that it can be a hybrid.

5. Note on **Veronica rakaiensis** J. B. Armstrong.

Specimens of what I take to be this species were given me by Mr. W. Willcox, of the Queenstown Domain, who found the plant near the Arrowtown–Macetown Road, in Lake County. The leaves do not show pubescence on the under-surface, but the characters of the flowers and capsules agree closely with Mr. Armstrong's description. It is a much taller and more slender plant than *V. pinguifolia* Hook. f., with shortly petiolate thinner narrower subacute leaves, and much longer and less pubescent racemes.

6. **Veronica albicans** sp. nov.

Species *V. amplexicauli* J. B. Armstrong affinis: differt foliis basi haud subcordatis, subtus nervis 2 subobscuris submarginalibus supra evanidis notatis; bracteis parvis brevibus anguste lanceolato-subulatis; corollae tubo lato calycem duplo superante; ovario glabro; capsula glaberrima elliptico-ovata subacuta.

A closely branched low shrub; main branches rather stout, much subdivided towards their tips, bark glabrous dark-brown closely ringed by leaf-scars; branchlets densely leafy almost to the base, marked by a pubescent tract running down from between the leaves and often extending along the leaf-bases.

Leaves decussate, spreading, closely placed, broadly ovate or orbicular-ovate (not subcordate), 1·7–2 cm. ($\frac{3}{4}$ in.) long, 1–1·5 cm. ( $\pm\frac{1}{2}$ in.) broad, silvery grey when fresh, coriaceous, obtuse, entire, glabrous, sessile by a broad base not keeled, more or less concave above, with 2 rather obscure submarginal nerves running up for three-quarters their length, midrib evident above and below.

Racemes in the axils of the upper leaves, usually in 2 or 3 opposite pairs, twice to thrice as long as the leaves, stout, many-flowered; rhachis naked below, pubescent or almost villous-pubescent; bracts small, short, narrow lanceolate-subulate, acute: peduncles rather stout, pubescent like the rhachis, twice as long as the bracts or more: calyx deeply 4-partite, the lobes ovate-oblong obtuse thin dark, delicately ciliate along the margins. Corolla-tube wide, twice as long as the calyx, the limb cut into 4 short broad obtusely rounded lobes; anthers and style exserted.

Capsule glabrous, ovate or elliptic-ovate, subacute, about twice as long as the calyx.

*Hab.*—Mount Arthur and Mount Cobb, north-west Nelson: H. J. Matthews! F. G. Gibbs!

In one specimen in fruit the leaves are narrower ovate-oblong and subacute, and the lines of pubescence on the ultimate twigs are less conspicuous.

7. **Veronica Lyallii** Hook. f. var. **angustata** var. nov.

Caules erecti graciles ramosi (plerumque a basi), dense villoso-pubescentes; foliis confertis patentibus angustis $\pm$ 1 cm. longis 2·5–4 mm. latis subacutis vix coriaceis sublonge petiolatis; rhachi puberulo, pedunculis ± pubescentibus.

*Hab.*—Low flat rocky bars across the Ngakawau River near its mouth, south-west Nelson. The habitat is but little above sea-level, and is frequently submerged during floods. Collected 25th February, 1913.

8. **Euphrasia diversifolia** sp. nov.

Annua: caules gracillimi atro-rubri 8–10 cm. alti, ramos paucos basim juxta emittentes. Folia parva ± sessilia obovata v. obovato-cuneata (raro sublanceolata), glabra obtusa integra v. sub apice bidentata, ± 2·5 mm. longa, tenuia, subfloralia majora multo latiora coriacea valde obtusata, marginibus manifeste recurvis. Flores in racemis 2·5–5 cm. longis dispositi; pedunculis gracillimis bracteas duplo v. ter superantibus; calyce obconico pedunculis $\frac{1}{2}$ breviore glabro, segmentis obtusis conspicue inaequalibus ac a marginibus recurvatis; capsula oblanceolata glabra vix emarginata calycem $\frac{1}{2}$ superante.

Annual: stems very slender, erect or arcuate below, 3–4 in. high, deep-brown marked by two faint pubescent lines running down from the base of the petioles, giving off a few filiform branches mostly near the base.

Leaves small, the lower $\frac{1}{12}$ in. long or less, sessile or almost so, obovate or obovate-cuneate (rarely sublanceolate), spreading, entire or with a shallow notch on either side near the tips, thin, distant, more or less recurved at the margins; the subfloral larger much broader and thicker, mostly appressed, margins obviously recurved.

Flowers in a raceme 1–2 in. long, solitary or more commonly in opposite pairs, in the axils of the bracts; peduncles two to three times as long as the bracts (± $\frac{3}{8}$ in. long), slender, erect, marked by 2 pubescent lines; calyx obconic, about half as long as the peduncles, glabrous, margins recurved, cut about half-way down into 2 principal segments that are again shortly notched at the top, segments obtuse; corolla not seen; capsules one and a half times as long as the calyx, oblanceolate, obtuse, glabrous, the top entire or very shortly and obliquely emarginate.

*Hab.*—Wet ground on Mount Hector, Tararua Range; about 3,500 ft.: B. C. Aston!

The present species is allied to *E. tricolor* Colenso. In the latter the calyx-segments are often more or less unequal, but never so conspicuously so as in Mr. Aston's plant, which is, moreover, annual, and has quite different leaves. Colenso's *E. tricolor* appears to me to be a valid species.

9. **Pimelea Poppelwellii** sp. nov.

Frutex subrobustus ramosus glaber ad 15 dcm. altus. Folia conferta imbricata crassa coriacea brevia, late ovata v. elliptico-ovata, 8–10 mm. longa ± 6 mm. lata, obtusa v. subacuta, vix appressa glabra, supra ± concava, evenosa carinata, breviter petiolata; floralia longiora ac latiora tenuiora ± venosa plana flavo-viridia. Flores terminales in capitulis 8–15-floris aggregati, ± 1 cm. longi sessiles pallide rosei dioici v. polygamo-dioici, sericeo-villosi; antheris vix exsertis; stylis elongatis gracillimis delicate capitatis. Fructus ignotus.

A rather robust much-branched erect shrub 5 ft. high or less.

Branches moderately stout, leafy towards the tops, glabrous.

Leaves very dark green, close-set, overlapping, more or less appressed, thick and coriaceous, broadly ovate or elliptic-ovate, about $\frac{3}{8}$ in. long and

$\frac{1}{4}$ in. broad, obtuse or subacute, glabrous, more or less concave above, keeled veinless, cartilaginous at the edges, contracted into a short stout petiole ; floral leaves longer and broader, much thinner, yellowish-green, and more or less obviously veined.

Flowers in terminal heads of 9–15, $\frac{3}{8}$ in. long, sessile, pale-rose, silky-villous, dioecious or polygamo-dioecious ; anthers scarcely exserted ; styles elongated, very slender, finely capitate.

Fruit unknown.

*Hab.*—Garvie Mountains, Southland County ; and Symmetry Peaks, Eyre Mountains, Lake County : D. L. Poppelwell ! Mount Cleughearn, Fiord County : J. Crosby Smith !

The present species is intermediate between *P. Traversii* Hook. f. and *P. Crosby-Smithii* (mihi).

### 10. Note on the Discovery of Simplicia laxa T. Kirk.

In Mr. Cheeseman's *Illustrations of the New Zealand Flora* this grass is stated to have been first collected by the late Mr. Kirk at the Dry River Station, Ruamahanga, Lower Wairarapa, in January, 1880. This is incorrect, as the plant was discovered by me near the Deep Stream accommodation-house or hotel at the end of February, 1877. That was the only occasion on which I visited that locality, or journeyed over the Rock and Pillar Road from Alexandra to Outram. The occasion was made memorable to me by the fact that I was hurriedly returning from Arrowtown to Dunedin because Mr. John Hislop (later Dr. Hislop), the Secretary to the Otago Education Board, had just been invited to proceed to Wellington to assist the Hon. Mr. Bowen in drafting the Education Act that was passed during the parliamentary session of 1877. I was at the time fully aware that my find belonged to a genus of grasses new to New Zealand, but the specimens were imperfect, and as the Kew authorities referred them to *Sporobolus* I took no steps to publish my discovery. When a few years later I got good specimens near Waikouaiti, Mr. Kirk sent me, in return for specimens forwarded to him, some pieces of the Wairarapa plant, named *Pyxidiopsis prona*, a name that he afterwards abandoned.

### 11. Note on Deyeuxia filiformis (G. Forst.) Petrie.

In January, 1913, I collected, at the seaside near Bluff (Southland), specimens of this species in which a few of the spikelets contain two florets. The upper floret terminates the rhachilla, and is considerably smaller than the lower. It is generally infertile, but in some cases it had developed a caryopsis. In works accessible here I have not been able to find any record of an abnormality of this kind, and it may be that the occurrence of a second floret in the spikelets of *Deyeuxia* has not been observed before. The rhachilla in this genus suggests the suppression of a second or upper floret, and the occasional development of the second floret lends to the rhachilla, in itself apparently a trivial character, considerable genetic significance, enhancing its value as a diagnostic character in marking the genus off from *Agrostis* L. and *Calamagrostis* Roth, in both of which there seems to exist no indication of descent from forms having more than one floret in the spikelet.

# ART. V.—*Notes on New Zealand Floristic Botany, including Descriptions of New Species, &c. (No. 2).*

By L. COCKAYNE, Ph.D., F.L.S., F.R.S., Hutton and Hector Memorial Medallist.

[*Read before the Wellington Philosophical Society, 23rd August, 1916; received by Editors, 30th December, 1916; issued separately, 9th July, 1917.*]

Plate VII.

## I. TAXONOMIC.

### 15.* Acaena Sanguisorbae Vahl. var. minor Hook. f.

The above variety was constituted in 1844 by J. D. Hooker in the *Flora Antarctica* to accommodate a certain form of *Acaena* collected by him on Lord Auckland and Campbell Islands, and differing from what Hooker considered the typical *Acaena Sanguisorbae* in its smaller size and greater degree of hairiness. Later, in the *Flora Novae-Zelandiae* (1853), he referred the pilose mountain form of the South Island to this variety. Strange to say, this var. *minor* of Hooker f. has been overlooked or disregarded by all who have dealt with *Acaena Sanguisorbae* since the publication of the *Flora Novae-Zelandiae*, including Hooker himself in the *Handbook of the New Zealand Flora*.

In the *Students' Flora of New Zealand*, 1899, p. 133, T. Kirk described under the varietal name *pilosa* what are almost certainly the same plants as those constituting the var. *minor* of the *Flora Novae-Zelandiae*—*i.e.*, the subantarctic form together with the South Island mountain form.

In 1904 I showed that the mainland plant differed in essential particulars from the subantarctic plant, for which I proposed the varietal name *antarctica* (*Trans. N.Z. Inst.*, vol. 36, p. 319, 1904), thus restricting Kirk's varietal name to the plant, or, as I now know, series of plants, of the mainland. This action of mine was approved by Cheeseman in the *Subantarctic Islands of New Zealand*, vol. 2, p. 403, 1909. Later, in 1911, G. Bitter (*Die Gattung Acaena*, Heft 4, p. 274) constituted his subspecies *aucklandica* to receive the subantarctic plant. But, undoubtedly, the latter is synonymous with my var. *antarctica*, an opinion in which Bitter in a letter to me concurred upon receiving some of my original material.

From the above it seems obvious, since Hooker's var. *minor* was the original name of the subantarctic plant, the names *antarctica* and *aucklandica* must be abandoned, and that the *Acaena* in question must be known henceforth as *A. Sanguisorbae* Vahl. var. *minor* Hook. f.

### 16. Carmichaelia Williamsii T. Kirk.

I have recently had an opportunity of examining fresh flowers of this shrub gathered from a cultivated specimen in the garden of my friend Professor H. B. Kirk. The colour of these flowers differed greatly from what had been stated in all previous descriptions, as may be seen from what follows, so that either the species is polymorphic so far as colour is concerned, or the descriptions hitherto have been inaccurate.

The species was originally described by T. Kirk in *Trans. N.Z. Inst.*, vol. 12, pp. 394–95, 1880, where it is stated, " The flowers appear to be of

* The numbers are continued consecutively from the first paper of this series, in *Trans. N.Z. Inst.*, vol. 48, pp. 193–202, 1916.

a lurid-red colour similar to those of *C. nana*."* Later, in Featon's *Art Album of New Zealand Flora*, p. 112, pl. 26, fig. 3, 1889, the flowers are described as pale yellow, but the plate shows the colour as fairly bright yellow marked with a few pale lines. Kirk, in the *Students' Flora*, p. 110, 1899, contrary to his first description, gives the colour as "lurid yellow, veined." Cheeseman, in the *Manual of the New Zealand Flora*, p. 112, 1906, states that the colour is yellowish-red, and this statement he upholds in the *Illustrations of the New Zealand Flora*, vol. 1, pl. 32, 1914; but the illustration depicts lines on the flowers, the colour of which is not stated.

The petals of the flower from Professor Kirk's garden are coloured as follows: *Standard* (on its upper surface) pale yellow, striped with rather dark purple coarse lines which broaden out towards the apex of the leaf so as to stain this recurved apex almost uniformly purple; the under-surface has the same pale-yellow ground-colour, but the purple lines are much finer, while, above, they broaden out into rich purple; at the base of the standard, just above its claw, there is a rich purple blotch. The *keel* and *wings* are pale greenish-yellow, stained near their apices with pale purple. The purple is richer upon the recurved apical margin of the standard than elsewhere. Certainly in all the flowers examined the purple was quite as conspicuous as the yellow, and perhaps more so.

17. **Celmisia glandulosa** Hook. f.

*Celmisia glandulosa*, as first described by J. D. Hooker in the *Flora Novae-Zelandiae*, referred only to certain specimens of a celmisia collected by Colenso on the Volcanic Plateau, near the base of Mount Tongariro. Since that time the species, as defined by Hooker, has been collected, or observed, in many parts of the subalpine belt of New Zealand, where it is common in bogs and wet peaty ground on those mountains where the rainfall is considerable, but it is wanting on the drier mountains. The species, generally speaking, is constant in its characters, and answers to the description in the *Manual of the New Zealand Flora*, p. 318. At the same time, taking a broad view of the contents of the species, there is some well-marked local polymorphism, so that the "type," here named "var. *vera*," can be readily distinguished from the two other varieties described below.

(*a*.) **C. glandulosa** Hook. f. var. *α* **vera** Cockayne var. nov.

This, the common form of what is here made an aggregate species, requires no special description, since it is sufficiently described in the *Flora Novae-Zelandiae*, p. 124, and in the *Handbook of the New Zealand Flora*, pp. 135–36. It is readily recognized by its small ovate- or oblong-spathulate, acute, acutely serrate, thin, pale-green leaves which are covered more or less closely with minute glandular pubescence, and its slender scape generally less than 12 cm. high.

(*b*.) **C. glandulosa** Hook. f. var. *β* **latifolia** Cockayne var. nov.

Folia late oblongo-spathulata, apice rotundata, in petiolum latum angustata, glanduloso-pilosa, margine ciliata.

North Island: Egmont-Wanganui Botanical District—Mount Egmont; common as a member of the tussock-grassland and herb-field plant associations. L. C.

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* The flowers of *Carmichaelia nana* are certainly *not* "lurid red," but in the absence of fresh flowers I cannot state the exact colour.

This well-marked variety is distinguished at a glance by the broadly oblong-spathulate leaves with wide petioles shorter than the lamina and rounded, never acute, apex.

Whether this variety is confined to Mount Egmont and the Pouakai Range I do not know, but it is apparently the only form of the species in that area.

(*c*.) **C. glandulosa** Hook. f. var. γ **longiscapa** Cockayne var. nov.

Folia oblongo-lanceolata vel obovato-lanceolata, cum petiolo ± 5·5 cm. longa, glabra, apice acuta; petioli laminam longitudine aequantes vel superantes. Scapus ± 20 cm. longus, gracilis, strictus.

South Island: Fiord Botanical District—Upper Clinton Valley, on old moraine. L. C.

At first sight this variety looks so distinct from the "type" (var. *vera*) that one feels inclined to separate it as a distinct species. But, except for its larger longer-petioled leaves and much longer scape, its characters are virtually the same as the plant of the Volcanic Plateau. It bears a good deal of resemblance to *Celmisia glabrescens* Petrie of Stewart Island, but the latter is separated by its still longer leaves, which are thinly tomentose beneath and which lack the strong network of veins.

18. **Celmisia longifolia** Cass. var. **gracilenta** (Hook. f.) T. Kirk, form with branched scape.

In the garden at Dunedin of the late Mr. H. J. Matthews there were at least two forms of *Celmisia coriacea* Hook. f. with branched scapes. To these names were given by T. Kirk (*Students' Flora*, p. 288), although he considered that the branching was due to cultivation. Cheeseman supports Kirk in this opinion, stating (*Manual of the New Zealand Flora*, p. 311), "In cultivation it [*C. coriacea*] varies still more largely, and often produces branched scapes, a peculiarity quite unknown in any *Celmisia* in the wild state, so far as my observations go."

Some years ago, however, before the above statement was published, I collected a number of specimens on the Port Hills, Banks Peninsula, from a wild plant of *Celmisia longifolia* var. *gracilenta* with branched scapes. Possibly the occurrence of such branching may be commoner than hitherto suspected. Nor do I see any reason for assuming that the branching in Matthews's plants was the result of cultivation, especially as they were grown under the purely natural conditions his garden supplied. Further, according to Cheeseman (*l.c.*), Matthews stated that var. *ensata* T. Kirk, another branched form, was collected by himself from a wild branched plant growing near Lake Harris, Cheeseman remarking, however, that "I have only seen cultivated specimens."

19. **Leptospermum scoparium** Forst. var. **incanum** Cockayne var. nov.

Folia lanceolata vel lineari-lanceolata, circ. 8 mm. longa, subtus praecipue juventute ± pilis sericeis albidis obsita; flores magni petalis roseis leve tinctis.

North Island: North Auckland Botanical District—Common, especially in the northern part of the district, in many places forming thickets. L. C.

This well-marked variety is distinguished at a glance from any other forms of the species with which it may be associated by its young branchlets and leaves hoary with silky whitish hairs which persist for a considerable time on older leaves especially near the base, its rather large flowers with the petals more or less stained rose-colour, and the rather large capsules. As the variety is widespread in its range and frequently occurs in considerable quantity, there can be little doubt regarding its coming true from seed and thus being a valid taxonomic variety.

So greatly was I impressed by the distinctness of the plant under consideration that in my original notes, taken near the Rangaunu Estuary on the 5th March, 1905, it is stated, "No description of the vegetation is complete which does not lay stress upon the two forms of manuka so distinct when growing," and also upon "the pink flowers" of the variety with hoary leaves.

### 20. **Notospartium Carmichaeliae** Hook. f. and **N. torulosum** T. Kirk.

In *Illustrations of the New Zealand Flora*, when dealing with the plate of *Notospartium Carmichaeliae*, Cheeseman writes, regarding that species and *N. torulosum* T. Kirk, "I have been much puzzled at finding little or no difference in the whole of the specimens brought under my notice, while there is considerable deviation in the shape of the pod." Regarding this shape of pod, I do not intend to discuss the question here, since I understand that Mr. D. Petrie proposes to deal with a quantity of material collected by Mr. B. C. Aston in the Clarence Valley, the pod of which is much broader than that of *N. Carmichaeliae* from farther north, but an examination of certain specimens has shown that there are considerable distinctions in the flowers of two species of the genus.

The material at my disposal for studying the flowers of *Notospartium* was derived from the following sources: (1) Avondale, which is a branch valley of the Waihopai, the original habitat of *N. Carmichaeliae;* (2) the neighbourhood of Hanmer Plain, only a few miles distant from one of the two original habitats of *N. torulosum*. The Avondale and Hanmer habitats have been already recorded by me (*Trans. N.Z. Inst.*, vol. 48, p. 206, 1916). I will assume for sake of argument that the Hanmer plant is *N. torulosum*, while the Avondale plant is certainly *N. Carmichaeliae*.

Description of the Hanmer plant (*Notospartium torulosum*):—

*Final twigs* extremely slender, drooping, ? rather dark green. *Racemes* frequently in pairs from a much-reduced branchlet, sometimes branching sparingly, ± 5 cm. long, flowers not crowded. *Flowers* with large black-purple blotch at base, whence many dark-purple lines radiate upwards to margin, becoming rather paler as they ascend; keel 8·5 mm. long, with black-purple blotch at apex, whence purple lines pass towards base; standard 9 mm. long and 5 mm. broad; wings rather shorter than the keel, linear-oblong about 1 mm. wide; calyx campanulate, glabrous except on teeth, which are large, broad, minutely pilose on margin and within, and rounded at apex.

*Notospartium Carmichaeliae* (Avondale) has racemes shorter (3·5 cm. long) than those of *N. torulosum;* they are unbranched, dense-flowered, and pilose. The flowers have a shorter but much broader standard and much shorter claw, subacute calyx-teeth, pilose calyx, and much broader wings. The flowers are far more showy.

*Notospartium torulosum* (Hanmer) differs from *N. Carmichaeliae* (Avondale) in its longer, glabrous, branched, more open-flowered racemes, narrower and longer standard, much narrower wings, and obtuse or rounded calyx-teeth, which are glabrous outside but minutely hairy within and on margins.

The colour-differences are also considerable, but I have no exact notes regarding the colour of *N. Carmichaeliae*, since the flowers quickly fade after gathering. But *N. torulosum* is purple, and it could never have received the popular name "pink broom" which *N. Carmichaeliae* bears.

21. Rubus Barkeri Cockayne.

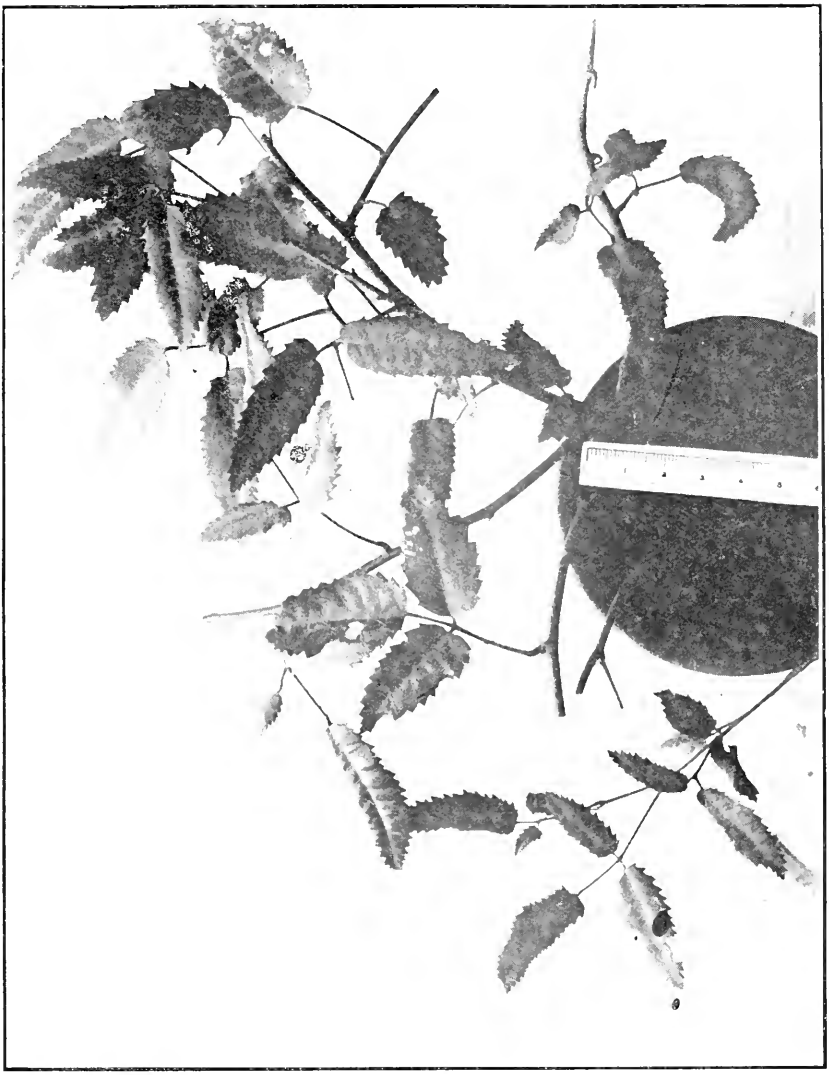
It may be remembered that the remarkable feature of the above plant was that *it had never flowered, although it had been cultivated in gardens, under different conditions, for nearly twelve years.* I had therefore suggested that it might be a "*non-flowering species.*" At the same time, I was careful to make no definite statement on this head, but wrote, "Whether the non-flowering depends upon the environments hitherto provided being unsuiteble, as is the case with certain non-flowering plants in Europe and elsewhere, or whether the species is actually unable to bloom, the future alone will determine" (*Trans. N.Z. Inst.*, vol. 42, p. 325, 1910). After about nineteen years since the plant first came into cultivation, a specimen, which was raised from the ground and tied to a support, grown in the garden of my friend Mr. D. L. Poppelwell, of Gore (Southland), has produced a small panicle of five flowers, all of which, but for the presenee of a stamen on one of them, are female, the species being apparently dioecious.

The following is a brief description of the flower, so far as may be ascertained from the scanty dried material: *Calyx-segments* broadly oblong, obtuse or subacute, about 2·5 mm. long, densely pilose beneath and on margin; *corolla* white, ovate, obtuse, about twice as long as the calyx-segments; *carpels* numerous. I have no female flowers of the closely related *Rubus parvus* Buchanan for comparison, but fruiting specimens show much longer, narrower, acuminate calyx-segments, which are similar to those of the male flower of the last-named species. (*Cf.* also the calyx-segments of the male and partly developed fruiting flower in Cheeseman's *Illustrations of the New Zealand Flora*, pl. 37, 1914.)

The eventual flowering of *Rubus Barkeri* after such a long period of vegetative growth only may arouse a suspicion that the original cuttings were taken from a juvenile and not from an adult plant. Such a suspicion may, I think, be dismissed, since the original cuttings taken by the late Mr. S. D. Barker were not only numerous, but, as shown by the photograph on Plate VII, too thick in the stem and too large generally to have been gathered from an immature plant. Also, since *R. Barkeri* resembles *R. parvus* so greatly in manner of growth, even had the original plant been a seedling it would almost certainly have flowered in a year or two. All who are acquainted with *R. Barkeri* in cultivation are fully aware of its extreme vigour and capability of most rapid vegetative increase. So, too, with *R. parvus*, both wild and in cultivation.

22. Senecio Christensenii Cockayne sp. nov.

Frutex parvus, pauciramosus, ± 10 cm. altus. Folia plerumque radicalia, pauca caulina, anguste oblonga, apice obtusa, integra, petiolata petiolis gracilibus, teretibus, tomentosis, usque ad 2 cm. longis; lamina ± 2·9 cm longa, 1·1 cm. lata, coriacea, supra primo subtomentosa deinde paena glabra dilute flavo-viridis conspicue reticulato-nervosa nervis impressis, subtus pilis tenuibus sordide albidis dense tomentosa medio nervo prominente. Scapus gracilis, rigidus, sparse tomentosus, basim versus interdum brachiatus, pilis numerosis brevibus glandulosis munitus; bractae numerosae, appressae, lineari-oblongae sed scapi apicem versus lineares, supra virides, infra capitula circ. ? 2 cm. diam.; involucri-bractae lineares,



[L. Cockayne, photo.

One of the original cuttings of *Rubus Barkeri* taken from the parent plant of Inch Bonny, near Lake Brunner, Westland. From this cutting, so far as the author knows, all the plants of this species now in cultivation have originated. Centimetre scale on surface of soil in flower-pot.

subcarnosae, primo tomentosae, mox virides pilis glandulosis obsitae; radii ligulae circ. 9, ungue 11 mm. longo munitae; disci flores numerosae: achenia scabra.

South Island: North-eastern Botanical District — Leslie Hills, near Hanmer, on dry rock. C. E. Christensen !

This species bears a superficial resemblance to *Senecio bellidioides* Hook. f. and to small forms of *S. lagopus* Hook. f.; but it differs from either in its shrubby or perhaps suffruticose habit, narrower and differently shaped leaves, some of which are cauline, sunken reticulating veins of upper surface of leaf, absence of bristles, and denser tomentum.

The description of the inflorescence and florets may need revision, since it was drawn up from scanty material taken from a plant cultivated for me by Mr. Glen, Curator of the Wellington Botanical Gardens, to whom my grateful thanks are due.

### 23. Veronica rotundata T. Kirk.

This species was founded by T. Kirk upon specimens of a veronica collected "near Wellington" and "near Southbridge," that botanist expressing the opinion that the plant was "probably not infrequent" (*Trans. N.Z. Inst.*, vol. 28, p. 530, 1896). Cheeseman, in his *Manual*, pp. 504–5, admitted the species as valid, but he had no material other than that originally used by Kirk. An examination of the specimens of *Veronica* in Kirk's herbarium, now in the possession of the Biological Department of Victoria College, showed that there was only one sheet of specimens of *V. rotundata*, and the habitat was "Newtown Park." Thus, so far as the Wellington habitat goes, the obvious assumption is that the veronica in question is possibly a garden form of hybrid origin. Nor is this discounted by the Southbridge habitat, since that locality is a most unlikely one for any rare New Zealand plant. The general appearance of the "species" also points to a hybrid origin, and this is further supported by the fact that the plant is more or less common in cultivation.

### 24. Veronica salicifolia Forst. f. var. longiracemosa Cockayne var. nov.

Frutex multiramosus usque 2·5 m. altus, valde floriferus. Folia lanceolata vel late lanceolata, apiculata, chartacea, ± 12 cm. longa, ± 2 cm. lata, integerrima, apicem versus interdum minutissime ciliata. Racemi longissimi, cum pedunculo ± 20 cm. longi; rhachis pedicelli calyxque pilosissimi: corollae-lobi apice rotundati.

North Island: Egmont-Wanganui Botanical District—Abundant with other shrubs in open places both wet and dry. L. C.

This exceedingly handsome shrub appears to be constant in its characters in such parts of the botanical district mentioned above as I have visited. It is distinguished from *Veronica salicifolia* Forst. f. var. *communis* Cockayne in *Trans. N.Z. Inst.*, vol. 48, p. 202, 1916, by its much longer racemes (which are frequently more than 18 cm. long), the more pilose rhachis, pedicels, and calyx, and the longer leaves.

The description of *V. Parkinsoniana* Col. in *Trans. N.Z. Inst.*, vol. 21, p. 97, 1889, in many particulars matches this variety, but the apex of the leaf is described as obtuse. Possibly the two varieties should be united, but uncertainty as to Colenso's plant forbids me using his specific name for my variety.

Occasionally the raceme of var. *communis* is much longer than ordinary. For instance, there is in my herbarium a specimen gathered from a cultivated plant in the former garden of Mrs. F. Weymouth, Christchurch, which originally came from Catlin's River (South Otago Botanical District), in which the raceme is 31 cm. long, while near its base the bracteoles are large and leaf-like. But such unusual development is a teratological matter, and, though a specific character of the variety under certain unknown conditions, does not appear under ordinary circumstances.

## II. Phytogeographic.

### *The Proposed Botanical Districts of New Zealand.*

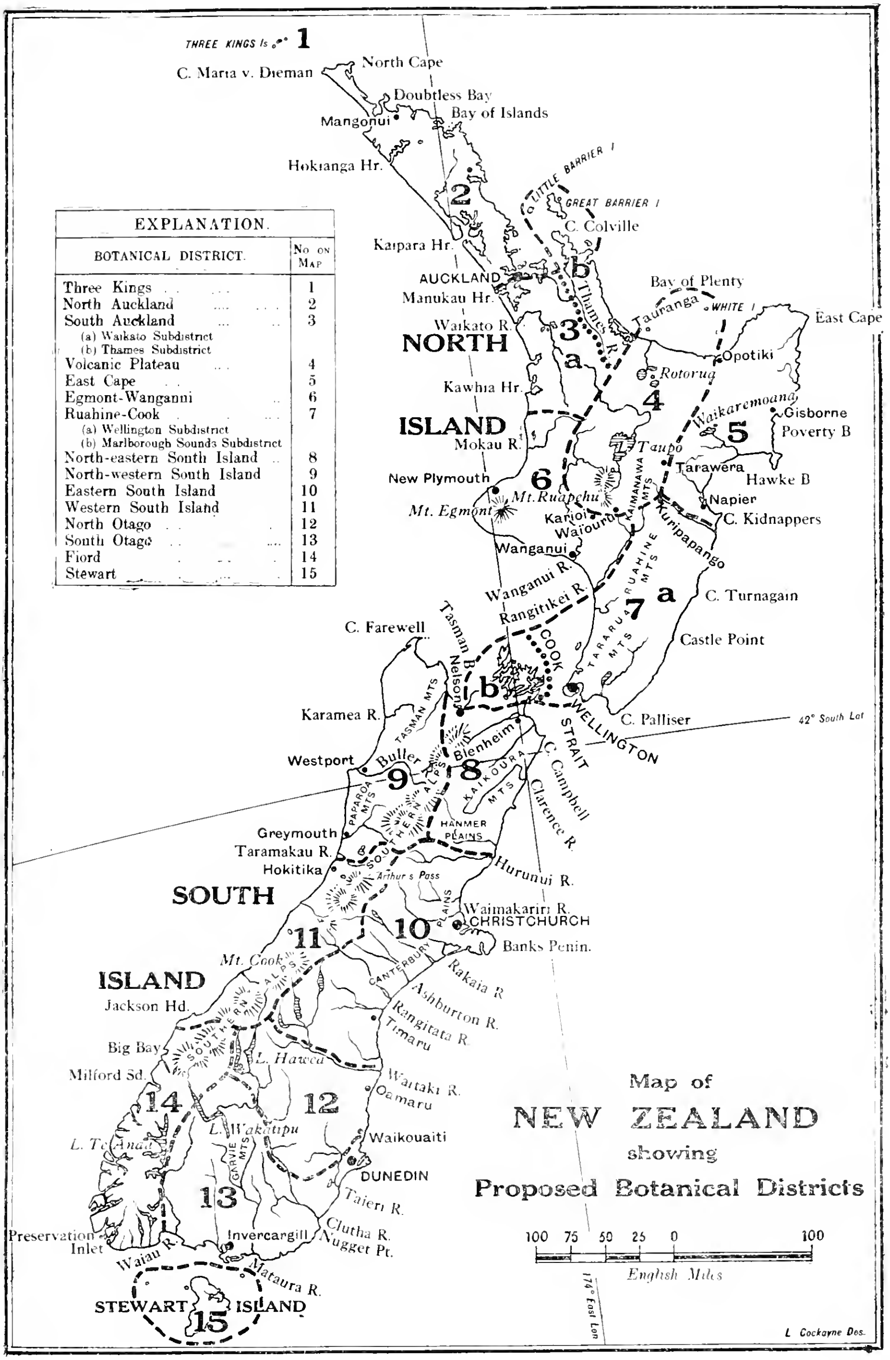
In certain papers published by me last year in the *Transactions of the New Zealand Institute* some of the botanical districts proposed in my yet unpublished *Vegetation of New Zealand* were cited and defined. As for the future I intend to use these "districts" when stating the distribution of plants, rather than the quite unnatural areas—the political provincial districts of New Zealand—hitherto used by me in common with other New Zealand botanists, it seems necessary to give a list of such districts, together with the boundaries of each, which can be still more easily seen on the accompanying map (p. 63). These districts are merely provisional, and will be subject to considerable modification for years to come. Further, I am not stating here my reasons for having adopted these subdivisions, accompanied by the necessary details, but reserve them for a further communication. Suffice it to say that in the delimiting of a "district" an attempt has been made to mark off *natural areas* which are distinguished principally by the following circumstances—some floristic (these the most important, since the districts are essentially floristic), some ecological: (1) The presence of a more or less extensive locally endemic element; (2) the absence of species more or less characteristic of adjacent botanical districts; (3) the presence of species of restricted distribution elsewhere; (4) the presence in abundance of widespread species much rarer elsewhere; (5) the relative abunbance of the various species comprising the florula; (6) the general physiognomy of the vegetation; (7) the presence of special characteristic plant-associations; (8) the differences in widespread plant-formations; (9) the agriculture, horticulture, and introduced plants of the proposed area. Here only the two main islands, their adjacent islets, and Stewart Island receive consideration. Some of the "districts" must ultimately be subdivided into subdistricts, while others may be united; and in all there are distinct altitudinal belts, each with its special floristic and ecological peculiarities.

The actual boundaries of many of the districts are extremely hard to fix, and in no few cases must always be artificial, though that detailed research which must take place in due course as phytogeographic workers increase in number will eventually find out the most natural limits. On the other hand, there are certain well-marked natural boundaries, of which the line marking the supposed average limit of the western rainfall in the South Island, as defined by junction of forest and grassland on the east of the dividing range, is the best example. Cook Strait, on the contrary, is of slight importance as a dividing-line.

The following are the names of the proposed botanical districts, and their boundaries:—

(1.) *The Three Kings Botanical District.*—This comprises the various islets of the Three Kings group.

(2.) *The North Auckland Botanical District.*—This includes all that portion of the North Island lying to the north of and including the Auckland Isthmus (excepting the Cape Colville Peninsula and the two Barrier Islands),


EXPLANATION.
BOTANICAL DISTRICT. No. on Map
Three Kings 1
North Auckland 2
South Auckland 3
(a) Waikato Subdistrict
(b) Thames Subdistrict
Volcanic Plateau 4
East Cape 5
Egmont-Wanganui 6
Ruahine-Cook 7
(a) Wellington Subdistrict
(b) Marlborough Sounds Subdistrict
North-eastern South Island 8
North-western South Island 9
Eastern South Island 10
Western South Island 11
North Otago 12
South Otago 13
Fiord 14
Stewart 15
Map of
NEW ZEALAND
showing
Proposed Botanical Districts
100 75 50 25 0 100
English Miles
L. Cockayne Des.
NORTH ISLAND
SOUTH ISLAND
STEWART ISLAND
THREE KINGS Is
North Cape
C. Maria v. Dieman
Doubtless Bay
Bay of Islands
Mangonui
Hokianga Hr.
Kaipara Hr.
AUCKLAND
Manukau Hr.
Waikato R.
Kawhia Hr.
Mokau R.
New Plymouth
Mt. Egmont
Wanganui
Wanganui R.
Rangitikei R.
LITTLE BARRIER I
GREAT BARRIER I
C. Colville
Bay of Plenty
Tauranga
WHITE I
East Cape
Opotiki
Rotorua
Taupo
Waikaremoana
Gisborne
Poverty B
Tarawera
Hawke B
Napier
C. Kidnappers
Mt. Ruapehu
Karioi
Waiouru
Kuripapango
KAIMANAWA MTS
RUAHINE MTS
TARARUA MTS
C. Turnagain
Castle Point
C. Palliser
WELLINGTON
COOK STRAIT
42° South Lat
C. Farewell
Tasman B.
Nelson
Karamea R.
TASMAN MTS
Westport
Buller
Blenheim
KAIKOURA MTS
C. Campbell
Clarence R.
PAPAROA MTS
SOUTHERN ALPS
HANMER PLAINS
Greymouth
Taramakau R.
Hokitika
Arthur's Pass
Hurunui R.
Waimakariri R.
CHRISTCHURCH
Banks Penin.
CANTERBURY PLAINS
Rakaia R.
Ashburton R.
Rangitata R.
Timaru
Mt. Cook
Jackson Hd.
Big Bay
Milford Sd.
L. Hawea
Waitaki R.
Oamaru
L. Wakatipu
L. Te Anau
GARVIE MTS
Waikouaiti
DUNEDIN
Taieri R.
Clutha R.
Nugget Pt.
Invercargill
Preservation Inlet
Waiau R.
Mataura R.
174° East Lon

together with the outlying islands. It can be naturally subdivided into two subdistricts, a north and a south, but neither their names nor boundaries are given here.

(3.) *The South Auckland Botanical District.*—This includes that portion of the North Island lying to the south of the North Auckland District and bounded on the south and south-east by a line extending from Te Reinga Point to about the source of the River Mokau and thence passing Tauranga a little to the south reaches the coast.

This district may be subdivided into (*a*) the *Waikato Subdistrict*, which includes all the area west of the River Thames, and (*b*) the *Thames Subdistrict*, which includes all the area to the east of the above river, together with the Little and Great Barrier Islands, and the islets lying off the east coast.

The southern limit of the district is little better than a guess, especially in its extreme southern portion.

(4.) *The Volcanic Plateau Botanical District.*—Although this district, as a whole, is well-marked, its boundaries are quite uncertain. These are —to the north, the coast from near Tauranga to Opotiki; on the west the boundary is as already cited for part of the southern boundary of the South Auckland District; thence it follows the course of the Main Trunk line to a little south of Waiouru; thence to a little to the east of Kuripaponga, and thence by a fairly straight line through Tarawera and Ruatahuna to Opotiki. Motiti and White Islands are included in this district.

(5.) *The East Cape Botanical District.*—This includes all that part of the North Island east of the eastern boundary of the Volcanic Plateau District, with its southern boundary extending from a little to the north of Kuripaponga to a few miles to the south of Cape Kidnappers. Possibly the southern boundary should extend considerably farther to the south, including some of the area south of the southern boundary of the Volcanic Plateau District.

(6.) *The Egmont-Wanganui Botanical District.*—This includes all that area of the North Island lying to the west of the southern part of the Volcanic Plateau District and of a line a little to the south of Waiouru and following the Rivers Hautapu and Rangitikei to the sea. On the north it is bounded by part of the southern boundary of the South Auckland District.

(7.) *The Ruahine-Cook Botanical District.*—This includes all the remaining part of the North Island, together with that portion of the South Island comprising the Marlborough Sounds area, including a narrow strip of land in Nelson subject to the same forest-climate as that of the Marlborough Sounds.

The district may be divided into two subdistricts—viz., (*a*) the *Wellington Subdistrict*, which includes the North Island portion, and (*b*) the *Marlborough Sounds Subdistrict*, which includes all the South Island portion.

Of the botanical districts already dealt with, the Three Kings and the two Auckland districts make up my Northern Botanical Province, and the remainder my Central Botanical Province. The following botanical districts make up my Southern Botanical Province:—*

* These provinces were first defined by me in 1907 (*Trans. N.Z. Inst.*, vol. 39, pp. 313–14, in footnote), but, as now defined, the actual boundaries are somewhat different, latitude 38° S. and latitude 42° S. being no longer used as the lines separating the Northern and Central Provinces and the Central and Southern Provinces respectively. The other botanical provinces of the New Zealand botanical region, together with their botanical districts in brackets, but not here defined, are: Kermadec Province (Kermadec District); Chatham Province (Chatham District); Subantarctic Province (Snares, Lord Auckland, Campbell, Antipodes, and Macquarie Districts).

(8.) *The North-eastern South Island* Botanical District.*—This includes all the north-eastern portion of the South Island except the Marlborough Sounds Subdistrict. It is bounded on the south by a line, as shown on the map, extending from the mouth of the Hurunui River to the average limit of the western rainfall east of the Hope Saddle, and thence on the west by the average eastern limit of the western rainfall to some point or other on Tasman Bay, probably near Motueka.

(9.) *The North-western South Island Botanical District.*—This is bounded on the east by the western boundary of the North-eastern District, and thence by a line following the average eastern limit of the western rainfall to near the Hurunui Pass. Its southern boundary extends from midway between Greymouth and Hokitika, thence to a few miles north-east of Lake Brunner, and thence to a little to the east of the Hurunui Pass.

(10.) *The Eastern South Island Botanical District.*—This is bounded on the north by the North-eastern District, on the south by a line following the Rivers Waitaki and Ohau to Omarama, and thence extending to a point, shown on the map, lying to the westward of Lake Ohau near the dividing range at the average eastern limit of the western rainfall. On the west the boundary is the average eastern limit of the western rainfall.

(11.) *The Western South Island Botanical District.*—This is bounded on the north by the southern boundary of the North-western District, on the east by a line following the average limit of the western rainfall, and on the south by a line not yet determined, but extending possibly from a few miles south of Jackson Head to a point, shown on the map, on the eastern limit of the average western rainfall, a little to the south of the Haast Pass.†

(12.) *The North Otago Botanical District.*—This is bounded on the north by the Eastern District, on the west by a short line marking the average eastern limit of the western rainfall, extending from the south-western corner of the Eastern District to a point, shown on the map, marking the average eastern limit of the western rainfall, a few miles to the south of Lake Wanaka. Its southern boundary, as shown on the map, is most irregular in shape, and extends from about Waikouaiti, along a line denoting the average northern limit of the south-western rainfall, and terminating at the point south of Lake Wanaka already mentioned.

(13.) *The South Otago Botanical District.*—The northern boundary of this district is the southern boundary of the preceding district; its western boundary the average eastern limit of the western rainfall as shown on the map; and its eastern and southern boundaries the sea.

(14.) *The Fiord Botanical District.*—This is bounded on the north by the southern boundary of the Western District, on the east by the western boundaries of the North and South Otago Districts, and on the west and south by the sea.

(15.) *The Stewart Botanical District.*—This includes Stewart Island and all the adjacent islets, including those of Foveaux Strait.‡ The Snares Islands are related floristically and ecologically to this district, but the evidence is in favour of their being constituted a special district of the Subantarctic Botanical Province.§

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* For sake of brevity in using the above term the words "South Island" are usually omitted, and so with certain other South Island districts.

† D. L. POPPELWELL, Botanical Results of an Excursion to the Upper Makarora Valley and the Haast Pass, supported by a List of the Species observed, p. 161 of this volume.

‡ Dog Island, though so close to the South Island, is included.

§ D. L. POPPELWELL, Notes on a Botanical Excursion to Long Island, near Stewart Island, including a List of Species, p. 167 of this volume.

# Art. VI.—*A Consideration of the Terms "Species" and "Variety" as used in Botany, with Special Reference to the Flora of New Zealand.*

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[*Read before the Wellington Philosophical Society, 22nd September, 1915; received by Editors, 30th December, 1916; issued separately, 6th July, 1917.*]

## Lack of Uniformity in the Taxonomic Employment of the Term "Species."

Notwithstanding the great progress made in botanical science during the last century, the present-day taxonomic conception of the terms "species" and "variety" is a heritage from the past which has been handed down with but little change from the time of Linnaeus. In other words, although Darwin revolutionized biological thought with his doctrine of organic evolution, taxonomic thought and procedure is even yet dominated by the dogma of special creation. Darwin prophesied that "Systematists will be able to pursue their labours as at present; but they will not be haunted by the shadowy doubt whether this or that form be a true species. . . . The endless disputes whether or not some fifty species of British brambles are good species will cease."* Unfortunately, the above prophecy is far from being realized. In every land where "species-making" is in progress the "lumpers" and the "splitters" are as hard at work as ever, but the latter are now in the ascendancy, perhaps partly because the stock of so-called "valid" species is rapidly declining, and partly because by many it is considered a more laudable action to "create" a species than a variety; but also there is being carried out a far greater amount of truly critical work than formerly.

That taxonomy should have proceeded on the old lines is really what might have been expected, the doctrine of evolution notwithstanding; for the taxonomist is working with species as they are, and not with what they may have been or are going to be. To all intents and purposes evolution has created distinct species many of which are presumably just as invariable as if they were the work of special creation;† and the taxonomist is not usually dealing with long rows of intergrading forms, but with fairly clear-cut groups of individuals, which are occasionally connected by intermediates, but for these latter are explanations available different from that of Darwin.

If one possessing a fairly wide knowledge of the actual plants critically examines the diagnoses of the species in almost any flora, it will stand out clearly that such species (and, for that matter, their varieties) belong to different biological categories—*i.e.*, that there is more than one kind of taxonomic species. *Those forming an extremely common class do not exist in nature as true-breeding entities: they may be considered ideas merely, or at best quite artificial groups of polymorphic forms.* The diagnosis of such a species includes a number of distinct groups of individuals which,

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* *Origin of Species*, 6th ed., pp. 399–400, 1872.

† Bateson strongly upholds the conception of specific distinctness, as opposed to the belief of those who consider that species are "impermanent groups, the delimitations of which are ultimately determined by environmental exigency or fitness" (see *Problems of Genetics*, pp. 10, 11, and 12, 1913).

though frequently differing greatly in appearance, each group having its peculiar characteristics, are distinguished by the possession of certain characters in common which appear to warrant the belief that such groups are of common origin. Species of this kind are of the utmost importance for phytogeographical and evolutionary reasons, and probably require increasing rather than suppressing. Modern taxonomy recognizes their utility, and speaks of them as "aggregate" or "collective" species. Aggregate species themselves, however, are of different biological values. The discussion of a few simple examples taken from the *Manual** should make this statement clear.

*Pseudopanax crassifolium* (Sol. ex A. Cunn.) C. Koch, as defined in the *Manual*, p. 235, does not exist in nature. The definition includes two supposedly† definite entities, the varieties *unifoliatum* Kirk and *trifoliatum* Kirk. It seems, therefore, incorrect to speak of having collected *P. crassifolium*, since this latter is an idea merely, for no plant can pass through two distinct life-histories at the same time. The entities are *P. crassifolium* var. *unifoliatum* and *P. crassifolium* var. *trifoliatum*, and these names should be used in floristic lists or catalogues; or another method would be to consider one or other of the above varieties the "type" of the species, and name it *P. crassifolium*, while the other variety‡ would be known by a varietal name.

*Olearia ilicifolia* Hook. f. has a variety *mollis* Kirk (*Manual*, p. 286). In this case the description of the species is that of a true entity,§ so far as is known, from which the variety *mollis* (which is not included in the specific description) differs so markedly that it can be recognized at a glance. But the latter also is a distinct true-breeding entity, which cannot be termed *O. ilicifolia*, but *O. ilicifolia* var. *mollis*, or, by those who consider it a species, *O. mollis*.

Another class of aggregate is that in which there is said to be a long series of intergrading forms, the extremes of which, at either end of the series, are very dissimilar. *Apium prostratum* Labill. is a case of this kind. In the *Manual*, p. 205, there are briefly described a var. *a*, a var. *b*, and a var. *c*, *filiforme*. No plant answering to the specific description occurs in nature. Var. *a* and var. *filiforme* are the extremes, but neither, on account of the connecting intermediates, is accorded specific rank, although var. *filiforme* comes true from seed. Here, then, the treatment adopted in the group of individuals comprising *A. prostratum* is quite different from that

* T. F. CHEESEMAN, *Manual of the New Zealand Flora*. Wellington, 1906. The name "Manual" used throughout this article refers to this work.

† The word "supposedly" is here used as it is quite likely that var. *unifoliatum* may itself be an aggregate. There are certainly a good many differences in individuals of this variety, especially in the juvenile leaves.

‡ The "type" is the comparatively rare var. *trifoliatum*, since A. Cunningham (*Flora Insularum Novae Zelandiae Praecursor*, p. 214, 1838) describes the leaves as "arboris adulti ternatis." This plant is also the one figured in the *Icones Plantarum*, t. 583, 1843.

§ Cheeseman (*l.c.*) speaks of "intermediates" between *O. ilicifolia* Hook. f. and *O. macrodonta* Baker, but, as the "typical" form of both comes true from seed, the occurrence of such intermediates would not invalidate my statement. The intermediates might quite well be, every one of them, either hybrids or true-breeding entities, but experiment is the only test. Since *O. ilicifolia* and *O. macrodonta* are so nearly related that their inflorescences and flower-heads are virtually identical (*Manual*, p. 286), the believer in unstable, non-hybrid intermediates should certainly unite these two species as an aggregate under one name, made up of, say, vars. *genuina*, *macrodonta*, and *mollis*, and ready to include other forms of recognizable distinctness.

of the group comprising *Olearia ilicifolia* together with *O. macrodonta*, where the extremes of the linear series of intergrading forms receive. specific rank.

The case of *Veronica salicifolia* Forst. f. may be next examined. The species, as defined by G. Forster in the *Prodromus*, probably originally referred to one or two plants at most,* but in the *Manual* the meaning has been greatly extended, so that the species, according to Cheeseman, contains three named varieties, a typical form which is not strictly defined, an unnamed variety from the Kermadecs,† and, in addition (*Manual*, p. 504), "numerous forms which appear to connect it with *V. macroura, Dieffenbachii, macrocarpa, ligustrifolia*, and others." What is meant in that sentence by the word "it" is vague, but it seems as if the type was thus indicated, while the varieties and intermediates are something different. At any rate, at one end of the series would be the "type" (whatever that may be), and at the other end one or other of the above species; or the whole of them, together with the "type," its varieties and the "intermediates," might constitute one huge aggregate.

Still another class of aggregate species is that large one said to be "variable," but where few or no varieties are defined. *Agropyron scabrum* Beauv., *Danthonia semiannularis* R. Br., *Veronica pinguifolia* Hook. f., and *Celmisia discolor* Hook. f., along with many other species, belong to this category. Usually no plant answering to the description of such species exists in nature.

Finally, species may be highly polymorphic, but no mention be made of such "variability." Thus *Acaena Sanguisorbae* Vahl is not spoken of in the *Manual* or by Hooker in the *Handbook of the New Zealand Flora* as variable, and yet Bitter, in his recent memoir on the genus,‡ has clearly shown that the species is a most puzzling complex, while my preliminary experimental studies are suggesting that his numerous subdivisions are insufficient.

The other great class of species is that which the layman practically concerned with plants—*e.g.*, the gardener—alone recognizes as such; that is, those in which there is no manifest variation§ except such as is quite unstable and caused by the environment of the varying individual. The *Manual* contains many species of this character,‖ of which *Agathis australis* Salisb., *Dacrydium cupressinum* Sol., *Carmichaelia gracilis* J. B. Armstg., and *Celmisia bellidioides* Hook. f. may be taken as examples.

The conception of a species as put forth by its author has been frequently modified not merely by other taxonomists, but by the author himself, and this without any statement to that effect. Generally a fairly invariable species is thus transformed into an aggregate, but occasionally the opposite course has been followed. *The citation of the original author's*

* Regarding Forster's type see certain remarks by myself in *Trans. N.Z. Inst.*, vol. 48, p. 201, 1916.

† Now *Veronica breviracemosa* W. R. B. Oliver.

‡ G. Bitter, Die Gattung Acaena, *Bibliotheca Botanica*. Heft 74. pp. 1–336. 1910, 1911.

§ In the case of certain species there is frequently a quite constant form in cultivation which owes its constancy either to being a microspecies or to all its members being the vegetative offspring of *one* individual. *Veronica Barkeri* Cockayne is a case of this kind, as is also the ordinary form of *V. Dieffenbachii* Benth.

‖ Of course, without actual breeding experiments it is impossible to know whether any species is really a true-breeding entity, so the word "many" can be taken for what it is worth.

*name is then no guarantee that the species is that of the author in question.* Thus *Celmisia discolor* Hook. f. of the *Flora Novae-Zelandiae* is not the *C. discolor* Hook. f. of Kirk's *Students' Manual. Veronica salicifolia* Forst. f., which, as stated above, was originally defined from one or at most two true-breeding groups of individuals, is certainly not the *V. salicifolia* Forst. f. of any subsequent New Zealand botanical author.

Much more could be written regarding the non-uniformity of the term "species" as used, not in the *Manual* only, but indeed in floras in general. As to how such inconsistencies have arisen, and why they are not only tolerated but perhaps necessary, demands, in the first place, a consideration of how the flora of New Zealand has reached its present stage; and, secondly, an historical examination of the species-question, and a consideration of the relations between a species and its subdivisions in the light of modern knowledge.

## History of the Conception of the Term "Species" in the New Zealand Flora.

The New Zealand flora has attained its present standpoint from the labours of many men, no two of whom have had exactly the same conception as to the limits of species and varieties, so that each has been more or less a law unto himself. Happily, one of the greatest taxonomists the world has ever seen, Sir Joseph Hooker, revised in a searching manner the work of the earlier botanists, while for many years he was virtually the sole author who dealt with New Zealand material. This led to a uniformity of treatment in his *Handbook of the New Zealand Flora*, published in 1864–67, which otherwise would have been lacking. At the same time, it must be pointed out that Hooker had at his disposal dried material only, together with the notes of various collectors regarding variation, &c. which certainly must have been of very unequal value. In his conception of the limits of species Hooker, as is essential for any botanist dealing with the plants of the world, or of very wide areas, favoured the creation of large aggregates.* This, as already pointed out, is a reasonable and, in many respects, an excellent course to take; but, in order to make it available for really finding out the prevalent forms of the species, varietal names are essential. These Hooker used to some extent, it is true; but the comparatively small amount of material at his disposal, the lack of knowledge regarding the great majority of the plants as they grew naturally, and an acceptance of that general belief, dealt with farther on, that varieties were not stable, made these Hookerian varieties, in many cases, of slight taxonomic value.

For example, *Leptospermum scoparium* Forst. is split up into var. $\alpha$—erect, leaves lanceolate; var. $\beta$, *linifolium*—erect, leaves narrow, linear-lanceolate; var. $\gamma$, *myrtifolium*—erect, leaves ovate, spreading or recurved; and var. $\delta$, *prostratum*—prostrate, branches ascending, leaves ovate or orbicular,

* See the classical Introductory Essay to the *Flora Novae-Zelandiae*, which demands as much attention now as it ever did, notwithstanding that it appeared more than sixty-four years ago. Hooker's explanation of his wide conception of species is put forth at considerable length: it must be read in its entirety, and so here but few quotations are given. He also explains the standpoint of those admitting much smaller species, and is quite sympathetic, declaring that "there is much to be said on both sides of the question," and that truth can only be arrived at through the joint labours of workers of the two schools.

recurved.* In no list of plants hitherto published, so far as I am aware, are these varietal names used, partly because New Zealand botanical authors have troubled little about varieties, and partly because the above do not represent true-breeding races. Kirk and Cheeseman both recognize these varieties of *Leptospermum*, but it is suggestive that the latter botanist assigns a habitat to var. *prostratum* only.† This plant, however, there is every reason to believe is merely prostrate owing to wind or some complex of ecological factors, and so has no right to a varietal name in the sense in which the term "variety" is now generally used. I could easily send to Europe dried specimens of different forms of *L. scoparium*, taken from shrubs growing in close proximity, which would at once receive varietal and perhaps specific names from any taxonomist monographing the genus and unacquainted with the species as they grow. At the same time, there are distinct and easily recognizable races of *L. scoparium* which come true from seed, but most of these as yet possess no distinguishing name.

This comprehensive view of species adopted by Hooker, although for many years religiously followed by the leading New Zealand taxonomists, is being rapidly departed from, since studies in a limited area, as Hooker early on explained,‡ force upon the observer the importance of minor characters. Thus it has come about that species after species has been added to the flora, especially of late years, which would have been included by Hooker, and, indeed, by nearly all New Zealand workers of a decade or two ago, in their aggregates. This multiplication of named groups has certainly in many instances simplified the work of the field botanist. For example, the acceptance of Haussknecht's arrangement of the genus *Epilobium*§ has made it much easier to place most of the individuals of this rather difficult genus into well-defined groups.|| Yet so great was the prestige of Hooker that, although the above work appeared in 1884, its conclusions were not generally accepted until 1899, when they received the sanction of Kirk's *Students' Flora*. The recent action of Cheeseman in segregating a group of individuals from the aggregate *Celmisia longifolia* Cass. under the name of *C. Morgani*¶ would have been accepted by few New Zealand botanists a dozen years ago, but it will certainly be welcomed by most at the present time.

## Conception of the Terms "Species" and "Variety" in General.

If a number of definitions of the term "species" as formulated by eminent taxonomists, both in the pre-Darwinian and post-Darwinian periods, be examined two essential differences of treatment stand out, the one

* *Handbook of the New Zealand Flora*, pp. 69–70, 1864.

† *Manual*, p. 60.

‡ "The local botanist looks closer, perceives sooner, and often appreciates better inconspicuous organs and characters, which are overlooked or too hastily dismissed by the botanist occupied with those higher branches of the science, which demand a wider range of observation and broader views of specialities." (Introductory Essay, p. xiii.)

§ C. Haussknecht, *Monographie der Gattung Epilobium*, Jena, 1884.

|| Haussknecht when dealing with an extensive aggregate species—*e.g.*, *E. junceum* Sol.—uses the term "form" for his subdivisions, and not "variety." Thus for the above species he describes six named forms, the names preceded by *a*, *b*, &c., each form corresponding to a species of some earlier author (*l.c.*, pp. 289–90). These "forms" of Haussknecht are evidently equivalent to the "varieties" of this paper, while his use of the term is contrary to ordinary taxonomic procedure.

¶ T. F. Cheeseman, Description of a New *Celmisia*, *Trans. N.Z. Inst.*, vol. 46, 1914, p. 21.

*morphological and artificial,* the other *physiological and natural.* Thus, according to the first conception, a species is a group of individuals which are distinguished by certain definite and unchangeable characters, and so differs from all other groups; but according to the second conception a species is a group of individuals resembling one another which on being *bred together produce like individuals.* This second definition holds that a species is a definite immutable entity, whereas the first is based, at best, only on a superficial examination of numerous individuals, and so permits the establishment of species which, as already explained, are not realities but ideas, the limits of which may be extended or reduced according to the whim of the taxonomist. Now, of recent years the careful experimental work of the Mendelists and others has clearly shown that if the breeding-test be accepted as the ultimate criterion of specific rank, species differing from one another in the most minute, perhaps outwardly unrecognizable, characters would have to be established by the thousand. That is to say, the main object of a flora, which is *the ready recognition of individual plants,* would be nullified. Therefore, since a true biological classification of individuals is probably taxonomically impossible, taxonomy is forced in no few cases to adopt such as is manifestly more or less artificial and to fall back upon the procedure of the pre-evolutionary taxonomists. But, as already pointed out, these investigators had no definite rules to observe, each was a law unto himself, and the species of one were frequently of quite different value from those of another, while it is even yet altogether a matter of opinion which of the two would be the more correct.

The classification of groups of individuals becomes far more complicated when groups smaller than species are to be constructed. The Mendelist gets over the difficulty by limiting his groups to the microspecies—*i.e.*, to the "biotypes," as he styles them, which breed true; but such treatment is not generally suitable for floristic botany. Still worse is the abandoning of groups smaller than species, and, without any experimental test whatsoever, splitting up easily recognizable aggregate species into dozens of so-called species which no one but their describer can possibly recognize! Even the orthodox taxonomist, when he attempts intensive work and defines subspecies, varieties, subvarieties, and even forms, is not infrequently impossible to follow.* Leaving out of consideration the work of such extremists, and turning to those who confine their groups of individuals to "species" and "varieties," it is here that the greatest differences of opinion occur, for the "species" of one are the "varieties" of another, and so on. This does not matter greatly so far as concerns floristic botanists themselves, but it is otherwise for investigators in other branches of botany, who demand definite names for the plants they are dealing with, together with some clue to their relationships. It is important, then, to get some idea of what is meant by "variety," and in order to do so a brief consideration of this term in taxonomy, from the time of Linnaeus, and incidentally of "species" also, should be of service.

Linnaeus himself considered varieties as anomalies to be brushed aside as not worthy of the attention of the philosophical botanist. This curious attitude has not even yet been altogether abandoned, for in few floras

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* A binomial, or even a trinomial, is a practical proposition, but if such names as Bitter's (*l.c.* pp. 263–66) *Acaena Sanguisorbae* subsp. *novae-zelandiae* var. *viridissima* subvar. *rubescentistigma* (not at all an extreme case) are to be used, then we had much better go back to the pre-Linnean practice of a brief description of the group, for it had the merit of telling something about the plant in question.

do "varieties" receive the attention they merit, while the somewhat contemptuous expression, "merely a variety," is certainly not unknown.

Taking the pre-Darwinian taxonomists as a whole, the conception of a variety was of a collection of similar individuals which differed from the remainder of the individuals comprising the species in certain supposedly unimportant particulars, and, if it came true from seed for a time, would eventually revert to the "type." Thus Abraham Rees, in *The Cyclopaedia* (1819), writing of varieties, states that "a little observation will prove how transient such varieties are and how uniformly their descendants, if they are capable of providing any, resume the natural characters of the species to which they belong." By A. P. de Candolle and K. Sprengel (1821)* the question of species and varieties is treated in a most illuminating manner. "Species," they write, "have existed as long as the earth has had its present form," and "have maintained the same properties invariably." At the same time, certain properties, they assume, are subject to change—*i.e.*, some properties are variable and others invariable. The variable properties supply the material for subspecies and varieties. The subspecies are defined as "such forms as continue indeed during some reproductions, but at last, by a greater difference of soil, of climate, and of treatment, are either lost or changed." . . . "Varieties," on the contrary, "do not retain their forms during reproduction." The cauliflower is cited as a subspecies, and the variable colours, tastes, and other properties of kitchen vegetables, ornamental plants, and fruit-trees "show what varieties are." De Candolle and Sprengel further remark, "The scientific botanist must therefore be particularly attentive to distinguish permanent species from the variable subspecies, degenerate plants and varieties." The authors conclude with this excellent advice which is certainly not inapplicable at the present time: "In order to decide respecting the idea of a species, an observation of many years, and of much accuracy, is often required; and the cultivation of plants from the most different climates in botanical gardens is in the highest degree necessary for their determination."

Sir James Edward Smith in 1827,† writing of varieties, says, "We frequently indeed see new varieties, by which word is understood a variation in an established species; but such are imperfectly, or for a limited time, if at all, perpetuated in the offspring."

John Lindley in 1832‡ defined a species as "a union of individuals agreeing with each other in all essential characters of vegetation and fructification, capable of reproduction by seed without change, breeding freely together and producing perfect seed from which a fertile progeny can be reared. Such are the true limits of a species; and if it were possible to try all plants by such a test there would be no difficulty in fixing them and determining what is species and what is variety." And again, "It is probable that, in the beginning, species only were formed; and that they have, since the creation, sported into varieties, by which the limits of the species themselves have now become greatly confounded."

Apart from Hooker's "Introductory Essay," the most interesting statements regarding the matter under consideration, so far as New Zealand students are concerned, is that of G. Bentham in his "Outlines of Botany," which forms an introduction to Hooker's *Handbook of the New Zealand*

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* *Elements of the Philosophy of Plants*, pp. 96–98.

† *An Introduction to Physiological and Systematic Botany*, 6th ed., p. 291.

‡ *An Introduction to Botany.*

*Flora* (1864), a work in constant use by all investigators of the New Zealand flora for a period of thirty-five years. Here (p. xxiv) a species is described as "all the individual plants which resemble each other sufficiently to make us conclude that they are all, or may have been all, descended from a common plant. These individuals may often differ from each other in many striking particulars, such as the colour of the flower, size of the leaf, &c.; but these particulars are such as experience teaches us are liable to vary in the seedlings raised from one individual. When a large number of the individuals of a species differ from the others in any striking particular they constitute a variety. If the variety generally comes true from seed it is often called a 'race.' A variety can only be propagated by grafts, cuttings, bulbs, tubers, or any other method which produces a new plant by the development of one or more buds from the old one. A race may with care be propagated by seed, although seedlings will always be liable, under certain circumstances, to lose those particulars which distinguish it from the rest of the species. A real species will always come true from seed."

*The above defintions of Bentham are clear enough, and show plainly that to him the ultimate test of a species was its capacity for breeding true.* Bentham (*l.c.*, pp. xxiv, xxv) also deals with "occasional or accidental anomalies" peculiar to one or a few individuals, which may prevent the species being "at once recognized by its technical characters." These "aberrations" he divides into two classes—viz., those for which some general cause may be assigned, and those of which the cause is unknown. To the first class belong changes due to various ecological factors, to use the modern term; while the second class includes those variations which some would now consider due to mutation, or to some factor acting on the embryo at an early stage of its development. Hybrids fall into Bentham's first class of "anomalies."

Biologically, if not taxonomically, the conception of species changed with the general acceptance of the doctrine of evolution, so that many considered them to be much less sharply defined than had up to that time been believed, while in no few instances they were thought to be not yet fully differentiated. According to Poulton, Sir E. Ray Lankester goes so far as to declare that "the 'origin' of species was really the abolition of species, and zoologists should now be content to name, draw, and catalogue forms" (*Essays on Evolution*, p. 62, 1908). Poulton himself considers that the usual diagnostic method of considering as species sets of individuals arranged according to certain characters fixed upon by the systematist, in a series without marked breaks, is not a sufficient conclusion, and he suggests that, in addition, the members of the group must interbreed and be of common origin. Romanes (*Darwin and after Darwin*, vol. 2, p. 231, 1895), after some discussion regarding the term "species," gives the following definition: "A group of individuals which, however many characters they share with other individuals, agree in presenting one or more characters of a peculiar and *hereditary** kind with some certain degree of distinctness."

Coming now to Darwin himself we find these words (*The Origin of Species*, ed. 6, p. 400): "Hereafter we shall be compelled to acknowledge that the only distinction between species and well-marked varieties is that

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* The italics are mine.

the latter are known, or believed, to be connected at the present day by intermediate gradations, whereas species were formerly thus connected . . . We shall have to treat species in the same manner as those naturalists treat genera who admit that genera are merely artificial combinations made for convenience." "This," concludes Darwin, "may not be a charming prospect, but we shall at least be freed from the vain search and undiscoverable essence of the term 'species.'"

Notwithstanding the last-quoted words of Darwin, the painstaking and epoch-making researches of Jordan, Mendel, de Vries, Bateson, Johannsen, and others have shed such light upon the species-question that the relation between a species and its subdivisions stands out far more clearly than in Darwin's time. Of especial importance is the fundamental difference shown by de Vries* between unfixed variants, whose forms depend upon the environment, and his elementary species (microspecies) which come true from seed under different outer circumstances—a distinction quite unsuspected by the early naturalists, as seen from the quotations already cited, *so far as groups distinguished by quite trivial characters were concerned.* In other words, if in the light of modern knowledge not only were the pre-Darwinian definition of Bentham to be accepted, but even that of the post-Darwinian Romanes, species after species would have to be rejected, variety after variety would be raised to specific rank, though others would be cast aside as mere fluctuations, and hundreds of trivial forms, apparently identical, as gauged by floristic methods, would have to be accepted as valid species, because they fulfilled perfectly the breeding test. Needless to say, the confusion would quickly become indescribable.

## Some Considerations from the Foregoing regarding Species and Varieties.

What, then, should be done in order to make a flora serve its primary purpose of enabling any member of a plant-population to be readily recognized? First of all, most will agree that no drastic changes are advisable. Linnean aggregate species answer admirably, provided it be understood that such are groups of varieties connected, it may be, by intermediate hybrids, and that species of this kind do not exist in nature as true-breeding entities, while their limitations are a matter of individual taste and not of scientific fact.

What really do occur in nature are the individuals, and these, obviously, should be the starting-point of classification. Unfortunately, these individuals are not all biologically equal. Some reproduce their like, and groups of these are the true self-breeding entities—*i.e.*, the microspecies, or biotypes. Others are of hybrid origin, and should, on the one hand, segregate in Mendelian fashion, or, on the other hand, be more or less intermediate in character between the parent species and come true from seed. Others, again, according to those believing either in natural selection or in neo-Lamarckism, should be neither microspecies nor hybrids, and would be expected in course of time to give rise sexually to individuals more or less distinct from their parents. Whether this last class really exists is, in the opinion of some, not scientifically established. It may quite well be that all "intermediates" which are not microspecies are merely hybrids between these latter or between the hybrids themselves. The hybrids of taxonomists are the result of crosses between one variety of a Linnean species and that of

* *Die Mutationstheorie*, Bd. 1, Lief. 1, pp. 32–41, Leipzig, 1901.

another such species, and not crosses between forms of the same aggregate hardly distinguishable from one another. But undoubtedly this latter class of hybrids—*i.e.*, crosses between microspecies—forms a considerable percentage in many plant-populations, and in no few instances these hybrids constitute connecting-links between groups otherwise distinct; in fact, they are then the so-called "intermediates." The surprising individual differences between the members of a young colony of *Leptospermum scoparium* which I recently studied in the neighbourhood of Wellington can be best explained on the above supposition, which doubtless holds good for many aggregate species. If this be true, the presence of "intermediates" loses much of its reputed taxonomic significance. In critical cases herbarium studies are obviously futile; no progress can be made by such means. *Experimental taxonomy, preceded by careful field observations, is alone of moment, and should eventually decide all doubtful points.* In this nothing novel is suggested; the procedure would be merely a return to the methods so wisely advocated by de Candolle and Sprengel in 1821.

The duty of the taxonomist is to arrange into groups the individuals he is dealing with. This he can do by comparing large numbers of individuals and placing together such as appear to possess constant characters in common. A number of such groups possessing definite characters common to all, but each group having one or more characters peculiar to itself, would form an aggregate species, the groups themselves being dealt with as varieties: or, where the aggregate species is extremely comprehensive, some authors may first unite certain of these varietal groups, according to their relationship, as "subspecies."* Such a plan as the above is rarely followed. The species itself is first defined, perhaps from the characters of a few individuals, or at times from one only. Later on other individuals come into consideration, which, though probably not exactly like those of the first defined group—they may, indeed, be very different—appear closely allied, and they are referred to the species, which accordingly is assumed to "*vary*." Should the new groups be fairly distinct from the original set of individuals, they may receive varietal names, and the species will be said to be "variable"; or if other more distinct groups are added as "varieties" it can be made "highly variable," or "protean," in which case the final word has been spoken, and further research is considered unnecessary.† This conception of

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* The term "subspecies" has been but little used by writers dealing with the New Zealand flora. Generally speaking, its use is confined to the primary subdivision of a species of such magnitude that it becomes a moot point whether to treat it as a huge aggregate or to split it up into smaller species. Where this latter course is not taken the establishment of a "subspecies" is not infrequently in the nature of a compromise, for the author, on the one hand, cannot make the aggregate of practical use in its entirety, and, on the other hand, is averse to acknowledging that the divisions he proposes are "good" species, so he adopts a group higher than a variety but rather lower in rank than a species. This aspect of the question is well illustrated by Kirk's treatment of *Hoheria populnea* in *The Students' Flora*, pp. 71–72. Or an author, as in the case of Bitter when dealing with *Acaena Sanguisorbae*, may establish subspecies as convenient subdivisions, whose components, for practical purposes, are the varieties. For the use of the syllable "sub" in taxonomic procedure, see Art. 12 of the *International Rules for Botanical Nomenclature.*

† The opposite course can be taken and a "highly variable" species can be made to "vary" comparatively feebly. The treatment of *Rubus australis* Forst. f. in this regard by Kirk (*Students' Flora*, pp. 125–26) and Cheeseman (*Manual*, p. 125) as compared with that of Hooker in the *Handbook*, p. 54, is an instructive case, Hooker defining the aggregate together with three varieties which he states "are united by every intermediate form."

variability is indeed remarkable! "Variability" of this kind is not the work of nature, but of the taxonomist. In order to produce a variety something must vary, and that something must be more primitive than the variant. But in taxonomic practice "variation" has an altogether different meaning from its everyday use. The "type" of the species is assumed to be the primitive form, and the "varieties" modifications of this "type." Of course, this may sometimes be the case and the varieties truly such, but usually no one variety can be considered the parent of the others; all may possess an equal claim, or, quite likely, the actual ancestor may no longer exist. As seen from the definition of the terms "species" and "variety" by the pre-evolutionary writers, the species was, *ipso facto,* the primitive entity, and it was assumed actually to give rise to varieties, which, if raised from seed, would sooner or later revert to the specific form. Species formed by evolution may also give rise to "varieties," but in this case, if the varieties are microspecies, neither the most accurate field observations nor even breeding experiments can decide whether "species" or "variety" is the parent. The "mere variety," to use the frequent phrase, is thus of equal rank to the "type," and in nine cases out of ten *it only escaped being constituted the "type" through its later discovery*—that is, it is a floristic variety by accident!

The "type," another most misleading term, was, with good cause, declared by Hooker to be a "phantom" (*l.c.*, p. xvi). One would naturally imagine a "type" to be the most widespread form of a species in its area of distribution, and in some instances this fortunately happens. Generally, however, the "type" is the form first described, which quite well may be the rarest form of the species. In such a case much commoner forms are later on described as "varieties." Now, these curious usages of the words "variety" and "type" can do but little harm so long as the student of a flora recognizes that they are terms which, though correct enough from the standpoint of special creation, no longer possess the meaning attached to them by the early taxonomists, but one which is quite technical. All the same, "variety" and "type" are established taxonomic terms which can hardly be abandoned, even were it biologically desirable to do so; still, so far as aggregate species are concerned, it seems much better to speak of them as "*polymorphic*" rather than as "*variable*."*

The term "variety" requires further discussion. In the case of aggregates all the varieties should be of equal value. Now, it can be readily conceived that, in process of time, all the varieties of an aggregate species except one may vanish from the face of the earth. This survivor, however, would at once change its rank and be deemed an invariable species. Also, it might not be closely related to any other species, yet the fact of its invariability would certainly place it not in the same category as the aggregates, but in that of the microspecies. According to this view, if the supposedly invariable *Agathis australis* Salisb. were considered the sole survivor of a number of closely related microspecies, it would biologically rank no higher than various unnamed true-breeding forms of *Veronica buxifolia* Benth., or the micro-

* Under this conception a "variety" is a microspecies—a stable entity—but a "variation" is an unstable form depending on its special environment. Moss, in the *Cambridge British Flora*, now in course of publication, calls such "variations" forms, and distinguishes them by names. For such fine distinctions, even if advisable, the time is not ripe so far as the New Zealand flora is concerned.

species segregated by Jordan from *Draba verna* L. (*Erophila verna* E. Meyer) in his classical experiments. The true *biological species* are, in fact, the microspecies, whereas the aggregates are merely collections of these and may be termed "*taxonomic species.*" Included with the biological species are the supposed true-breeding species, on the supposition either that these were once parts of aggregates, or that they are true-breeding entities which have originated from some earlier species by a change of great magnitude,* but are none the less biotypes. To the gardener and farmer, both of whom are deeply concerned with species, it is only the microspecies (biotypes) and the supposed invariable species, no matter their origin, which are of any moment.† And these alone answer the conception of a species as a true-breeding entity of both the pre-Darwinian and post-Darwinian biologists.

*The paramount importance of varietal names stands out clearly enough.* As noted early on in this paper, in all the floras of New Zealand up to the present time an aggregate species, if it has been split up at all, has usually been treated in two distinct ways. In the one case the specific name has been applied to one distinct variety, the so-called species; but in the other case each variety has been accorded a distinct name, and the specific name applied to the varieties taken together. In the latter case there is really a trinomial nomenclature, the species being but an idea. Moss has adopted the latter method in his *Cambridge British Flora*, and it seems to me the only biologically sound procedure. By the believer in species having originated through small changes each of the invariable species should be accorded, in addition to its specific name, a varietal name, since each is, in his opinion, the surviving variety of a former aggregate; but in practice this does not seem necessary, or even advisable. On the other hand, in the case of aggregates each variety, including the "type," should receive a distinguishing name. Of course, this procedure would lead to many new varietal names being given; but it would, of necessity, take place by slow degrees, while its value for extending a real

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* Lotsy is of opinion, according to his highly suggestive theory of the origin of species by crossing (*Proc. Linn. Soc.*, p. 73 *et seq.*, 1914), that changes may be of extraordinary size. "So," he writes, "the introduction of the unknown factor $x$ may have caused in some invertebrate the formation of the skeleton, and, if this is true, it is hopeless to look for a transition between an invertebrate and a vertebrate, as none such ever existed" (*l.c.*, p. 84).

A recent paper by C. S. Hoar (Sterility as the Result of Hybridization and the Condition of the Pollen in *Rubus*, *Bot. Gaz.*, vol. 62, pp. 370–88, 1916) gives various examples of more or less fertile interspecific hybrids. He points out how Linnaeus considered various hybrids good species, using *hybrida* for the specific name. The case of *Viola*, investigated by Brainerd, is also cited, where hybrids made between closely related but distinct species with characters intermediate between unlike characters of the present forms bred true from generation to generation (Hybridization in the Genus *Viola*, *Rhodora*, vol. 8, pp. 6 and 49, 1906).

Willis, as the result of studies in the distribution of the Ceylon flora, based on the comparative frequency of species (*Phil. Trans. Roy. Soc.*, ser. B, vol. 206, p. 307 *et seq.*, 1915), considers that all species arise by mutation, and that the new character may be either small or of great size. This botanist does not believe in the killing-out of intermediate forms (*l.c.*, p. 330).

† Horticultural and agricultural common-sense is far in advance of taxonomic science, as evidenced by the gardener and farmer having definite names for their innumerable varieties of ornamental plants, vegetables, and cereals. A binomial or even a trinomial nomenclature is of little use in actual horticultural or agricultural practice.

insight into plant-distribution can hardly be overestimated.* Doubtless many varieties would themselves frequently be aggregates, so that it might be advisable in some instances to establish further subdivisions. But without experiment it is impossible to deal with the ultimate microspecies (biotypes), nor in an admittedly artificial classification is this necessary. Finally, unstable forms, dependent on some particular environment, should never receive a varietal name; therefore many such names, the result either of the pre-evolutionary views or of ignorance, would have to be abandoned, unless, as explained in the footnote on p. 76, they were treated as "forms."

At the present time, in New Zealand floristic botany, as elsewhere, the tendency of authors is to split up the aggregates, and, in addition, to accept as species newly discovered plants which a few years ago would have been referred to existing species and hardly have received varietal rank. This method possesses the merit of convenience only, insomuch as it is easier to use a binomial than a trinomial. Biologically it is a retrograde step, for the aggregate emphasizes the intimate relationship of its component groups, as well as being an important biological conception for phytogeography. If the fact were generally recognized that such taxonomic varieties as are here suggested are far nearer being biological units than are species, and that their accurate delimiting is a matter of quite equal or even greater skill than the establishing of "new" species, and certainly redounds as much to the credit of the describer, probably fewer of the latter and more of the former would be published. But it will be a long time, if ever, before the student of a limited area can look at plant-classification with the same eyes as the general systematist. These words of Hooker written in 1853 still reflect the attitude of many: "There are local observers . . . who take the exclusion of plants accidentally introduced into the flora of their neighbourhood, and the reduction of supposed local types to varieties of better-known and wider-spread plants, as little short of an insult to their understandings and a slight upon the natural history of their village or island, and suppose that because the systematist cannot see with their eyes he therefore takes a less true interest in what he observes" (Introductory Essay to the *Flora Novae-Zelandiae*, p. xvii).

Bateson in no uncertain language declares his belief in intensely critical taxonomic work, and in the inadequacy of undivided aggregate species, in these words: "Between Jordan with his 200-odd species for *Erophila* (*Draba*)† and Grenier and Godron with one there is no hesitation possible. Jordan's view, as he again and again declares with vehemence, is at least a view of natural facts, whereas the collective (aggregate) species is a mere abstraction, convenient indeed for librarians and beginners, but an insidious

* There is a good deal to be said in favour of constituting "subspecies" (looking on this term as virtually equivalent to species) in widely distributed aggregate species which occur in areas far distant from one another. Skottsberg has proposed (and rightly, in my opinion) that the aggregate *Sophora tetraptera* should be maintained, and that the various groups of that species in New Zealand, Lord Howe Island, Easter Island, Juan Fernandez, and south Chile should be dealt with as subspecies or varieties (*Plant World*, vol. 18, p. 134, 1915). In New Zealand the groups of *Sophora* are so distinct both in form and life-histories that the term "subspecies" is more applicable to them than "variety." Were it not for phytogeographical reasons they should certainly be considered species.

† The words in parentheses are added by me.

misrepresentation of natural truth, perhaps more than any other the source of the plausible fallacies regarding evolution that have so long obstructed progress."*

Before publishing either a species or a variety it seems best to be in no hurry. Few dream of testing the stability of characters in a plant by cultivation, and fewer of extending this to methods of pedigree-culture. Taxonomy is assuredly not a matter of the herbarium merely; real progress depends upon intensive studies in the field and cultural experiments in the garden. It is surely better to apply a temporary "*nomen nudum*" to a supposed new species or variety than to rush into print and bestow a name based upon insufficient material and with no knowledge of the plant other than that which a few scraps of dried material afford. A temporary name for a plant may be a necessity in the case of ecological studies, but for a permanent one wrongly bestowed, which must enter into synonymy, there is generally no excuse, since it can serve no conceivable purpose. There is ample room for taxonomic research in the New Zealand flora apart from the hunt for "something new." There are few aggregates which do not demand a most searching examination, and variety after variety requires delimiting and naming. But this work cannot be carried out merely by an examination of dried material. Examples of the species must be brought together from every part of its area of distribution. Material of all kinds, both dried and living, must be accumulated, and the latter cultivated under various conditions. Above all, actual field-knowledge is an essential. Research of the above character could employ many investigators, while specialization would be fundamental. For instance, a searching examination of the little-known aggregate *Veronica pinguifolia*† carried out on the above lines would require several years' close study. In the case of certain trees and shrubs, and also in that of herbs difficult to cultivate, the experimental method might be too prolonged or almost impossible to apply, but, on the other hand, there are dozens of species easy to cultivate and raise from seed. Experimental taxonomy should become in course of time a most important branch of botany. At present, however, it is hampered by the methods of the university, where the garden plays so small a part and the laboratory rules; by the taxonomic traditions of the past; by the lack of sympathy between taxonomy and ecology, genetics, and horticulture; and by the length of time that must elapse before results can be published.

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* *Problems of Genetics*, Yale University Press, p. 250, 1913.

† There is hardly a more "variable" species in the flora, and yet no varieties have as yet been described. But in gardens where veronicas are extensively cultivated there are frequently several absolutely different plants which under the circumstances must all be accorded the name *V. pinguifolia*—a proceeding which does not increase the gardener's respect for botany. Doubtless in their natural habitats these forms might be connected by intermediates, but constantly raised from cuttings in the garden they appear invariable. Cheeseman, *e.g.*, writing of *V. Buchanani* (*Manual*, p. 527), states, "Larger forms approach *V. pinguifolia* so closely that it is difficult to draw a line of demarcation between the two species. My var. *major* might be referred to either."

## Art. VII.—*Studies in the New Zealand Species of the Genus* Lycopodium: *Part II—Methods of Vegetative Reproduction.*

By the Rev. J. E. Holloway, D.Sc.

[*Read before the Philosophical Society of Canterbury, 6th December, 1916; received by Editors, 30th December, 1916; published separately, 6th July, 1917.*]

Plates VIII, IX.

It is characteristic of the lower classes of plants that they show great capacity for vegetative propagation. With regard to the mosses this is a common phenomenon. "In the pleurocarpous forms, the main axes gradually die away from behind, the lateral branches becoming isolated, and constituting the main axes of new plants. In probably the majority of the Musci almost any portion of the body, a piece or stem, or a leaf, will, under proper conditions, grow out into protonemal filaments, which give rise to adult shoots in the usual manner. In certain species belonging to the Bryineae, multicellular gemmae are produced at the apex of the stem [and are either] modified leaves [or] are smaller and consist of but few cells [or] are borne on long stalks. On being placed under . . . favourable conditions, the cells of the gemma grow out into protonema." (Vines, *Text-book of Botany*, p. 337, 1898.)

Reproduction by gemmae is characteristic also of the Hepaticae. "Brood-buds" have been described and figured as occurring in the Psilotaceae (*e.g.*, Engler and Prantl, 1900). Also, in *Ophioglossum vulgatum*, two observers, Land (1911) and Pfeiffer (1916), have recorded that vegetative reproduction, probably by adventitious budding of older roots, is the common method of spreading.

In the genus *Lycopodium* we find a variety of methods of vegetative reproduction which are closely analogous to those cited above. The present paper is devoted to a description of the methods of vegetative propagation which I have observed in the New Zealand species of the genus *Lycopodium*.

I have not been able to gain access to Treub's *Études sur les Lycopodiacées*, in vol. viii (1890, pp. 14–23) of which is his description of the root-tubercles of *Lycopodium cernuum*.

### I. Vegetative Propagation of the Prothallus.

Treub (1886) has described three methods of vegetative propagation which he observed in the prothalli of *L. Phlegmaria*. Firstly, by the progressive rotting of the older parts of the prothallus the lateral branches are set free and thereupon constitute new individuals; secondly, by the formation of small ovoid multicellular bodies ("brood-buds") from single epidermal cells of the prothallus, these becoming isolated by the rupture of their pedicels; thirdly, by the formation of thick-walled bodies consisting of only a few cells, which probably are designed to undergo a period of rest during an unfavourable season. Treub compared these two latter kind of organs to the gemmae of the Hepaticae.

On old or injured prothalli of *L. Selago* Bruchmann (1898, pp. 95–97) found adventitious shoots on which rhizoids and sexual organs were developed, and which were able to live a separate existence when isolated from the parent prothallus.

Goebel (1905) found that broken-off portions of the crown of lobes of the prothallus of *L. inundatum* developed into new prothalli. These adventitious prothalli rooted themselves to the soil with rhizoids, and produced lobes and sexual organs.

In the New Zealand species *L. Billardieri*, which is very similar to the other epiphytic species, *L. Phlegmaria*, noted above, Miss Edgerley (1915, p. 105) states that the branches on the prothalli sometimes die off from behind and form new individuals. She found "some prothalli surrounded by numerous detached branches whose rhizoids were interlaced with those of the parent prothallus."*

The long-drawn-out prothalli of *L. ramulosum* (Holloway, 1916, pp. 269–71) are suggestive of the same methods of vegetative propagation—*i.e.*, by the isolation of portions of the prothallus as new individuals through the decay of the intermediate regions. I have not, however, actually observed that this has taken place. Some of those prothalli found by me showed several tubercular swellings along their length, each of which was infested by a fungus and bore a group of rhizoids. In close association with some of these swellings were groups of filamentous lobes at the base of which archegonia were developed (*ibid.*, figs. 32c and 32d, p. 269). It will thus be seen that if through injury to the prothallus or by the dying-away of an intermediate region of it a portion should become detached from the whole, that portion could still be possessed of all the essential organs for an independent existence and for the development of a young plant.

Treub (1886) was of the opinion that the majority of the prothalli of *L. Phlegmaria* found by him had been produced adventitiously from older prothalli, and that the germination of the spore was slow and the production of prothalli direct from spores consequently somewhat rare. I have shown elsewhere (1916, pp. 262–64) that in the case of the terrestrial New Zealand species the formation of prothalli from spores is by no means as uncommon as has been hitherto supposed of the Lycopodiaceae, although this may very possibly be due to the temperate climate and abundant rainfall in those parts of this country where Lycopods abound. Vegetative reproduction of the prothallus does not seem to be as common in the case of other species as it is in the epiphytic species of *Lycopodium*, but the fact that it has been noticed in certain abnormal cases in several other species shows that it may still be found to be a common method of propagation in the genus when certain conditions are present.†

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* The present writer has recently found the prothalli of *L. Billardieri* var. *gracile*. In some instances these showed a central more or less bulky region (on which were paraphyses and archegonia), with several branches, either long and slender or short and club-shaped, arising from it. But the majority of the prothalli found consisted of a single stout or slender branch of greater or lesser length, on which paraphyses and antheridia occurred in places, and on which also several short club-shaped vegetative branches had arisen. These latter prothalli were invariably broken off short at one or at both ends. They had probably originated by being detached from older prothalli. Not a few quite short club-shaped vegetative branches (densely packed with the fungal element, &c.) broken off at one end were also dissected out. (Out of thirty or forty prothalli found, only three undoubtedly showed the original end of the prothallus intact.)

† In Part I of these Studies (Holloway, 1916, p. 274) I figured several prothalli of *L. scariosum* in which a pseudo-branching had taken place. These prothalli were of unusual size, and their peculiar form, in which the two halves of the prothallus were separated by a constriction, suggests the possibility of the separation of the parent prothallus into two or more individuals capable of separate existence.

## II. The Isolation of Portions of Lateral Branches or of the Main Axes of the Plagiotropic Species.

This method of spreading is commonly found in all the plagiotropic species of the genus. The young prothallial plants are orthotropic in the case of all the New Zealand species whose adult plants have this plagiotropic habit of growth, but sooner or later they adopt the latter habit. The main axis, which in some species is subterranean and in others above ground, is generally speaking of unlimited growth, as are also certain of the lateral branches. Adventitious roots arise at intervals from the dorsal surface along both the main axis and the lateral branches. The vegetative spread of such a species takes place by the dying-away of the older parts of the main stem or by the isolation of the lateral branches. It is obvious that the form and habit of the plagiotropic species are adapted to this method of propagation.

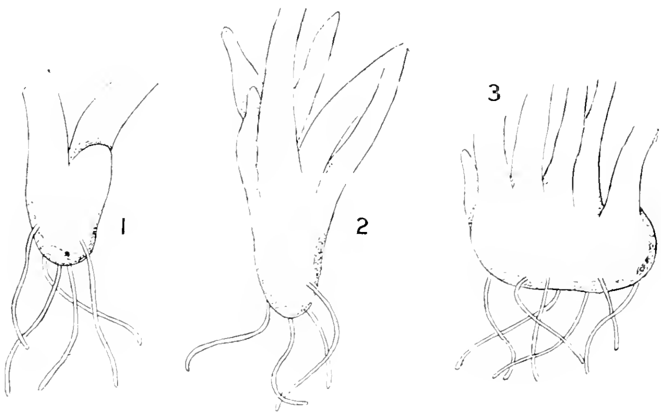
The plagiotropic species of *Lycopodium* are thus most fitted for rapid extension over new areas. These are the species found in large spreads over recently disturbed areas, such as forest clearings, roadside cuttings, sluiced goldfields, &c. This method of propagation is in all probability the main one in these species, except perhaps in the initial establishment of the species in the new area. Germination of the spores of these species does readily take place where the right conditions are present, but the delicate nature of the prothallus of some of them (*e.g.*, *L. cernuum*, *L. laterale*, and *L. ramulosum*), and the unusual length of time required for the full development of the prothallus of others (*e.g.*, *L. fastigiatum*, and also *L. volubile*, *L. scariosum*, and *L. densum*), are the reasons why only in exceptional localities, or during an exceptional series of seasons, are sexually produced plants firmly established. In Westland, where the rainfall is extremely high, I have frequently found in many localities colonies of young plants of the species *L. fastigiatum*, *L. volubile*, *L. scariosum*, and *L. ramulosum* which had been sexually produced, and of which a considerable proportion had come to maturity. In those parts of Canterbury and Nelson, however, where dry seasons are common I have on several occasions come across colonies of the young plants of *L. fastigiatum*, *L. volubile*, and *L. scariosum* which had become dried up. And on the clay gum-lands of Auckland, which are generally subject to being dried up in the summer, and where the two species *L. cernuum* and *L. laterale* commonly occur, it is probable that the young plants, which I have frequently found together with the prothalli, rarely come to maturity.

The form and habit of the plagiotropic species are probably to be regarded as a direct adaptation to the environment. The anatomical structure of the stem will also be modified in accordance with this. I have shown (1910, pp. 362–64) that the development of the parallel structure in the vascular cylinder of the developing stem of *L. volubile*, *L. fastigiatum*, and *L. scariosum* is the direct result of the restriction of branching to one plane. We may, of course, expect to find that the plagiotropic habit of growth has been evolved in species which belong to different natural sections of the genus. The fact that in the plagiotropic species there are at least two main types of stem vascular anatomy—viz., the "mixed" type of *L. cernuum* (and also *L. laterale*, *L. ramulosum*, and *L. Drummondii*), in which the xylem and phloem elements are intermingled and present no definite structure, and the "parallel" type of *L. volubile* (and also *L. scariosum*, *L. fastigiatum*, and *L. densum*), in which the vascular elements are disposed in parallel plates—is an indication that the species which conform to one type are to be more or less widely separated from those which belong to the other. The comparative study of the different species and the correlation of their characters is undoubtedly yielding indications of the different lines along which the genus has evolved, and also of the degrees of relationship existing between them: and such characters as habit of growth and stelar anatomy must also be taken into account in the construction of a natural classification of the Lycopodiaceae.

## III. Bulbils on Adult Plants.

Vegetative reproduction by means of bulbils borne on the stem is well known in *L. Selago* and certain other allied species. These bulbils are stated to be modified leafy branches.

While searching for young plants of *L. cernuum* near Henderson, Auckland, some years ago, I found on a damp mossy bank a number of very young plantlets of this species which had obviously been produced vegetatively. Mature plants were also growing on the bank immediately above. It would seem that the plantlets had originated as bulbils on these older plants, but I was not able to ascertain on what part of them they had been borne. The plantlets were simply resting upon and entangled in the ends of the moss-branches, and were not in any way anchored by their rhizoids to the humus. The youngest plantlets consisted of a basal tuberous portion,




Figs. 1–3.—*Lycopodium cernuum*. Bulbils from adult stems. × 20.

which was either round or more or less elongated, surmounted by one or two protophylls (fig. 1). Many of them, which showed several protophylls, were of a drawn-up spindly form, as if the stem-apex had been initiated very early and its upward growth had been rapid, whilst the basal portion was more feebly developed (fig. 2). It is possible that these individuals may not have been detached from the parent plant till they had attained this extent of growth. In a few instances the basal portion of plantlets was extended horizontally, as is usual in the sexually developed young plants of *L. laterale* and *L. ramulosum*, and as sometimes occurs also in the corresponding case of *L. cernuum* (Holloway, 1916, pp. 287–89). One or two of these plantlets bore as many as six protophylls (fig. 3) without a stem-apex having been initiated. The basal portion in all cases appeared opaque and brownish at the centre. Sections showed that this was due to a somewhat compact core of narrow cells containing much protoplasm (fig. 4). Minute starch-grains were present in abundance in the basal portion of the plantlets, especially in the epidermal cells and central cells. These stained blue with an aqueous solution of iodine. No fungal hyphae were seen. The leaves were crowded with stomata.

## IV. Root-tubercles.

Treub (1887) has described root-tubercles in *L. cernuum* thus: "The root-tips change into propagative organs of a remarkable form. These root gemmae or bulbs produce on germinating young plants very much like those which come forth from prothalli." This method of vegetative reproduction is found in several species of *Ophioglossum*. Land (1911) thoroughly investigated colonies of *O. vulgatum* in a Mexican locality, in which many young plants were seen to be present. He noticed that the plants were generally in groups of three to ten, usually radiating from a large plant. When the root-system of these groups was laid bare it was found that nearly all the plants of a group were connected, and that the smaller plants were produced by adventitious budding of the roots of the larger

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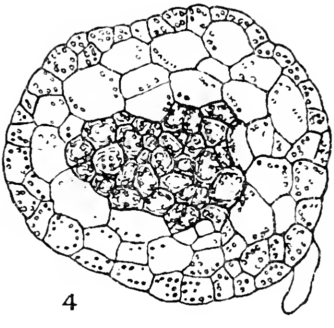

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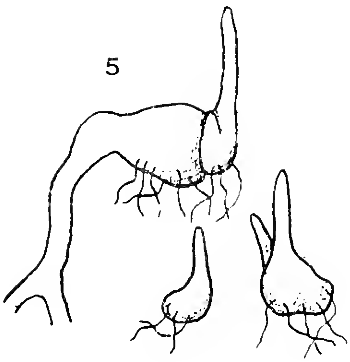


Fig. 4.—*Lycopodium cernuum.* Transverse section of basal region of such a plantlet as that shown in fig. 2. × 100.
Fig. 5.—*Lycopodium ramulosum.* Root-tubercle with attached and detached plantlets. × 6.

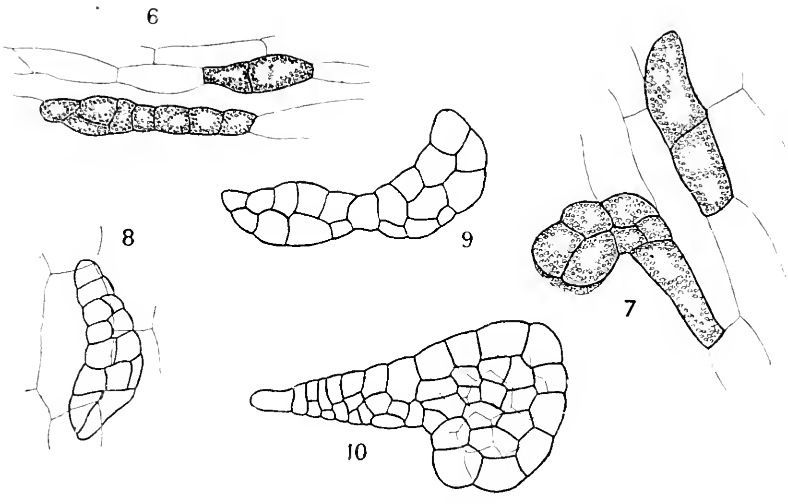
plants. Pfeiffer (1916) found the prothalli of *O. vulgatum* in a wet locality near Chicago. At the end of her paper she remarks that probably reproduction of this species by vegetative spread is by far the more common method, but scattered among plants so produced are the far less numerous specimens arising after gametophyte production has occurred.

I have found root-tubercles in both *L. cernuum* and *L. ramulosum.* In the former of these species instances were observed in which the actual tip of the root had turned into a swollen tuber, as described by Treub. Again, in the case of the adventitious plantlets of the same species described in Section III of this paper, two instances were seen in which a tuberous swelling occurred immediately behind the apex of the root of a plantlet—*i.e.*, the root-tip itself was not concerned with the process but grew on in the ordinary way. I was not able to collect sufficient material to enable me to trace the development of the root-tubercle of this species into the young plant, but there is no doubt that the tubercles observed were instances of the same process which Treub has described. In *L. ramulosum* I have found many instances in which the root-tip was swollen to form a somewhat egg-shaped tuber. On one occasion I dissected out from each other several pieces of old roots, one of these pieces bearing a secondary root whose tip had swollen to form a tuber, whilst entangled amongst the roots were two very young plantlets, one with two protophylls and the other with one. I have no doubt that these latter had originated as root-tubercles. In several other instances a detached root was found whose end was swollen to form a large massive irregularly-shaped tuber (*e.g.*, fig. 5), at the growing end of which a secondary tuber was attached surmounted by one or more developing protophylls. Both tubers were always green in colour, and both bore rhizoids. In the case of the plant shown in fig. 5 two other young green plantlets were disentangled from the rhizoids of the tuber. They had probably been budded off from it. Plate VIII, fig. 3, is a photograph of a root-tubercle of *L. ramulosum*.

## V. GEMMAE PRODUCED FROM CORTICAL CELLS OF OLD ROOTS.

In dissecting out young plants and prothalli of *L. ramulosum* from mossy turves obtained from a clay roadside cutting near the Mikonui River, Westland, I discovered a large number of instances of very young green plantlets attached along old isolated rootlets of this species. The older of these plantlets did not seem to be very firmly attached to the roots, but could be more or less easily brushed off with a camel's-hair brush in the process of cleaning. The youngest plantlets, however, were more firmly attached. A large number of these old isolated rootlets were found in the material dissected, and adventitiously produced plantlets were also in great abundance. In no case was a prothallus found attached to a plantlet, and only two isolated prothalli altogether were here found. Each plantlet consisted of a basal tuberous portion, the central region of which was opaque and brownish owing to the dense protoplasmic contents of the centrally placed cells, surmounted by one or more developing protophylls. Thus these plantlets were in general structure closely similar to all other young plants of this species, whether vegetatively or sexually produced, of the same degree of development. The original end of the basal tuberous region, however, was generally irregularly shaped, and in older plantlets the whole tuber spindly and even sausage-shaped, in this respect these plants being distinguishable from sexually produced plantlets. The characteristic form of these adventitiously produced plants corresponded closely with what I had previously noticed in the case of a number of very young plantlets of the same species found in material obtained from quite a different locality. I had there dissected out a good many plantlets of this form, and had been struck by the fact that none of them were attached to prothalli. I have no doubt now that they had been produced adventitiously from roots in the manner described in this section. It would seem, then, that this method of vegetative reproduction is not uncommon in this species. Whether or not it is due to an unusual season, or to some other such cause, I was not able definitely to determine. It is to be noted that none of the more fully grown plantlets gave any evidence of that extended horizontal habit of growth of the basal tuber with the postponement of stem-formation such as is so characteristic a feature in the sexually produced plants of this species. The development of the stem-apex is early, so that the plant becomes somewhat spindly in form. Abundant starch commonly occurred in the plants both in the tuberous region and in the rhizoids.

The old roots on which these plantlets were borne were frequently seen to be green, and even vividly green, in isolated patches, especially in the neighbourhood of the attached plants. Where a young plant was torn away from a root by brushing, a gaping hole was left in the latter, showing that the plant had taken its origin in the interior of the root and had had to emerge through a split in its external tissues. It was observed that at the point where a young plant was attached a group of rhizoids was present, and these rhizoids were found to be developed not from the plant but from the epidermal cells of the root. Plantlets at a somewhat later stage, and those detached from the parent roots, showed rhizoids on their basal portions. Isolated plantlets in a few instances were seen to show fragments of torn parenchymatous tissue attached to the basal region at one point or other. This would probably represent the remains of the cortical tissues

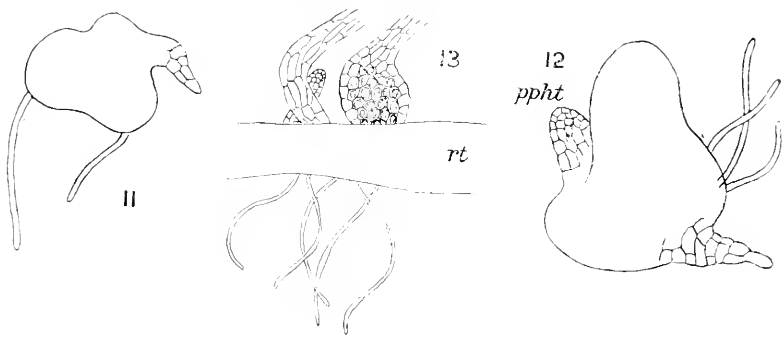



FIGS. 6-10.—*Lycopodium ramulosum.* Gemmae developed from cortical cells of old isolated rootlets. Figs. 6 and 10 × 100; figs. 7, 8, and 9 × 120.

of the parent root. The first-formed end of the tuber of some of the plantlets was of irregular form, the superficial cells growing out, or one or more haustoria-like prolongations of the tuber being developed. Probably this is to be put in connection with the nutrition of the developing plant from the root-tissues.

It commonly was the case that several plantlets in different stages of development were borne at the same spot on the root (fig. 13, and Plate VIII, fig. 2). In one instance I noticed, before dissecting out a certain piece of mossy turf, that three groups of protophylls were showing above the surface of the moss at distances of about a quarter of an inch from each other, and all in a straight line. These groups were found to be connected by an old root. In each group were well-grown young plants, as well as a large number of plantlets of all ages, some separate and others attached to the old root or to its various branches. All the individuals in these three groups had probably arisen adventitiously.

By dissecting under the microscope portions of old roots which showed green patches in the cortical tissues I was able to obtain a good series of developing plantlets. Certain individual cells of the cortex, which are similar in appearance to the other cortical cells except that they contain abundant protoplasm and chloroplasts, divide transversely (figs. 6 and 7). In some cases transverse division is continued so that the original cell becomes a filament several cells in length (fig. 6). In most cases, however, longitudinal walls appear early in the cells of the filament, so that it begins at its growing end to take on the form of a cell-mass (figs. 6–10). The growing end soon becomes globular in shape and bends away more or less at right angles from the original direction of the initial and other cortical cells, evidently turning towards the upper surface of the root (figs. 7 and 10). The globular growing end of the young plant becomes the basal tuberous region of the plantlet of a later stage of development. In some cases it grows very regularly to form an egg-shaped cell-mass, the summit of which is continued as the first protophyll (fig. 13). Again, in other cases the tuber grows very irregularly before the first protophyll appears (figs. 11 and 12).

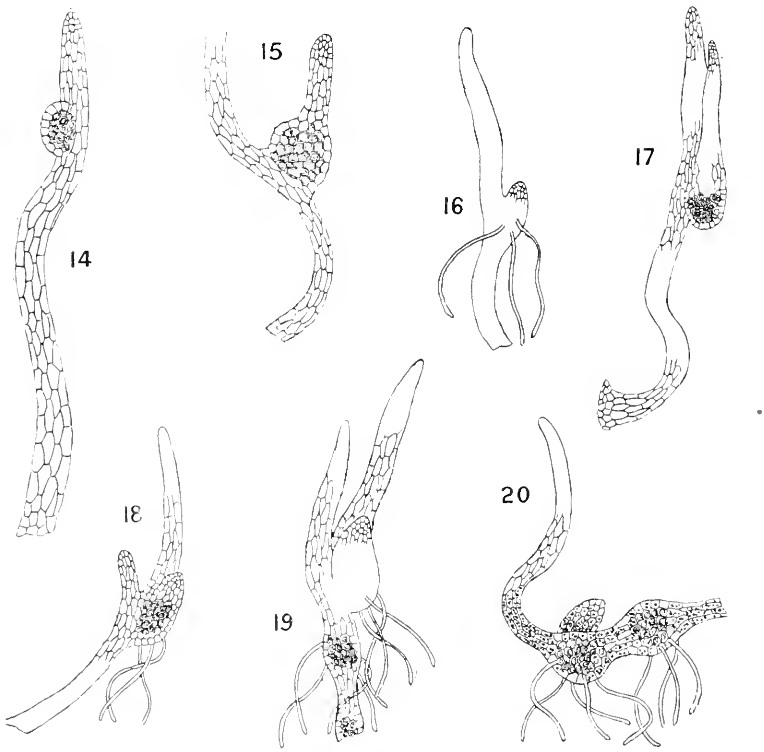



FIGS. 11, 12.—*Lycopodium ramulosum.* Gemmae developed from cortical cells of old isolated rootlets. × 45.
FIG. 13.—*Lycopodium ramulosum.* Group of adventitious plantlets in different stages of development attached to old rootlets. × 12.

About the stage of development attained by the plantlet shown in fig. 11 rhizoids first make their appearance on the tuber. From the first initiation of the young plant the adjacent cells of the root give rise to a group of rhizoids, showing that the developing plant is in its first stages nourished from the cells of the parent root. As the plantlet increases in size it bursts the outer tissue of the root, and the first protophyll is then quickly developed (Plate VIII, fig. 1). The first-formed tapering portion may clearly be seen on the developing plantlets (figs. 11 and 12), and may sometimes still be distinguished at the base of plants which show as many as three or four full-sized protophylls. As the plant grows, the tuberous basal portion becomes elongated in most cases by the swelling of the lower extremity of the protophyll till it assumes a sausage-like shape, but the original end of the tuber retains its first-formed somewhat irregular form. As has been noted above, I have observed one or two plants in which the young developing tuber had grown very irregularly so as to form one or more distinct haustoria-like protuberances. There can be no doubt that these penetrated the cortical tissues of the parent root and functioned as absorbing surfaces.

## VI. Bulbils on Detached Leaves.

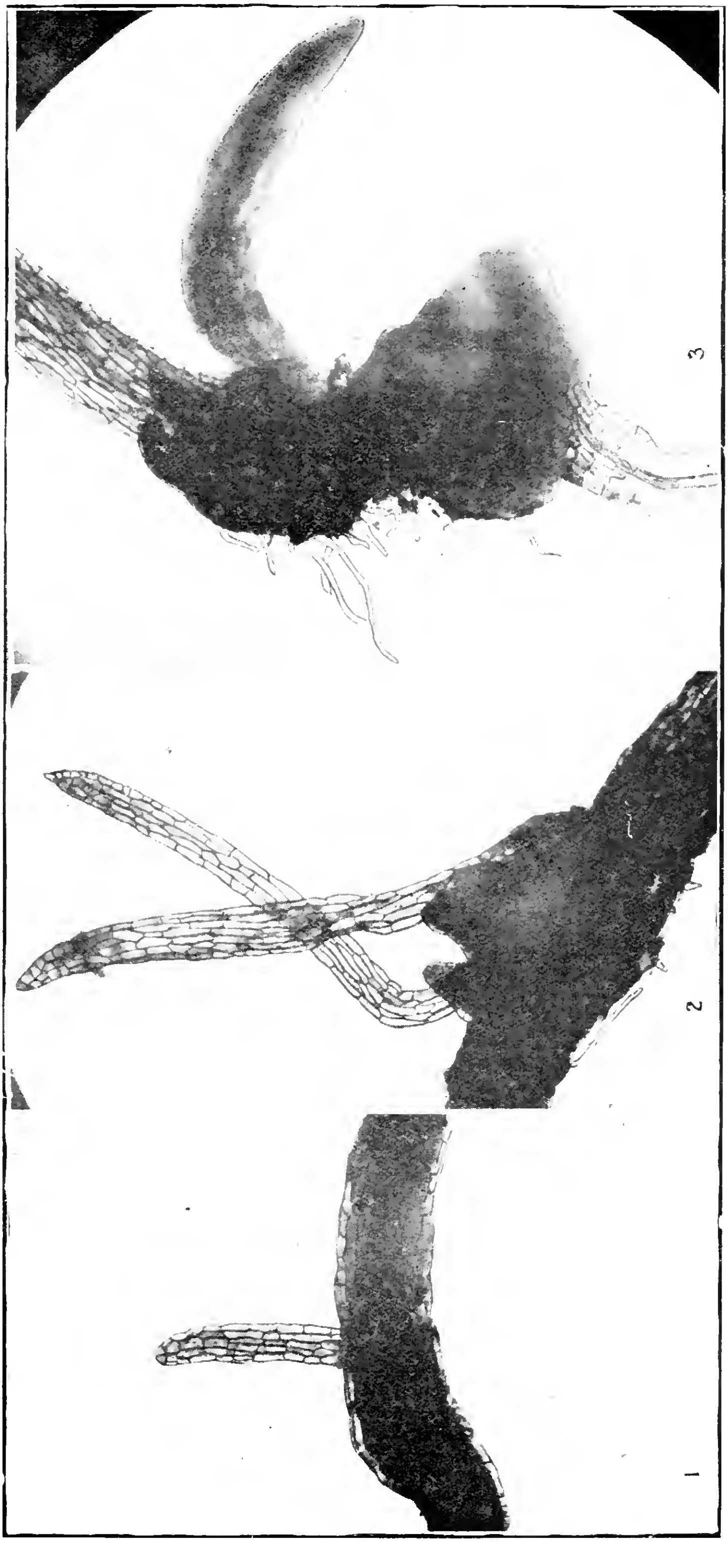
In the same material in which the vegetatively produced plants described in the last section were found I discovered a large number of young plantlets of the same species (*L. ramulosum*) developing on detached leaves. I could not ascertain for certain whether these leaves had become detached from mature plants or from young sexually produced plants of the previous season. The material dissected contained many old detached roots and rootlets. A somewhat dry year had intervened since the previous season, and it is possible that a colony of young plants, or perhaps a mat of adult




Figs. 14–18.—*Lycopodium ramulosum.* Adventitious plantlets developed as buds from detached leaves. Figs. 14 and 15 × 12; figs. 16–18 × 10.

Figs. 19, 20.—*Lycopodium ramulosum.* Detached leaves bearing daughter plantlets, and showing bulbous swellings in their lower portions. × 10.

plants, had gradually died off, and that the conditions had stimulated the adventitious budding of their detached roots and leaves. An adventitious bud on a leaf shows first as a small roundish green cushion of meristematic tissue (fig. 14), which has originated probably from one or more epidermal cells. This cushion develops into a roundish or egg-shaped cell-mass, which gradually elongates, and on which at an early stage rhizoids arise (fig. 16). The attachment of the young bud to the parent plant is clear from fig. 15,




*Lycopodium ramulosum.*

FIG. 1.—Adventitious plantlet arising from cortical cells of an old detached root. × 28.
FIG. 2.—Adventitious plantlets arising from cortical cells of an old detached root. × 28.
FIG. 3.—Adventitious plantlet arising from tuber at the end of an old detached root. × 22.


*Lycopodium ramulosum.*

FIG. 1.—Adventitious plantlet arising from an old detached leaf. × 28.
FIG. 2.—Adventitious plantlet arising from leaf of a second adventitious plantlet × 28.
FIG. 3.—A detached leaf which has branched twice. × 22.

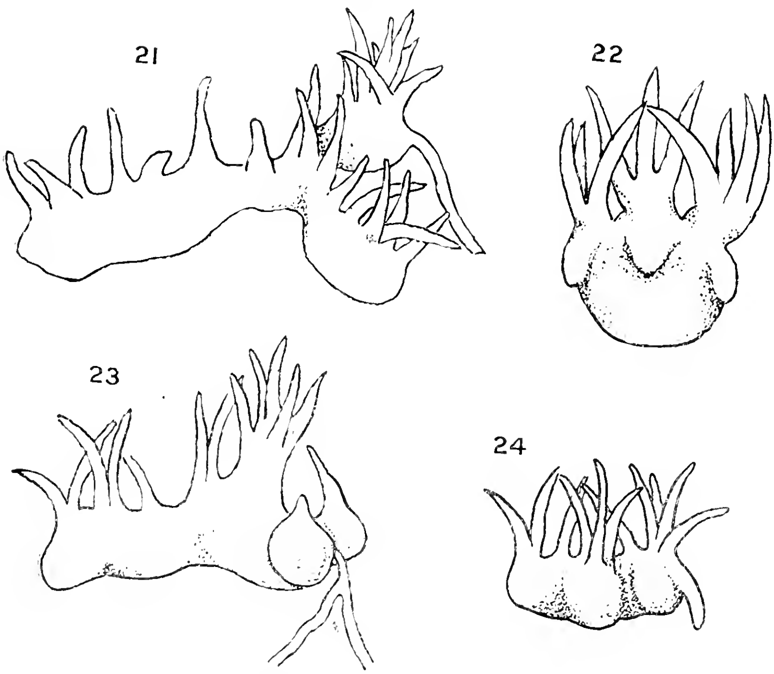
which shows that the main tissue of the leaf at the point of attachment is undisturbed. The bud from the first is vividly green, and is usually crowded with minute starch-grains. Its central cells appear brownish and opaque, owing to their dense protoplasmic contents. The first protophyll arises simply by the continued growth of the buds (figs. 15 and 18, and Plate IX, fig. 1). A second protophyll and then a third arises from the first-formed bulbous portion alongside the first (fig. 19). By this time the young plant has become well attached to the underlying humus by means of its rhizoids, and the parent leaf is beginning to rot away. In one instance a plantlet which had originated adventitiously from the cortex of an old detached root, to which it was still attached, had developed a very young bud near the apex of its single protophyll. Both protophyll and bud were packed with starch-grains, and a single rhizoid had developed about half-way up the protophyll from one of its epidermal cells. Plate IX, fig. 2, shows a well-grown bulbil developed upon a second adventitiously produced plantlet. A second example of a rhizoid being formed on an old leaf which bore a young adventitious plant was also observed, the leaf in this case being detached.

The parent leaf is generally greenish in its upper portion but colourless below, and is always obviously broken off at the lower extremity. The leaves shown in figs. 19 and 20 had each developed two swollen areas in their lower portions. These bulbous places on the leaves were of much the same appearance as the first-formed swollen portion of the developing bud, the central cells being brownish and opaque owing to their abundant protoplasmic contents. A group of rhizoids was present on each of these swollen areas. In many cases it was noticed that the rhizoids arising from the developing buds, and also the cells of the lower portion of their protophylls, and especially the cells of the basal bulbous regions, were crowded with starch-grains. Some of the parent leaves also, including the two in which swollen areas had formed, showed the presence of starch in their lower portions. A single instance of a branched leaf was found (Plate IX, fig. 3). Two branches had arisen upon the parent leaf, but on neither of these were rhizoids present, nor were their bases swollen. They had evidently developed somewhat differently from a bulbil.

Fungal hyphae do not seem to be present in the cells either of the parent leaf or parent root of the plantlets. The transverse section of the base of an adventitiously produced bulbil of *L. cernuum*, shown in fig. 4, is closely similar to sections of plantlets of *L. ramulosum* which had developed from detached roots and from leaves. The central cells of the lower bulbous portion of the plantlet contains abundant protoplasm and also numerous minute starch-grains. As the plantlet develops, these cells become narrow and elongated, and seem to function both as a storage and as a conducting tissue. A distinct epidermal layer of small-sized cells is differentiated from which rhizoids arise, whilst the cells in the zone which lies between the epidermal layer and the centrally placed cells gradually assume in the developing plantlet a large size, and are then for the most part empty. It is clear that the core of slightly elongated parenchymatous cells in the young plantlets is not to be regarded as the primordium of the permanent stem vascular cylinder. That, of course, arises, as in the case of the sexually produced plants of *L. cernuum*, *L. laterale*, and *L. ramulosum*, in the first place by the extension of the protophyll-strands down into the tissues of the plant, and their aggregation there, and secondly by the development of a plerome from the meristematic tissue at the stem-apex.

## VII. Vegetative Reproduction of the Protocormous Rhizome.

In the two New Zealand species *L. laterale* and *L. ramulosum* the "protocorm" of the young sexually produced plant elongates sideways and attains a considerable size before a stem-apex is differentiated on its dorsal side. This protocormous rhizome plays a much larger and more important part than does the simple protocorm of *L. cernuum.* It constitutes the plant-body for a whole season, and may even branch. It appears also that in both *L. laterale* and *L. ramulosum* it is able to reproduce itself vegetatively. I found one branched protocorm of the former species, on each of the branches of which a stem-axis had been initiated (Holloway, 1916, fig. 67).




Figs. 21, 22.—*Lycopodium ramulosum.* Branched protocormous rhizomes with two or more stem-axes. × 6.

Figs. 23, 24.—*Lycopodium ramulosum.* Protocormous rhizomes with bulbils attached. × 6.

In Part I of these present Studies I briefly described one young plant of *L. ramulosum* at the growing end of whose procormous rhizome two young bulbils were developing (*ibid.*, p. 285). Since then I have found eight to ten additional instances of the vegetative reproduction of the rhizome of this latter species. From the material mentioned above as having been obtained near the Mikonui River, Westland, I dissected out several young plants whose rhizome was branched. In these instances the rhizome was generally an old and abnormally large one. The growing end had given rise to two more or less equal branches, which were green in colour and bore a number of young protophylls, whilst the old first-formed portion was brown and surmounted by only a few old brown and decayed protophylls. Fig. 21 shows one such plant, in which the two growing ends were swollen and slightly globular in form, each being marked off from the rest of the rhizome by a slight constriction. There is no doubt that both these branches would sooner or later become independent individuals.

At least two other instances were observed in which two swollen and vividly green branches were present on the end of the rhizome. Three plantlets with branched rhizomes were found on which two, and in one case three, separate stems had arisen. It would seem that the original rhizome persists intact well over one season, although its empty cells show that it no longer functions as an absorbent or storage organ before by its decay it sets free the daughter plants. It may be noted here that in almost all young developing plants of this species, as also in *L. laterale*, the protocormous rhizome remains attached to the base of the plant-stem till the latter attains a length of an inch or more, although it probably ceases to function soon after the development of the first root. Fig. 22 shows the end view of the rhizome of a young plant of *L. ramulosum* on whose branching end three stems had arisen. It will be seen that the formation of the first root had just been initiated at the base of each of the three stems, the three roots having been developed simultaneously.

As well as the vegetative reproduction of the protocormous rhizome of *L. ramulosum* by means of the isolation of daughter branches, reproduction sometimes takes place by the formation of bulbils on the end or on some other part of the rhizome. A figure of a rhizome with two such bulbils was given in Part I of these studies (Holloway, 1916, p. 269), and is reproduced in the present paper (fig. 23). In another instance quite a small and comparatively young unbranched rhizome was found on which were borne two such bulbils (fig. 24). These bulbils are very simple swollen globular protuberances of the tissues of the rhizome. They are vivid green in colour, and are surmounted by one or two young green protophylls. The colour of the bulbils is in striking contrast to the opaque yellow appearance of the parent rhizome. Not a few instances of a group of very young plants, consisting of from two to seven individuals in different stages of development, were found, where there was every appearance of their having arisen as bulbils from an old original rhizome. In several of these groups an old broken-down rhizome was in close proximity to the young plantlets. Although many of these plantlets were exceedingly small and young, in no case was a prothallus present, this fact indicating that they had arisen by vegetative reproduction. It was noticed that these detached adventitious plantlets almost invariably consisted each of a basal globular mass of opaque brownish-looking tissues with one or two semi-decayed protophylls, whilst at some point or other on the plantlet there was a vividly green area which was obviously the growing-point of the plantlet. In some cases this green area was in the form of a bluntly rounded protuberance of the tuberous portion of the plant, and in others it was a single protophyll or a very young developing protophyll. In connection with this it may be noted that a possible interpretation of the detached leaves bearing adventitious buds, described above in Section VI, is that they had become detached from an old rhizome, or from a bulbil produced vegetatively from such a rhizome. The fact that these bulbils become brownish in colour after being detached from the parent rhizome, and that their growth becomes localized in one spot, seems to indicate that their development is arrested for a time, and that they act as resting bodies till the external conditions are suitable for their further development and for the initiation of a stem-axis.

## Conclusions.

Vegetative reproduction is a common phenomenon in the Lycopodiaceae, as it is well known to be also in the Mosses, and it may take place in a great variety of ways. It is noteworthy that the swollen tuberous basal region termed the "protocorm" by Treub in the case of the sexually produced plants of *L. cernuum* is present also in the adventitious plantlets of *L. cernuum*, and in all the plantlets of *L. laterale* and *L. ramulosum* whether produced sexually or adventitiously. In no case in any of these three species have I ever noticed the presence of fungal hyphae in the cells of the "protocorm," although Goebel (1905, p. 233) says that a fungus infection occurs in the root tubers of *L. cernuum* and in certain swellings on the stem of *L. inundatum*, and that it there appears to promote an increase of plastic material. In all the cases of protocormous swelling examined by me I have never been able to discover more than abundant protoplasm and starch-grains, and have concluded that the swelling acts mainly as a storage region, although it must be added rhizoids are always developed early on the tubers, and in some cases also these rhizoids show the presence of starch-grains. A swollen area comparable to the "protocorm" occurs sometimes on detached leaves of *L. ramulosum*, in conjunction with the formation on the leaf of an adventitious bud; and also the plantlets which are developed adventitiously from cortical cells in the roots of the same species begin as "protocorms" more or less regularly formed. Plantlets formed vegetatively as outgrowths from the protocormous rhizome of the sexually produced plantlets of *L. ramulosum* also begin as tubers. It may not be out of place also to add to this list of vegetatively produced "protocorms" the annually produced tuber in *Phylloglossum* which is the first stage in the development of the new plant. Here also the tuber acts as a storage tissue.

It is instructive to compare the Lycopod "protocorm" or bulbil with the flat or sometimes solid gemma of the Hepaticae, and with the filamentous protonema which in the Musci precedes the formation of vegetatively produced plantlets. They may be compared in the light of being a response made by the plants belonging to those different classes to certain external conditions. Klebs' well-known experiments in the Algae and Fungi have shown that sexual or vegetative reproduction may be respectively induced by varying the conditions of light, water, and food under which the plants are growing. This may well be a natural phenomenon also in the case of the Hepatics and Mosses, or even of the Lycopodiaceae and other pteridophytes. It is possible that in the Lycopodiums the vegetative tuber or "protocorm" is to be regarded as a resting body designed to withstand a dry season. If this can be accepted as a possible explanation in the case of the vegetatively produced plantlets, there is a strong suggestion that the same interpretation should be applied to the case of the first-formed "protocorm" in the sexually produced plants of the species of the *cernuum* type. The tuber of the vegetatively produced plant is similar in appearance and function to that of the sexually produced plant, and the origin from it of the protophylls, stem-axis, and first root is also identical. Thus the study of the protocormous tuber in the three New Zealand species *L. cernuum*, *L. ramulosum*, and *L. laterale* suggests that in all its forms it is to be regarded as a vegetative adaptation characteristic of certain sections of the Lycopodiaceae, rather than as the persisting rudiment of a highly primitive organ.

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## APPENDIX.

While this paper was being printed, Chamberlain's paper on "Prothallia and Sporelings of Three New Zealand Species of *Lycopodium*" (*Bot. Gaz.*, vol. 63, No. 1, 1917, pp. 51–65) came to hand. In it he gives a short account of preserved specimens of the prothalli of *L. laterale*, *L. scariosum*, and *L. volubile*, and also describes the stele of the sporeling of the two last-named species. In Part III of these studies I hope to give an account of the internal structure of the prothalli of seven New Zealand species which were described in Part I, and will compare my results with Chamberlain's observations. In the course of his paper Chamberlain draws attention to the fact that those who have hitherto been at work upon the Lycopodiums have devoted the greater part of their attention to the prothallus and to the adult plant, and that the vascular structure of the sporeling has received little notice. There is no doubt that this has been largely true, although the understanding of the various types of the Lycopodium stele can only come, as Chamberlain remarks, through the comparative study of their ontogenetic development in complexity. I hope to supplement my observations on the vascular structure of the sporelings of eight New Zealand species given in Part I of these studies by a more detailed account in a further contribution, now partially completed. This will include also an account of the vascular structure of the adventitious plantlets described in the present paper, and will deal as well with the young plants of one or two other New Zealand species found by me.

## Art. VIII.—*The Vegetation and Flora of Lord Howe Island.*

By W. R. B. Oliver.

[*Read before the Auckland Institute, 15th December, 1916; received by Editors, 30th December, 1916; issued separately, 6th July, 1917.*]

Plates X–XVI.

Contents.



### I. GENERAL.

Situated in a tract of ocean which bounds three biological regions of the globe, and on a submarine ridge connecting two of these, Lord Howe Island is at once of intense interest to the biologist. This island, remarkable not only for its biological productions but also on account of its geological structure, lies about 430 km. eastward of the Australian Continent, in S. lat. 31° 32′. Yet in the character of its animal and plant life it presents a striking contrast to that of Australia, though, owing to the proximity of the continent and consequent occasional accidental means of transport, certain features of the continental life are stamped on that of the island. Fundamentally, however, there is a wide difference.

The present paper is based mainly on collections, notes, and photographs obtained during a short stay on the island in 1913. I left Sydney on the 1st November in the "Makambo," and after a fine passage Lord Howe Island was sighted on the afternoon of the 3rd, the two mountains, Gower and Lidgbird, being visible at a distance of over forty miles. Being dark when we arrived, anchor was cast outside the reef on the western side of the island, but by the kindness of Mr. R. S. Bell, who was then residing there, I was rowed ashore through an opening in the reef and landed on the beach near Mrs. Nicholl's residence, which I made my headquarters. Altogether I remained fifteen days on the island, and, despite some bad weather, spent practically the whole time in investigating the flora. I visited most parts of the island, from the Northern Hills to the western base of Mount Gower. Four days were spent on the mountains, where, in company with Mr. Bell, I camped in Erskine Valley. Twice from this camp I ascended Mount Gower, once with Mr. Bell and his assistant and once by myself. On the 17th November the "Malaita," returning from the New Hebrides, called at Lord Howe Island, and I embarked with my collections, and after a tempestuous voyage of two days arrived at Sydney.

Altogether I have admitted as vascular plants indigenous to Lord Howe Island 209 species. The difference, sixteen species, between this and Hemsley's list published twenty years ago is mainly due to the investigations of Maiden and Watts. I have added only one name, *Kyllinga monocephala*, and this species may have been recently introduced. Several species about which there is some suspicion of their having been recorded in error are retained because I have no good reason for omitting them, while there is evidence of the presence on the island of two or three species of woody plants not included in my list on account of insufficient material for determination.

I have taken some trouble to give the names of the species in accordance with the rules of botanical nomenclature adopted at the Vienna Congress of 1905. This has involved several changes from the names commonly in use. In the systematic part of the paper, therefore, I have in all cases quoted the original reference. Following this I have given the principal references to works where some information is to be found regarding Lord Howe Island specimens, and also the earliest reference recording the species in Lord Howe Island under each name to which it has been referred. "Habitat" is used in an ecological sense, and is to be distinguished from "distribution," used only to mean geographical range.

My thanks for assistance in the production of this paper are due—in the collection of specimens, to Mr. R. S. Bell, who, by giving me the benefit of his wide knowledge of Lord Howe Island and acting as guide on several of my excursions, made possible the amount of work I was able to do during my stay on the island; in the identification of my specimens, to the Rev. W. W. Watts and Mr. C. H. Cheel, of Sydney, and Mr. T. F. Cheeseman, F.L.S., F.Z.S., of Auckland; and to the Board of Governors of the New Zealand Institute and the Council of the Philosophical Institute of Canterbury, for grants of money, by the former out of the Hutton Memorial Research Fund, to help defray expenses. To Dr. L. Cockayne, F.R.S., of Wellington, I am indebted for many valuable suggestions.

## Physiography.

Lord Howe Island is evidently but a fragment of a once more extensive area, sheer cliffs of 800 m. showing sections of horizontal lava-flows, testifying to a vast amount of denudation. The island is roughly crescent-shaped, the convexity facing west. The extreme length is 9·6 km., and greatest breadth 2·8 km.; the total area is about 13 sq. km.

Considered according to its geological structure, which determines the physical features, Lord Howe Island may be divided for purposes of description into (*a*) two contiguous and much-denuded mountain masses forming the southern end, with a low-lying portion stretching from their base in a northerly direction and consisting of (*b*) three groups of volcanic hills connected by (*c*) flat ground of marine origin. Across the bay on the west side of the island a detached portion of the limestone formation of which the flat ground is composed forms a reef uncovered at low water.

The southern, or mountain, portion of the island consists of Mount Gower (865 m.) and Mount Lidgbird (763 m.), connected by a ridge which dips to 380 m. at its lowest point. Mount Gower is flat-topped, and on three sides presents to the sea perpendicular cliffs, access to the summit being gained only by the northern ridge leading to Mount Lidgbird. The eastern face is a sheer drop from summit to sea-level. The summit plateau is about 500 m. long by 300 m. wide, and slopes gently from east to west. Its surface is traversed by two small valleys. Mount Lidgbird is more pyramidal in shape. Its sides lead up by a series of huge cliffs and steep declivities to a short narrow ridge at the summit.

Splendid opportunities for observing the structure of the mountains are afforded by their sides, which are for the most part sheer cliffs. Both are composed of nearly horizontal beds of lava, which viewed from the sea to the west are seen to incline very slightly in a northerly direction. The present mountains are, therefore, but fragments of a large volcano whose crater was probably to the south.

The low volcanic hills lying to the north of the mountains fall into three groups: (*a.*) The Northern Hills form a short ridge with a perpendicular face to the sea and a gentler slope inland. (*b.*) Transit Hill stands alone in the centre: its east slope reaches the sea: the remaining sides are surrounded by limestone beds. (*c.*) Intermediate Hill abuts against the precipitous northern face of Mount Lidgbird, and has clearly been thrown up after the mountain masses had been denuded almost to their present state. It thus affords striking proof of a long period of time having elapsed between the eruptive outbursts producing the mountains and those forming the low hills. Except the Northern Hills, which are most exposed to westerly seas, the volcanic hills are but little denuded by marine action. This is perhaps further evidence of their being much younger than the mountains.

The flat ground connecting the volcanic hills, together with the reef across West Bay, are formed of stratified limestone beds of marine origin. They contain marine shells, bones of *Meiolania*, and shells of *Placostylus*. The latter are probably collections of dead shells embedded in superficial rain-water deposits, or odd shells which have found their way to the sea and there become entombed. I found numbers of these shells on the rocks between tide-marks, many of them utilized by hermit crabs.

The soils of Lord Howe Island are of two kinds: firstly, that on limestone rock, which is loose, sandy, and dry; secondly, that on volcanic ground, which is darker in colour and contains a good deal of moisture and humus. A sample from the summit of Mount Gower taken in November, 1913, during showery weather contained water to the extent of 68 per cent. of its weight. In a sample from Transit Hill collected in fine weather the water-content was 32 per cent. of the total weight.

## Climate.

Situated on the northern limits of the region of prevailing westerly winds and in a tract of ocean over 400 km. to the eastward of Australia, Lord Howe Island enjoys a climate distinctly insular in character—that is, there is no great range in temperature, and the rainfall is ample, averaging 1,818 mm. per annum. But the frequent high winds probably account for a comparatively low relative humidity, as shown in the annexed tables. The meteorological station is situated on the flat limestone ground between Transit Hill and the Northern Hills, and about 3 m. above sea-level. The observations on which my figures are based were taken by Mr. G. M. Kirby, to whom I am indebted for his kindness in allowing me to inspect his record, but I am entirely responsible for the figures as they appear here corrected and tabulated. I chose a period of one year, beginning in the winter (1st July), as it shows a complete growing season, and may thus be compared with a calendar-year period in the Northern Hemisphere.

Table 1 shows the weather month by month. Table 2 shows the length and character of each kind of weather, classed by wind-direction, and brings out some interesting points, the chief of which are noted below.

Atmospheric pressure varies regularly with the direction of the wind, being highest in south-east and east weather, and lowest in north-west and west weather. The highest reading recorded was 774·4 mm., on the 9th June, 1912; wind east: the lowest, 750·3 mm., on the 16th September, 1911; wind north-west.

Temperature, judged by both season and direction of wind, varies in a regular manner. The maximum temperature recorded was 30° C., on the 8th February, 1912; the minimum, 6·1° C., on the 30th August, 1911.

Rainfall is distributed fairly evenly throughout the year, though the average for the winter months is higher than that of the summer months. The average annual rainfall for twelve years is 1,818 mm., on 196 days. During the period selected for analysis, out of a total of 1,265 mm., 779 mm., or over 60 per cent., fell during northerly weather. This result, as well as others noted in this section, agrees closely with that recorded for Sunday Island (Oliver, *Trans. N.Z. Inst.*, vol. 42, 1910, p. 125). The two islands are situated in nearly the same latitude, and their climates are similar in most respects. In the Kermadecs, however, the rainfall and relative humidity are apparently higher than they are at Lord Howe Island, which differences may result from the greater distance of the Kermadecs from the Australian Continent.

Relative humidity varies in accordance with the direction of the wind. Northerly winds bring the most humid conditions, southerly winds the least. On only three days the air was recorded as saturated, while on twenty-one more the degree of relative humidity was above 90: the lowest record was 49 per cent., on the 31st January, 1912; direction of wind south-east.

TABLE 1.

| | Barometer | Temperature C°. | | | Rainfall. | | Relative Humidity. | Cloud. | Wind. |
|---|---|---|---|---|---|---|---|---|---|
| | Mm. | Min. | Max. | Mean. | Days. | Mm. | Per Cent. | 0–10 | Direction. |
| 1911. | | | | | | | | | |
| July .. | 762 | 13·1 | 17·9 | 15·5 | 21 | 192 | 79 | 6·4 | S.W., S.E. |
| August .. | 764 | 12·0 | 17·4 | 14·7 | 22 | 97 | 75 | 5·9 | S.E. |
| September .. | 762 | 13·6 | 20·2 | 16·9 | 8 | 154 | 75 | 7·1 | S.W. |
| October .. | 764 | 14·4 | 21·5 | 17·9 | 11 | 132 | 66 | 5·7 | S.W. |
| November .. | 762 | 16·8 | 23·8 | 20·3 | 8 | 91 | 73 | 5·6 | N.W., S.W. |
| December .. | 757 | 19·2 | 26·1 | 22·6 | 6 | 17 | 73 | 6·4 | N.W. |
| 1912. | | | | | | | | | |
| January .. | 760 | 18·8 | 25·5 | 22·2 | 10 | 83 | 65 | 6·2 | S.E. |
| February .. | 762 | 19·2 | 26·1 | 22·6 | 5 | 83 | 66 | 6·2 | S.E. |
| March .. | 761 | 18·3 | 25·3 | 21·8 | 14 | 73 | 62 | 7·0 | S.E. |
| April .. | 762 | 17·2 | 23·4 | 20·3 | 14 | 102 | 71 | 7·5 | S.W. |
| May .. | 764 | 14·1 | 20·5 | 17·3 | 20 | 113 | 71 | 6·4 | S.E. |
| June .. | 766 | 14·3 | 19·2 | 16·7 | 15 | 128 | 72 | 6·3 | S. |
| Averages .. | 762 | 15·9 | 22·2 | 19·1 | 154 | 1,265 | 71 | 6·4 | |

Table 2.

| | Barometer | Temperature C°. | | | Rainfall. | | Relative Humidity. | Cloud. | Wind. |
|---|---|---|---|---|---|---|---|---|---|
| | Mm. | Min. | Max. | Mean. | Days. | Mm. | Per Cent. | 0–10. | Days. |
| South-east .. | 764 | 15·3 | 21·9 | 18·6 | 23 | 44 | 67 | 6·0 | 71 |
| East .. .. | 765 | 16·2 | 22·6 | 19·4 | 12 | 75 | 70 | 6·6 | 28 |
| North-east .. | 764 | 15·7 | 22·5 | 19·1 | 17 | 136 | 71 | 5·8 | 39 |
| North.. .. | 761 | 18·0 | 23·2 | 20·6 | 20 | 317 | 77 | 8·2 | 30 |
| North-west .. | 760 | 18·6 | 24·2 | 21·4 | 21 | 326 | 77 | 7·4 | 46 |
| West .. .. | 760 | 14·3 | 22·5 | 18·4 | 13 | 165 | 77 | 7·3 | 22 |
| South-west .. | 761 | 15·0 | 21·8 | 18·4 | 34 | 157 | 69 | 5·7 | 80 |
| South .. .. | 762 | 15·2 | 21·7 | 18·5 | 14 | 45 | 70 | 5·7 | 50 |

## Animals.

Before the advent of man on Lord Howe Island the only animals that had any effect on the plant formations were two species of burrowing-petrels (*Puffinus carneipes* and *Pterodroma melanopus*). In talus slopes near the sea these birds make their burrows each year, completely overturning the soil and replenishing it with a rich manure; but whether or not this process is essential to bringing forth the edaphic conditions which result in the tussock-sedge and herbaceous-plant formations there found is difficult to say.

The large herbivorous animals introduced by man have had an important effect on the forest formations. This is dealt with below under the heading "Introduced elements."

## Anatomical Structure.

An anatomical examination of the leaves of the leading forest-trees of physiognomic importance in Lord Howe Island shows that the main features of their structure are due to systematic affinity. But as the

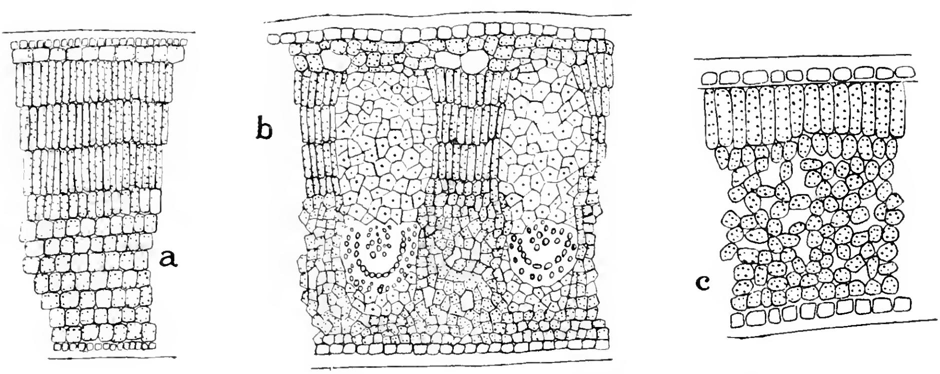



Fig. 1.—*a*, *Acicalyptus Fullagari*; *b*, *Metrosideros nervulosa*; *c*, *Hemicyclia australasica*.

habitat determines the relative proportions in which the species are represented, the result is somewhat the same as though the main peculiarities in the structure were due to the direct adaptation of the species to the habitat, and thus the effect of the habitat is shown by the minute structure of the leaf, though probably only the specific differences in the endemic species are due to the direct effect of the environment.

Briefly, the chief features presented by the leaves of the principal forest-trees are (1) the presence in most species of a cuticle, (2) the frequent occurrence of water-tissue consisting of two or three layers of large cells

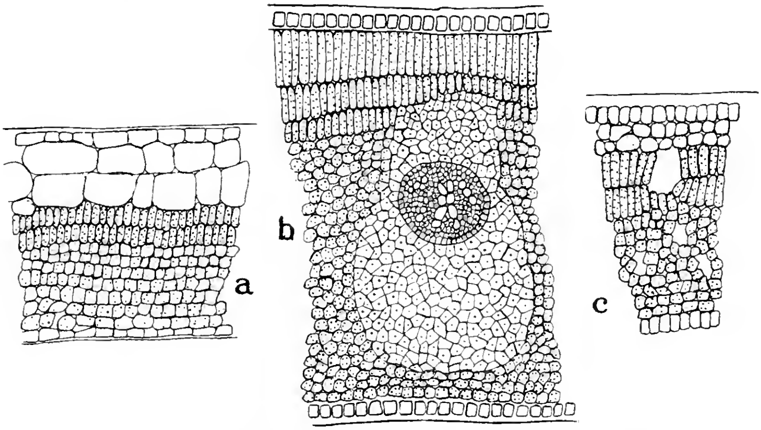



FIG. 2.—*a*, *Coprosma putida* ; *b*, *Baloghia lucida* ; *c*, *Cryptocarya Gregsoni*.

beneath the upper epidermis, and (3) the dorsiventral arrangement of the tissue of the mesophyll, the chief exceptions being *Drimys howeana* and *Randia stipulosa*.

So far as one can judge from the leaf-structure, most of the trees of Lord Howe Island have devices for conserving water. This is perhaps

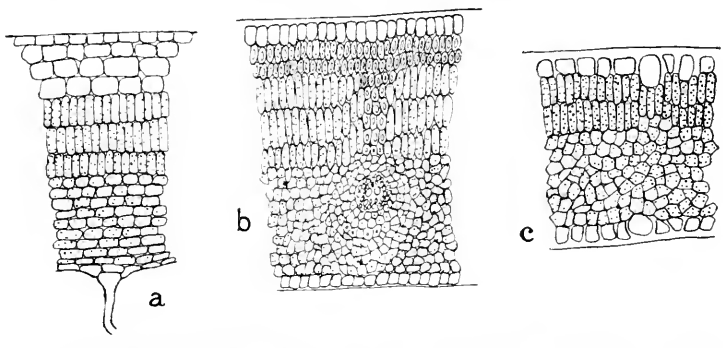



FIG. 3.—*a*, *Negria rhabdothamnoides* ; *b*, *Dracophyllum Fitzgeraldi* ; *c*, *Rapanea platystigma*.

necessary on account of the frequent winds, which must have a considerable desiccating effect on the foliage.

The cuticle is especially thick in *Ficus columnaris*, *Acicalyptus Fullagari*, and *Hemicyclia australasica*, three of the dominant trees in high forest. There is also a thick cuticle in *Metrosideros nervulosa* and *Baloghia lucida*, two shrubs widely separated systematically, but agreeing in this particular as well as in the presence in the leaf-lamina of close parallel veins with large sheaths of sclerenchyma. In a few species the cuticle is little developed or wanting. This is the case with the two species with undifferentiated mesophyll, *Randia stipulosa* and *Drimys howeana*.

Hypoderm consisting of one to three rows of cells between the upper epidermis and the palisade tissue is developed in a great many of the dominant trees. There is a single row of small cells in *Acicalyptus Fullagari* and *Notelaea quadristaminea*, but in the coastal *Ochrosia elliptica* the cells are very large. A two-layered hypoderm is present in *Metrosideros nervulosa*, *Coprosma putida*, *Coprosma prisca*, and *Cryptocarya Gregsoni*. In *Ficus columnaris* the lower two rows of a three-layered epidermis perhaps function as water-tissue. The hypoderm consists of three rows of cells in *Lagunaria Patersoni*, *Negria rhabdothamnoides*, and *Olearia Mooneyi*.

The mesophyll is not clearly differentiated into palisade and spongy parenchyma in *Randia stipulosa* and *Drimys howeana*. There is but a single row of palisade cells in *Hemicyclia australasica* and *Notelaea quadristaminea*, but in both cases the cells are large. In all other plants examined the palisade tissue was well developed, being near the upper surface in those species having no hypoderm, and near the centre of the leaf in those in which a subepidermal aqueous tissue is present. Sclerenchymatous tissue is a feature of the leaves of *Dracophyllum Fitzgeraldi*, *Baloghia lucida*, and *Metrosideros nervulosa*. In all these the leaf-lamina is characterized by the presence of close parallel veins, which consist of vascular bundles ensheathed in sclerenchyma, extending almost across the mesophyll. In *Dracophyllum* there is as well a layer of sclerenchyma two cells deep beneath the upper epidermis.

## Classification of Plant Formations.

Normal conditions of climate and soil on Lord Howe Island favour the growth of temperate rain forest about 20 m. in height. Exposure to constant wind, as on the sea-coast and on the summits of the mountains, causes forest to pass gradually into scrub. But in the former salt spray and in the latter high relative humidity determines the floristic and ecological character of the scrub. Changes in soil give rise to meadow formations. On damp ground a sedge meadow is found, on sandy sea-shore are grasses and herbaceous plants which tolerate salt spray, and in an exposed gap meadow and scrub intermix. Limited time permitted only a cursory examination of the principal plant formations on Lord Howe Island. These will be described under the headings just indicated, while their chief characters and determining factors are expressed in synoptical form below. This scheme, however, makes no provision for the vegetation on cliffs, which constitute such a conspicuous feature in the landscape of Lord Howe Island. But the vegetation there found does not constitute a single formation: it is rather a mixture of formations which have spread from the surrounding area according as exposure, holding-surface, or supply of moisture permits. Thus, when moist soil has collected, shrubs appear; but where there is not sufficient room for shrubs there will be a collection of herbaceous plants and ferns. Similarly, the course of a stream over the cliffs is marked by the abundance of the large tussocks *Gahnia* and *Cladium*, and dry rocky places support *Asplenium nidus*, and on the rock-faces lichens.

## II. PLANT FORMATIONS OF LORD HOWE ISLAND.

### Synopsis of Formations and Associations.

### SERIES I.—WOODY-PLANT FORMATIONS (CLIMATIC).

#### 1. *Forest.*

Habitat: From sea-level to 600 m. Climatic conditions normal; well-drained soil. Structure: Trees 8–20 m. tall, palms, pandani, and tree-ferns; lianes abundant; undergrowth of shrubs, ferns, and herbaceous plants. Associations: Lowland high forest—*Ficus columnaris, Howea Forsteriana;* upland high forest—*Acicalyptus Fullagari, Howea Belmoreana;* lowland low forest—*Hemicyclia australasica, Howea Forsteriana;* mountain low forest—*Notelaea quadristaminea, Hedyscepe canterburyana, Pandanus Forsteri.*

#### 2. *Moss Forest.*

Habitat: Mountain summits above 600 m. Constant wind, with frequent rain and fog. Structure: Shrubs, palms, and tree-ferns, 3–4 m. tall; dense undergrowth of shrubs and ferns; epiphytes abundant, ferns, lichens, and mosses. Association: *Dracophyllum Fitzgeraldi, Clinostigma Mooreanum, Cyathea brevipinna.*

#### 3. *Scrub.*

Habitat: Edge of forest along sea-coast, and on exposed ridges. Constant wind bearing along the coast salt spray. Structure: Shrubs 1–2 m. tall; few trailing and herbaceous plants. Associations: Coastal scrub—*Ochrosia elliptica, Lagunaria Patersoni, Myoporum insulare, Melileuca ericifolia, Cassinia tenuifolia;* hill scrub—*Dodonaea viscosa, Hemicyclia australasica, Rapanea platystigma.*

### SERIES II.—HERBACEOUS-PLANT FORMATIONS (EDAPHIC).

#### 4. *Low Succulent Plants (Halophytes).*

Habitat: Coastal rocks and sand within reach of salt spray. Structure: Herbaceous plants 15–20 cm. tall, with succulent leaves and stems, erect or trailing. Associations: On slopes facing sea—*Lobelia anceps, Mesembryanthemum aequilaterale;* on rocks near high-water mark—*Salicornia australis.*

#### 5. *Sand-binders.*

Habitat: Sand-dunes along coast, also sandy exposed headland. Structure: Trailing sand-binding plants, with some herbaceous plants. Association: *Spinifex hirsutus, Ipomaea pes-caprae, Wedelia uniflora.*

#### 6. *Rushes.*

Habitat: Exposed (usually sandy) places near coast. Frequent wind bearing salt spray. Structure: Close growth of erect rushes and grasses with trailing-plants. Associations: Sandy flat—*Scirpus nodosus, Spinifex hirsutus, Poa caespitosa;* gap in coastal hills—*Scirpus nodosus. Poa caespitosa, Phragmites communis, Ipomaea palmata.*

#### 7. *Tussock Sedges.*

Habitat: Talus slopes facing sea. Structure: Close growth of large tussocks. Association: *Mariscus haematodes.*

### 8. *Herbaceous Plants.*

Habitat: Damp ground and dry places not occupied by forest. Structure: Herbaceous plants, grasses, and sedges, about ½ m. tall. Associations: On damp ground—*Kyllinga monocephala;* on dry ground—*Poa caespitosa.*

## Series III.—Marine Formations.

### 9. *Mangrove.*

Habitat: Muddy shores between tide-marks. Structure: Shrubs (*Avicennia* with pneumatophores to roots). Association: *Avicennia officinalis, Aegiceras corniculatum.*

## Description of Formations and Associations.

### 1. Forest.

What may be described as a temperate evergreen rain forest, 15–20 m. high, occupies the whole of Lord Howe Island except where it is inhibited by adverse climatic conditions or by edaphic influences. As already stated, along the coast steady wind carrying salt spray causes the forest gradually to pass into scrub, which dwindles to nothing along the actual shore. Similarly, on exposed ridges the trees are reduced to shrubs: and also on the mountain-tops, where a constantly humid atmosphere and high wind prevail, the trees are dwarfed. In all these situations the associations alter by the disappearance of certain characteristic forest-trees and the appearance of species which are able to tolerate the more severe weather. These changes probably indicate differences in ecology of the plants, and the formations are therefore here classed separately but in the same series.

### *High Forest.*

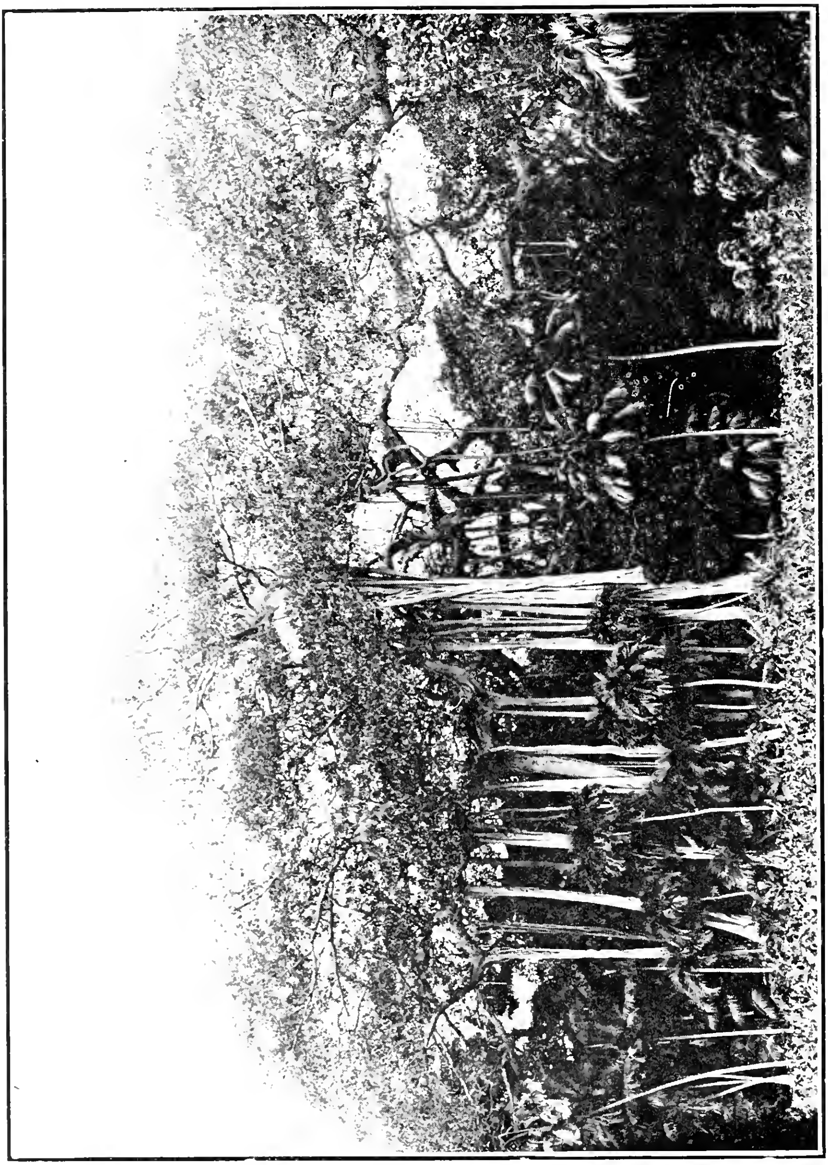
In this the main tier of foliage is composed of trees and palms, and is about 15 m. above the ground; but this is displaced in most places by a discontinuous tier of vegetation composed of trees, isolated or in large or small groups, nearly 20 m. tall. The undergrowth is not usually dense, and consists of young trees and palms, and, on the ground, a low growth of ferns and seedling trees. Lianes contribute considerably to the forest, their numerous rope-like stems forming regular entanglements.

High forest occurs from sea-level to about 300 m. altitude, and is generally distributed except on the Northern Hills. There are two associations, one in which *Ficus columnaris* is present and gives a characteristic appearance to the forest, and the other in which it is absent and *Acicalyptus Fullagari* is the dominant tree. The former occurs on Transit Hill and on the flat ground round its base, and also on Little Slope, at the western base of Mount Gower. The latter is found in Erskine Valley and on the lower slopes of Mount Lidgbird.

### *Ficus columnaris* Association.

*Transit Hill.*—On Transit Hill the forest, owing to its proximity to the settlement, is not overrun with goats or pigs. It has scarcely been touched by the inhabitants, and is therefore for the most part in its original state. Forest-trees of the upper tier, 20 m. tall, are so far apart that usually their heads do not meet. *Ficus columnaris* is abundant, especially on the lower levels. Higher up *Acicalyptus Fullagari* occurs as the dominant tree.

Interior of lowland forest, Lord Howe Island



*Ficus columnaris*, Lord Howe Island.



[R. S. Bell, photo.

FIG. 1.—Mount Gower, from east coast.
FIG. 2.—Western base of Mount Gower, showing *Mariscus haematodes* and palm (*Howea Forsteriana*) forest.

[R. S. Bell, photo.

Fig. 1.—Moss forest on summit of Mount Gower.
Fig. 2.—*Howea Belmoreana* in forest, Lord Howe Island.

*Ficus* forest viewed from above presents rather a striking appearance. Above the level of the mixed green foliage of the palms and trees the large rounded brown heads of the *Ficus* project. The brown colour is caused by the wind turning and exposing the underside of the leaves. In many places the forest appears to be composed solely of palms and *Ficus* trees.

What may be called the main forest tier is composed of palms, pandani, and trees about 15 m. tall. The plants are 2 m. to 3 m. apart, so that progress through the forest is easy except where the undergrowth or lianes are thick. On the lower levels, especially among the *Ficus*, the palm *Howea Forsteriana* is the dominant plant. Higher up it gives way to trees mixed with *Howea Belmoreana*. *Pandanus Forsteri* is frequent in the gullies. The forest comprises a good mixture of species of trees. *Hemicyclia australasica* and *Acronychia Baueri* are both common, and, though not the dimensions of *Ficus* or *Acicalyptus*, are fairly tall trees. Other large trees commonly found in this association are *Olea paniculata*, *Cryptocarya triplinervis*, *Guioa coriacea*, and *Lagunaria Patersoni*. The smaller trees are of slender habit, but contribute largely to the forest foliage. Those of frequent occurrence include *Drimys howeana*, *Randia stipulosa*, *Coprosma putida*, *Psychotria Carronis*, *Geniostoma petiolosum*, *Sophora tetraptera howinsula*, *Rapanea platystigma*, *Myoporum insulare*, *Dysoxylum pachyphyllum*, *Homolanthus populifolius*, *Elaeodendron curtipendulum*, and others.

Lianes are especially abundant in the forest, climbing to the tops of the highest trees, and their rope-like stems form a characteristic feature of the forest-interior. The largest of these remarkable plants are *Marsdenia rostrata*, *Flagellaria indica*, *Malaisa scandens*, and *Lyonsia reticulata*. Other common species are *Smilax australis*, *Jasminum simplicifolium*, *Clematis glycinoides*, and *Geitonoplesium cymosum*. *Arthropteris tenella* climbs up the bases of the trees.

There is an undergrowth of young palms and trees, and of the shrubs *Senecio insularis*, *Exocarpus homalaclada*, *Macropiper excelsum psittacorum*, *Baloghia lucida*, and *Alyxia ruscifolia*.

The ground is not thickly covered with vegetation, large spaces being bare except for dead leaves and sticks. There are low ferns, sedges, grasses, trailing herbs, and seedling trees. Of ferns, *Asplenium Milnei*, *Pteris comans*, and *Hypolepis tenuifolia* are the most frequent. *Carex gracilis* is abundant; while the grasses *Poa caespitosa* and *Oplismenus aemulus* are common. Trailing plants are *Commelyna cyanea*, *Polypodium diversifolium*, *Geitonoplesium cymosum*, and *Tylophora biglandulosa*.

Epiphytes are scarce, only the orchid *Dendrobium Moorei* being noted. The parasite *Korthalsella articulatum* occurs fairly frequently on *Cryptocarya triplinervis* and other trees.

## *Acicalyptus Fullagari* Association.

*Erskine Valley*.—The forest in the Erskine Valley between 200 m. and 300 m. altitude was examined. The upper tier of vegetation is composed of trees over 15 m. tall, but they occur in clumps or singly, and their heads, therefore, do not touch over the whole forest. They are usually erect wide-branching trees. The dominant species is *Acicalyptus Fullagari*, but *Dracophyllum Fitzgeraldi* and *Guioa coriacea* are frequent. *Hemicyclia australasica* and *Notelaea quadristaminea* are large forest-trees common in Erskine Valley. The main tier of forest foliage is composed of trees, palms, tree-ferns, and pandani, about 10 m. tall. Here again, as on Transit Hill, there is a good mixture of species. Those of most frequent occurrence include

*Drimys howeana, Coprosma putida, Psychotria Carronis, Geniostoma petiolosum, Dysoxylum pachyphyllum, Randia stipulosa, Homolanthus populifolius*, and the palm *Howea Belmoreana*. In valleys *Negria rhabdothamnoides* and *Pandanus Forsteri* are conspicuous. The tree-ferns, which are not common, are *Cyathea Macarthuri* and *Alsophila robusta*.

Lianes are fairly common, and climb to the tops of the tallest trees. *Flagellaria indica* and *Malaisa scandens* are frequent and conspicuous.

The undergrowth is scanty, this being doubtless due to the presence of pigs, which destroy young trees and ferns. The ground is therefore mostly bare, while stones, more frequent as one ascends the mountain-sides, cover a considerable portion of the surface. Mixed with young palms and trees are the shrubs *Macropiper excelsum psittacorum, Senecio insularis*, and, less frequently, *Metrosideros nervulosa*. The ferns *Pteris comans* and *Blechnum capense* occur, while damp rocky banks are covered with filmy and other low ferns, those noticed being *Trichomanes Bauerianum, Polystichum Whiteleggei*, and *Dryopteris apicalis*.

*Mount Lidgbird.*—On the northern slopes of Mount Lidgbird the structure and floristic composition of the forest is somewhat similar to that in Erskine Valley. The upper tier of vegetation is composed of large trees, about 20 m. tall, whose heads do not touch. *Acicalyptus Fullagari, Acronychia Baueri*, and *Hemicyclia australasica* are the dominant species, while *Ficus columnaris* and *Lagunaria Patersoni* are occasionally met with. The main mass of the forest is a mixture of trees, palms, and pandani, 10 m. to 15 m. tall. The trees are *Drimys howeana, Lagunaria Patersoni, Coprosma putida, Randia stipulosa, Homalanthus populifolius*, and others. *Howea Belmoreana* is the principal palm, being in fact in many places the dominant forest-plant, though patches of *Howea Forsteriana* occur as high as 300 m. above sea-level. *Pandanus Forsteri* is most abundant in the valleys. *Cyathea Macarthuri* and *Alsophila robusta* occur sporadically. The lianes *Flagellaria indica* and *Malaisa scandens* are everywhere common.

There may be a fairly dense undergrowth of young palms (*Howea Belmoreana*), with which may be mixed a little *Senecio insularis*. The forest-floor is mostly bare of vegetation, being overrun by pigs, and is covered chiefly with fallen palm and pandanus leaves. Here and there, however, patches of *Pteris comans* or *Carex gracilis* occur. *Platycerium bifurcatum* occurs on stones, trees, and palms, but is not common.

### *Lowland Low Forest.*

This type of forest is due principally to the absence of such large trees as *Ficus columnaris* and *Acicalyptus Fullagari*. It covers the Northern Hills and parts of the flat ground between these and the mountains. The forest is of a nearly uniform height of 8 m. to 10 m., and is composed of trees and palms, with scant undergrowth. Lianes are very common, making dense entanglements in places.

*Northern Hills.*—The forest which covers the southern slopes of these headlands is composed mainly of small trees and shrubs. The palm *Howea Forsteriana* is abundant along the base, but occurs less frequently on the hillsides. The trees are not close together, but their heads touch, forming a fairly close covering. The species most commonly met with are *Hemicyclia australasica, Acronychia Baueri, Cryptocarya triplinervis, Notelaea quadristaminea, Lagunaria Patersoni*, and *Elaeodendron curtipendulum*; while less frequently are found *Myoporum insulare* and *Coprosma prisca*.

Lianes are very abundant, making dense entanglements in places. The larger species are *Flagellaria indica*, *Malaisa scandens*, and *Smilax australis*; while smaller trailing species are *Tecoma austro-caledonica*, *Jasminum simplicifolium*, and *Ipomaea palmata*. There is an undergrowth of shrubs, but it is not anywhere dense. The chief species are *Bologhia lucida*, *Pisonia Brunoniana*, and *Alyxia ruscifolia*, with a few plants of *Cassinia tenuifolia*. The forest-floor is usually bare of vegetation; where, however, more light penetrates, either because of breaks in the foliage or on the outskirts of the forest, there will be an undergrowth, about ½ m. tall, of ferns, sedges, and herbaceous plants. The species commonly seen are *Asplenium Milnei*, *Adiantum aethiopicum*, *Pellaea falcata*, *Carex gracilis*, *Oplismenus aemulus*, *Commelyna cyanea*, and *Hydrocotyle hirta*.

Epiphytes are rare. The grass-like orchid *Denrobium Moorei* was noticed, also a few plants of *Platycerium bifurcatum*. The parasite *Korthalsella articulatum* was also occasionally seen.

*West Bay.*—On the flat sandy ground behind the dunes in West Bay scrub begins along the exposed outer edge, but it rapidly increases in height and passes into low forest 6 m. to 10 m. tall, which itself eventually passes into high *Ficus* forest. The low forest is composed of small trees and palms. The trees comprise a number of species, the following being common: *Rapanea platystigma*, *Hemicyclia australasica*, *Cryptocarya triplinervis*, *Acronychia Baueri*, *Hymenanthera novae-zealandiae*, *Pisonia Brunoniana*, and *Celtis amblyphylla*. In many places palms of the species *Howea Forsteriana* are the dominant plants. Mixed with them are a few trees and specimens of *Howea Belmoreana*. The undergrowth is seldom dense, and is composed of young palms where these plants are dominant, and elsewhere of young trees, together with *Alyxia ruscifolia* and *Macropiper excelsum psittacorum*.

Lianes are numerous, including the species *Malaisa scandens*, *Flagellaria indica*, *Smilax australis*, and *Jasminum simplicifolium*.

### *Mountain Low Forest.*

On the higher slopes of the mountains, above 300 m. altitude, high forest passes over into a low forest composed of trees, palms, and pandani of a uniform height of 8 m. to 10 m. This forest extends from the upper limit of high *Acicalyptus* forest until it merges into the moss forest on the summit of the mountains. Lianes are few or absent. Palms of the genus *Howea* are here absent, but their place is taken by *Hedyscepe canterburyana*, which is abundant. *Pandanus Forsteri*, in a smaller form than on the lowland, is also common, especially in the valleys at the lower edge of this region.

The trees forming this forest include *Notelaea quadristaminea*, *Coprosma putida*, *Geniostoma petiolosum*, *Dracophyllum Fitzgeraldi*, *Drimys howeana*, *Erodia polybotrya*, and others.

As one ascends the forest decreases in height and other species occur. Among these may be mentioned *Pittosporum erioloma*, *Metrosideros nervulosa*, *Olearia Ballii*, and *Alyxia squamulosa*.

An undergrowth of small shrubs and ferns occurs, but is not dense. *Macropiper excelsum psittacorum* and *Senecio insularis* are shrubs, while the ferns include *Pteris comans*, *Dryopteris apicalis*, and others. There also occur on damp rocky places *Luzula longiflora*, *Brachycome segmentosa*, and *Asplenium howeanum*.

Over large areas no soil is visible, the trees growing among the rocks.

### *Autecology of Forest-plants.*

The trees are usually of irregular growth, with trunks in high forest 10 m. or so before branching into a large rounded head. Plank buttresses are frequent. *Ficus columnaris* and *Acicalyptus Fullagari* have trunks up to 1 m. or 1½ m. in diameter with large plank buttresses. In *Hemycyclia australasica* and *Acronychia Baueri* the bases of old trees show a tendency toward plank buttresses, small ones ½ m. or so up the stem being the rule, and the roots often run for some distance along the surface.

Adventitious roots are developed in *Metrosideros*, *Ficus*, and *Pandanus*. They are small in *Metrosideros nervulosa*, springing from the underside of some of the branches and hanging freely down. In *Ficus columnaris* they arise from the horizontal branches, and, growing downwards, take root on reaching the ground, eventually forming columnar supports similar to the main stem. This itself in most cases began in the same way as the *Ficus* usually begins life—as an epiphyte. As with some other species of the genus, *Ficus columnaris* habitually forms columnar roots, and, like the famous banyan, single specimens may cover a considerable area of ground.

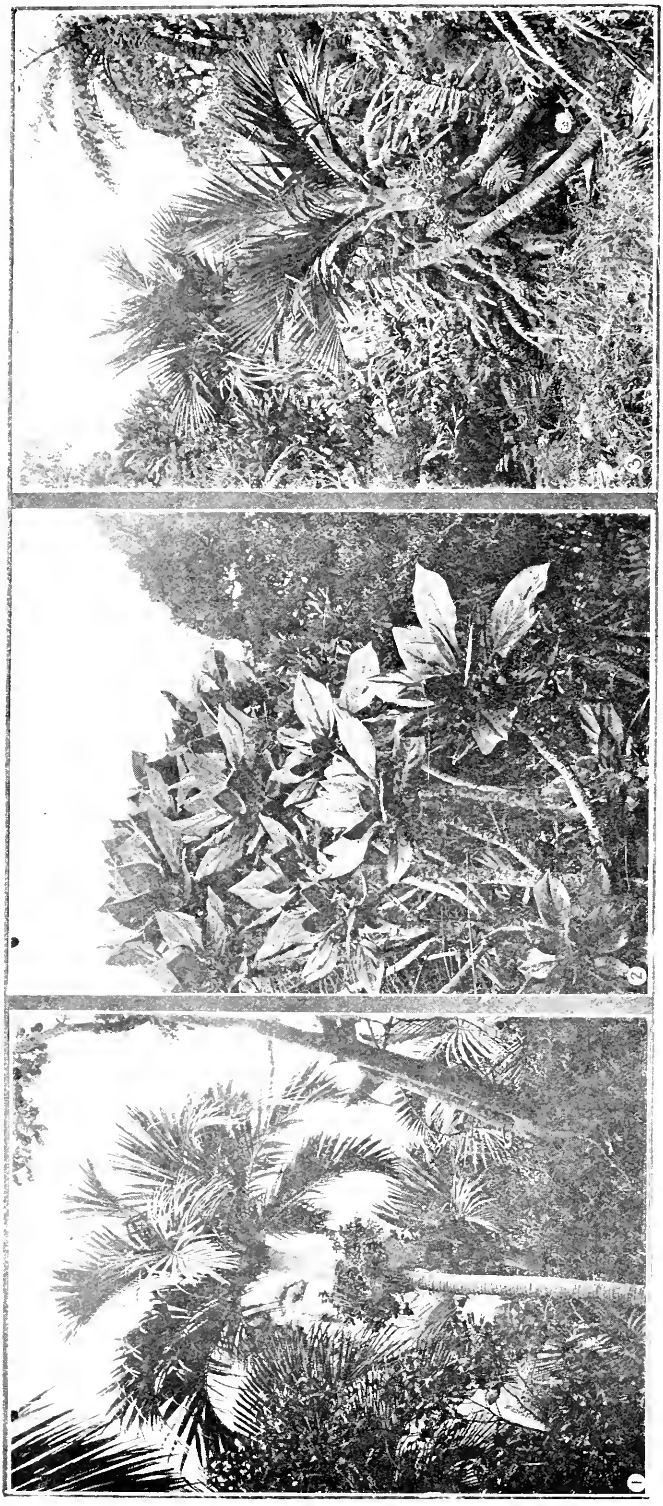
*Pandanus Forsteri* throws out obliquely downwards from all sides of the stem cylindrical stilt-like roots which eventually replace the main stem. This, when once formed, does not increase in size, and thus it is smallest at the base and gradually thickens upwards. In old plants the lowest and therefore oldest and smallest portion of the main stem is usually withered and dead, the plant depending entirely on the stilt roots for support and nourishment.

Subepidermal aqueous tissue is developed in *Ficus columnaris* (really a three-layered epidermis), *Acicalyptus Fullagari*, *Lagunaria Patersoni*, *Coprosma putida*, *Notelaea quadristaminea*, *Negria rhabdothamnoides*, and *Metrosideros nervulosa*. The mesophyll is not differentiated into palisade and spongy parenchyma in *Randia stipulosa* and *Drimys howeana*. There is a thick cuticle in *Ficus columnaris*, *Acicalyptus Fullagari*, *Hemicyclia australasica*, *Metrosideros nervulosa*, and *Baloghia lucida*. It is thinner in *Cryptocarya triplinervis*, *Notelaea quadristaminea*, *Coprosma putida*, *Lagunaria Patersoni*, *Rapanea platystigma*, and *Dracophyllum Fitzgeraldi*. There is a layer of sclerenchyma beneath the upper epidermis in *Dracophyllum Fitzgeraldi*.

### 2. Moss Forest.

The summit of Mount Gower, which, as already mentioned, forms an undulating plateau, is covered with dense scrub or low-forest vegetation, which extends a little way down the steep sides of the mountain. The scrub varies in height, and slightly in composition, according to exposure. Where it is most sheltered, as in the ravines, its height is about 4 m. It is composed of a mixture of small trees or shrubs, palms, and tree-ferns. There is an undergrowth of low ferns and sedges, while the floor is for the most part covered with mosses. Epiphytes cover almost every available space on the larger plants. Clouds frequently envelop the mountain-summit, and in consequence the vegetation is usually reeking with moisture. One finds here, therefore, a luxuriance and wealth of plant-life unknown on the drier habitats at lower altitudes. I am informed by Mr. R. S. Bell that some moss forest occurs on the summit of Mount Lidgbird.

Standing on a tree on the highest point of Mount Gower one may get a bird's-eye view of the plateau. The upper surface of the scrub is compact



[R. S. Bell, photo.

Fig. 1.—*Hedyscepe canterburyana*, Erskine Valley.
Fig. 2.—*Negria rhabdothamnoides*, summit of Mount Gower.
Fig. 3.—Moss forest on summit of Mount Gower, showing *Clinostigma Mooreanum* and *Blechnum attenuatum*.

Interior of lowland forest, showing *Pandanus Forsteri*.

but not even. Above the general level project palms, tree-ferns, and *Dracophyllum*. The colour is varied. The numerous round heads of *Dracophyllum Fitzgeraldi* are reddish-brown, the more numerous tree-ferns are light green, while various shades of darker green make up the rest of the surface. As for relative abundance, no one species is dominant. *Dracophyllum Fitzgeraldi* by its colour attracts the eye, as every plant is visible. It is scattered about all over the plateau, sometimes forming small clumps. The tree-ferns *Hemitelia Moorei*, *Cyathea brevipinna*, and *Cyathea Macarthuri* are everywhere most abundant. The palms *Clinostigma Mooreanum* and *Hedyscepe canterburyana*, though scarcely fewer in numbers than the tree-ferns, are less conspicuous from above. *Leptospermum flavescens*, a shrub or small tree, occurs in small patches throughout, and apparently best tolerates wind, as it is especially in evidence in exposed places. The other shrubs making up the bulk of the remainder of the foliage visible from above are *Drimys howeana*, *Metrosideros nervulosa*, *Olearia Mooneyi*, *Coprosma putida*, *Exocarpus homalodada*, *Pittosporum erioloma*, and *Cryptocarya Gregsoni*. Other species of small trees and shrubs contributing to this formation are *Randia stipulosa*, *Negria rhabdothamnoides*, *Coprosma lanceolaris*, and *Alyxia squamulosa*.

The undergrowth is often extremely dense and almost impenetrable, especially on exposed places, where the scrub is lowest. The large tussocks of *Gahnia xanthocarpa* present formidable obstacles to the person who tries to cross the plateau. The sharp scabrid edges of the leaves cut one's clothes and skin at every movement. Other large tussocks occurring less commonly are *Cladium insulare* and *Moraea Robinsoniana*. Small shrubs noted were *Senecio insularis*, *Olearia Ballii*, and a few plants of *Macropiper excelsum psittacorum* and *Cassinia tenuifolia*. Of low ferns there is a great variety. The most abundant species are *Asplenium pteridoides*, *Blechnum capense*, *Diplazium melanochlamys*, *Blechnum Fullagari*, *Dryopteris apicalis*, and *Histiopteris incisa*.

Mixed with the ferns are commonly *Luzula longiflora*, *Uncinia filiformis debilior*, *Hydrocotyle hirta*, and *Plantago Hedleyi*; while in wet ground in the ravines *Elatostemma reticulatum grande* covers the ground, and in open places *Brachycome segmentosa* appears.

Sometimes there is little or no undergrowth, but the ground is almost everywhere covered with mosses.

Epiphytes form the most conspicuous feature of this moss-forest formation, and thereby contribute largely to the appearance of luxuriance and rankness of growth which impresses the explorer. Almost every available space, whether on standing or prostrate stems and branches of trees, tree-ferns, and palms, appears to be thickly covered with ferns, mosses, and lichens. Horizontal trunks of trees are especially rich in plant-life. On the upper side will be *Tmesipteris tannensis*, *Hymenophyllum multifidum*, *Hymenophyllum tunbridgense*, *Dendrobium gracilicaule howeanum*, *Polypodium diminutum*, and *Polypodium pulchellum*; on the underside will be *Hymenophyllum pumilum*. On erect stems epiphytes show a zonal arrangement. At the base the climbing fern *Blechnum attenuatum* or the moss *Spiridens Muelleri*, or both together, may completely hide the tree-trunk; above this will be the foliaceous lichen *Sticta Freycinetti* and the filmy fern *Hymenophyllum multifidum*. Higher up still the branches of trees or tops of palm-stems may be covered with foliaceous lichens and the beard-like moss *Barbella enervis*.

### *Autecology of Moss-forest Plants.*

*Metrosideros nervulosa* gives out numerous small adventitious rootlets, but I saw none of any size, and only the lower ones reached the ground.

Aqueous hypoderm is present in *Cryptocarya Greysoni*, *Negria rhabdothamnoides*, *Olearia Mooneyi*, *Metrosideros nervulosa*, and *Coprosma putida*. The mesophyll is not differentiated into palisade and spongy tissue in *Drimys howeana* and *Randia stipulosa*. In *Dracophyllum Fitzgeraldi* there is a layer of sclerenchyma beneath the upper epidermis.

## 3. Scrub.

### *Coastal Scrub.*

Along the coast, not far above high-water mark, the forest everywhere passes over, sometimes fairly abruptly, into scrub characterized by its single tier of woody vegetation 1 m. to 3 m. in height, mixed perhaps with a few herbaceous or trailing plants. The scrub at the top of the lower sea-cliffs may be classed in the same formation.

At Ned's Beach, on the east coast, the scrub is very dense, and can be penetrated only with difficulty. It is composed of prostrate entangled shrubs, whose upper surfaces are shorn down by the wind to a certain general level. The most abundant species here are *Celtis amblyphglla*, *Ochrosia elliptica*, *Myoporum insulare*, *Lagunaria Patersoni*, and occasionally *Hemicyclia australasica*. In exposed places are *Coprosma prisca* and *Cassinia tenuifolia*, while the trailing plants *Spinifex inermis* and *Caesalpinia Bonducella* tend to bind together the already dense thicket.

There is little variation in this, either in structure or floristic composition, in other parts of the island. Among rocks in the most exposed places, where constant wind carrying salt spray determines the character of the vegetation, *Melaleuca ericifolia* is sure to be found. At the western base of Mount Gower and at the base of Transit Hill it is this plant, with *Corposma prisca*, which form the outer edge of the woody vegetation. In West Bay the front facing the sea, but separated from high-water mark by a stretch of sand, is composed of shrubs of low dense growth, with their upper surface presenting an even slope to the wind. The principal species here are *Ochrosia elliptica*, *Myoporum insulare*, *Rapanea platystigma*, and *Cryptocarya triplinervis*; also outlying plants of *Coprosma prisca*.

On cliffs where small holding-surface and exposure are inimical to the growth of trees detached shrubs constitute the woody vegetation. On the northern sea-cliffs the species are those of coastal scrub—namely, *Melaleuca ericifolia*, *Cassinia tenuifolia*, *Coprosma prisca*, and *Myoporum insulare*, together with *Tecoma austro-caledonica* and the tussock sedge *Mariscus haematodes*.

On overhanging cliffs at the base of Mount Gower, where the only water available is that which percolates through the rocks, *Melaleuca ericifolia* was the only shrub noticed; while on the floor of the cave, where the dripping water fell, there were low straggly shrubs of *Coprosma prisca* and *Myoporum insulare*.

In a gap between two hills in the north-west of Lord Howe Island, which is swept by westerly winds, an open-scrub association mixes with the herbaceous-plant formations. In the most exposed portions there occur large rounded bushes of *Melaleuca ericifolia*, 6 m. to 8 m. across and ½ m. to 1½ m. high, closely fitting the ground all round, and highest in the centre. Other shrubs scattered here and there in the meadow formation are *Cassinia tenuifolia*, *Myoporum insulare*, and *Coprosma prisca*.

FIG. 1.—Mount Lidgbird and Mount Gower, Lord Howe Island.

FIG. 2.—Western side of Lord Howe Island, showing palm (*Howea Forsteriana*) forest on sand-dunes.

*Face p. 108.*]

*Autecology of Coastal-scrub Plants.*—An aqueous hypoderm is present in *Coprosma prisca*, *Ochrosia elliptica*, and *Lagunaria Patersoni*, but not in *Celtis amblyphylla*, where the palisade tissue occupies half the mesophyll.

### *Hill Scrub.*

On the top of sea-cliffs and on exposed ridges and cliffs on the mountains forest gives way to scrub identical in structure with coastal scrub, but containing quite another association of species.

On the Northern Hills the scrub on the ridges is 1 m. to 2 m. high, and composed of dense, close-growing shrubs. It usually forms an impenetrable mass of vegetation, with no undergrowth: but where the foliage is more lax or broken an undergrowth of low ferns and grasses appears. The following species of shrubs are usually present: *Cassinia tenuifolia*, *Baloghia lucida*, *Dodonaea viscosa*, *Rapanea platystigma*, *Pimelea congesta*, *Notelaea quadristaminea*, *Myoporum insulare*, *Lagunaria Patersoni*, *Hemicyclia australasica*, *Cryptocarya Gregsoni*, *Jasminum simplicifolium*, and *Alyxia ruscifolia*.

The undergrowth, where present, may contain *Adiantum aethiopicum*, *Poa caespitosa*, *Asplenium nidus*, and on light rocky places *Platycerium bifurcatum*.

Scrub similar in structure and floristic composition to that just described is found in exposed places at low elevations on the mountains.

## 4. Low Succulent Plants.

### *Lobelia-Mesembryanthemum* Association.

In the gap between Mount Eliza and North Head the wind continually sweeps through, usually with great violence. Here there are no trees and only a few detached shrubs, but the area is occupied by formations of herbaceous plants. In the most exposed portion are low succulent plants, while leeward of these is a rush formation. On windy days the whole valley is drenched with salt spray. On the slope facing the sea there are a few detached rounded shrubs of *Melaleuca ericifolia*. Except for these the ground is entirely covered with a low even growth of succulent herbs 15 cm. to 20 cm. high. *Mesembryanthemum aequilaterale* and *Lobelia anceps*, together with some *Cynodon dactylon*, are fairly well mixed. On the crest of the ridge small plants of *Scirpus nodosus* occur, while *Melaleuca ericifolia* disappears.

### *Salicornia* Association.

On coastal rocks just above high-water mark there occurs in West Bay several small patches of *Salicornia australis*.

## 5. Sand-binders.

*Ned's Beach.*—Below the scrub is a formation of herbaceous plants covering the steep slope of a headland. The soil is chiefly loose limestone rock undermined by shearwaters (*Puffinus carneipes*), which burrow out heaps of looose sand. The soil is therefore very dry and not unlike a sand-dune. The dominant plants are a trailing sand-binding grass, *Spinifex hirsutus*, and a trailing herb, *Wedelia uniflora*, fairly evenly intermixed. With these are associated several herbaceous plants, all, however, of secondary importance. Fairly common are *Lepidium howei-insulae*

*Atriplex cinerea*, *Sonchus oleraceus*, *Polycarpon tetraphyllum*, *Parietaria debilis*, *Senecio vulgaris*, and the trailing plants *Vigna lutea*, *Lyonsia reticulata*, and *Ipomaea palmata*. Near the sea *Scirpus nodosus*, *Tetragonia strongylocarpa*, *Apium prostratum*, and *Mesembryanthemum aequilaterale* appear, while *Wedelea uniflora* is absent.

Sand-dunes, which are found chiefly in Blinkenthorp Bay, Ned's Beach, and West Bay, are occupied chiefly by *Spinifex hirsutus* and *Ipomaea pes-caprae*.

### 6. Rush Formations.

*West Bay.*—Between the beach and the forest is a stretch of level sand about 50 m. wide, and extending almost the whole length of the beach. This is covered with a dense growth of rushes and grasses up to 1 m. tall. The dominant plant is *Scirpus nodosus*, but along the sea-edge a fair amount of *Spinifex hirsutus* is found. Mixed with the *Scirpus* and *Spinifex* are sundry other plants of lesser importance. A few shrubs of *Myoporum insulare*, *Ochrosia elliptica*, and *Coprosma prisca* occur, but scarcely grow higher than the *Scirpus*. *Poa caespitosa* is common, also *Lepidium howei-insulae*. Trailing plants are *Wedelia uniflora*, *Vincetoxicum carnosum*, and *Mucuna gigantea*.

*North Hills.*—In the gap between Mount Eliza and North Head the succulent-plant formation on the exposed side is replaced on the leeward side by a covering, 1 m. or more tall, of rushes and grasses, with a few shrubs intermixed. The whole valley is usually drenched with salt spray. *Scirpus nodosus* is the dominant plant. Each side up the hill-slope it mixes with *Cassinia* scrub, which then passes to forest. Among the *Scirpus* there grow *Poa caespitosa*, *Cynodon dactylon*, *Lobelia anceps*, and the trailing plant *Ipomaea palmata*.

Over extensive areas the tall grass *Phragmites communis* is mixed with *Scirpus nodosus* and the shrub *Cassinia tenuifolia*. The whole association is very dense, and up to 2 m. in height. Trailing over it are *Ipomaea palmata* and *Stephania Forsteri*. In the lowest portion of this formation near the forest large shrubs, 3 m. tall, of *Coprosma prisca* and *Myoporum insulare* are fairly common.

### 7. Tussock Sedges.

At the western base of Mount Gower is a talus slope, known as the Little Slope, and occupied chiefly by *Ficus* forest. At the northern end is a large patch of *Mariscus haematodes*. The large tussocks occupy the whole surface. Few other species are present, the most conspicuous being the trailing *Ipomaea palmata*. The ground is everywhere undermined by petrels (*Pterodroma melanopus*), which breed in burrows during the summer months.

On the steep sides of the gap in the Northern Hills, already referred to, there are large patches of *Mariscus haematodes*.

### 8. Herbaceous Plants.

Damp ground: A small area of the flat ground in West Bay is sufficiently damp as to be called locally a swamp. This is occupied by a close growth, about ½ m. high, of *Kyllinga monocephala*. Here and there are a few plants of *Juncus pallidus* and *Mariscus haematodes*.

Dry ground: On exposed ridges on the Northern Hills, where not occupied by scrub, rocky ground supports a miscellaneous lot of herbaceous plants. Those noted in this situation were *Poa caespitosa*, *Dichelachne crinita*, *Polycarpon tetraphyllum*, *Oxalis corniculata*, *Cynodon dactylon*, *Gnaphalium luteo-album*, *Sonchus oleraceus*, *Scirpus nodosus*, *Sporobolus indicus*, and *Bidens pilosa*.

9. MANGROVE.

On a shingle beach between tide-marks at the north end of the lagoon there are a few detached plants of *Avicennia officinalis*. Farther south, near the mouth of Deep Creek, *Aegiceras corniculatum* occurs.

### Geographic Relationships of the Forest Formations.

The forest which clothes the greater part of Lord Howe Island is a temperate rain forest. Except for the absence of gymnosperms it agrees closely in essential characteristics with the rain forests of New Zealand and Tasmania, and apparently with the forest along the northern rivers of New South Wales and the "vine scrub" of south Queensland. It is quite unlike the *Eucalyptus* forest of Australia and Tasmania.

The moss forest of Mount Gower is similar to that on Sunday Island and on high ground in the North Island of New Zealand, especially where clouds are frequent. The most accessible example occurs on Te Aroha Mountain, while an apparently similar association is described by Cockayne (*Report on Waipoua Kauri Forest*, p. 14, 1908) as occurring on the upper slopes of Toetoehatiko, south of Hokianga.

## III. ORIGIN OF THE FLORA.

### GEOLOGICAL HISTORY OF LORD HOWE ISLAND.

Between New Zealand and the islands of the tropical Pacific is an expanse of ocean broken on the surface only by the three island groups of Lord Howe, Norfolk, and the Kermadecs, but with a most irregular bed. Study of a map showing ocean-floor contour-lines reveals the presence of two submarine ridges extending from New Zealand in northerly directions. The Kermadec ridge extends as far northward as the Samoan Group. To the eastward of it is an unbroken expanse of ocean over 5,000 m. in depth. A broader submarine ridge trends from New Zealand towards New Caledonia and tropical Australia. Its western edge is comparatively high, a continuous raised ridge less than 1,800 m. stretching from the South Island of New Zealand to the latitude of New Caledonia. It is on the extreme western limit of this that Lord Howe Island is situated.

The eastern edge of the broad ridge presents a more uneven surface, being between the northern peninsula of New Zealand and New Caledonia raised in a line of detached portions coming within 1,800 m. of the surface. One of these raised portions reaches the surface at Norfolk Island. Between the Lord Howe Island ridge and Australia is a deep trough, over 4,000 m. in depth, stretching as far north as S. lat. 25°.

Assuming the comparative permanence of the main features of the ocean-floor, at least during Tertiary times, these ridges would indicate that at a former period of upheaval Lord Howe Island would be in closer touch with New Zealand and New Caledonia than it would with temperate Australia. The presence of this remarkable submarine ridge is the only evidence of a dynamical nature that can be advanced to support the theory of a former land connection of New Zealand and New Caledonia with Lord Howe Island; but it has been many times pointed out that the relationships of the animals and plants of this island can best be explained by assuming such a connection.

As to the age of Lord Howe Island its geological characteristics yield little evidence, but the nature of the fauna and flora indubitably proves that the island has been above the surface of the ocean ever since there was a direct land connection between it and New Caledonia. Thus the Lord Howe Island volcano was in existence before the land bridge joining New Zealand and New Caledonia finally disappeared. Mr. Speight tells me that my specimens of rocks from Mount Gower are not likely to date before the commencement of the Tertiary era. But early Tertiary gives ample time for the subsidence of the ocean-floor to its present depth.

The more recent geological history of Lord Howe Island throws little light on the present subject. Briefly it is as follows: A long period of quiescence following on the building-up of the Lord Howe Island volcano resulted in it being denuded by sea-action to the fragments represented by the two remarkable mountains Gower and Lidgbird, and the pinnacle of Balls Pyramid. A revival of thermal activity next resulted in the building-up of three small volcanic hills, which, except at the extreme north-west portion of the island, have not suffered much from the effects of marine denudation. In point of fact, certain conditions which I am unable to explain, but no doubt coincident with subsidence of the area, allowed the deposition of limestone beds in shallow water. The area has since risen, exposing these beds for perhaps 30 m. above sea-level, this being the last vertical movement of the land in this region of which there is evidence.

## Land Connection with Lord Howe Island.

The idea of a land connection to explain the origin of the fauna and flora of Lord Howe Island has been supported by practically all scientific writers who have dealt with the subject.

Moore (*Trans. Roy. Soc. N.S.W.*, 1871, p. 29), after discussing the geographical relationships of the plants, concludes, "I am constrained to adopt . . . that this island, Norfolk Island, New Zealand, New Caledonia, and the islands of the Western Pacific formed at one time either a portion of this or another vast continent."

Wallace (*Island Life*, p. 455, 1880), in discussing the New Zealand fauna, states that the Bampton Shoal, west of New Caledonia, and Lord Howe Island, farther south, probably formed the western limits of an extensive land in which were developed the great wingless birds and other isolated members of the New Zealand fauna.

Hedley (*Proc. Linn. Soc. N.S.W.*, vol. 7, p. 338, 1893) argues for "the essential unity of the *Placostylus* area as a zoological province, embracing the archipelagoes of Solomon, Fiji, New Hebrides, New Caledonia, Lord Howe, and New Zealand—a unity explicable only on the theory that they form portions of a shattered continent. . . . This Melanesian plateau was never connected with, nor populated from, Australia; probably its fauna was derived from Papua, via New Britain." Again (*Proc. Linn. Soc. N.S.W.*, vol. 24, p. 397, 1899), in discussing the migration of Pacific faunas, he places Lord Howe Island in the continental area connecting New Zealand with New Caledonia. A stream of migration is described as branching off in New Guinea and traversing the Solomons and the New Hebrides. It then turns to New Caledonia, sends an offshoot to Lord Howe Island, and ultimately reaches New Zealand.

Hemsley (*Ann. Bot.*, vol. x, p. 282, 1897) favours a land connection to explain the character of the flora of Lord Howe Island when considered in connection with that of New Zealand, Norfolk Island, and east Australia. He quotes Engler as having the same view, but Drude as thinking a land connection between New Zealand and Lord Howe Island improbable on account of the endemic character of the flora of the latter.

My own conclusions, derived from a study of the birds (*Trans. N.Z. Inst.*, vol. 44, p. 216, 1912) and of the flora, are that a land connection is necessary to account for the remarkable set of animals and plants endemic in the island; but a considerable element due to a trans-oceanic immigration of Australian forms is present. The evidence on which these conclusions are based will now be considered.

### *Genera.*

Of the 169 genera of vascular plants represented in Lord Howe Island four are endemic. *Colmeiroa* and *Hedyscepe* are allied to New Zealand forms, *Negria* to both New Zealand and New Caledonian genera, while *Howea* is related to Malayan and tropical Australian genera. If the five species belonging to these four genera be taken as modified descendants of species which arrived by a land bridge, then they would indicate a New Caledonia - New Zealand migration, with the land connection severed first at the southern end, thus accounting for a greater degree of peculiarity for the New Zealand related species.

Of the non-endemic genera ninety-five are widely distributed, occurring in New Zealand, Australia, and Polynesia; and forty-seven more range widely through tropical countries, but do not reach New Zealand. Their presence may largely be due to the accident of latitude, and stamps the flora as subtropical. The remaining genera have the following range: New Zealand, 1 (*Carmichaelia*); Australia, 5; Polynesia, 3; New Zealand and Australia, 11; New Zealand and Polynesia, 2; Africa, 1 (*Moraea*). Numerically, therefore, Australian genera (158) preponderate; Polynesia comes second with 147, and New Zealand has 109. The presence of a large proportion of widely distributed genera and species might have been expected in the flora of an isolated island, because species possessing facilities for wide dispersal would naturally form the bulk of immigrants after land connection had been severed.

### *Species.*

There are seventy endemic species of vascular plants in Lord Howe Island, or 33 per cent. of the total number of species occurring there. If these be divided according to their affinities, which can only be done approximately, the following result is obtained: Related to species found in New Zealand only, 17; Australia only, 11; Polynesia only, 10; New Zealand and Australia, 3; New Zealand and Polynesia, 2; Australia and Polynesia, 11; widely distributed, 16. Stated in this way the relationships of the endemic species are about evenly balanced between the three regions named. As supporting evidence of a former land connection it may be pointed out that, compared with the Australian forms, the Polynesian and New Zealand elements in the endemic plants are far higher than they are in the non-endemic species.

The non-endemic species are mainly widely distributed forms with a large proportion of Australian types. The distribution of these species is as follows: New Zealand only, 5; Australia only, 27; Polynesia only, 4; New Zealand and Australia, 28; New Zealand and Polynesia, 2; Australia and Polynesia, 36; all three regions, 37. (The more extended distribution of most of the species is here not taken into account.) I believe that with every species common to Lord Howe Island and one or more of the adjacent regions there is a suspicion of immigrants having from time to time been received across the intervening tract of ocean; consequently, if it be assumed that the greater number are capable of being transported across wide expanses of ocean, their presence must not be regarded as supporting a land connection.

*Geographical.*

The New Zealand element in the Lord Howe Island flora is important, as it includes two (*Colmeiroa* and *Hedyscepe*) of the four endemic genera, to which should perhaps be added a third (*Negria*). A highly characteristic New Zealand genus, *Carmichaelia*, with nineteen species in that country, has a twentieth in Lord Howe Island. Other genera represented in Lord Howe Island by endemic species related to New Zealand species include *Coprosma*, *Sideroxylon*, *Dracophyllum*, *Senecio*, *Pittosporum*, *Melicope*, and *Pimelea*; while amongst those species restricted to the two places are *Uncinia filiformis*, *Hymenanthera novae-zelandiae*, and *Gahnia xanthocarpa*.

The Polynesian element stamps the flora as distinct from that of New Zealand. The genera include important members of the flora, two of them, *Acicalyptus* and *Clinostigma*, being dominant in their respective habitats; while *Boehmeria* is not now common, but is suspected of having been destroyed in many places by introduced pigs. *Metrosideros nervulosa*, *Alyxia squamulosa*, *Alyxia Lindii*, and *Symplocus candelabrum* are endemic species related to Polynesian forms; while confined to Lord Howe Island and Polynesia are *Metrosideros villosa*, *Tecoma austro-caledonica*, *Zanthoxylum pinnata*, and *Blechnum attenuatum*.

The Australian element, considered numerically, is considerably larger than either the New Zealand or Polynesian. But the proximity of the Australian Continent, its great extension in a north and south direction, and the direction of the prevailing winds in the south-west Pacific Ocean no doubt account for this preponderance. The genera confined to Australia and Lord Howe Island are *Notelaea*, *Lyonsia*, *Melaleuca*, *Lagunaria*, and *Westringia*. It may be noted here that the most characteristic Australian genera are either entirely absent from Lord Howe Island or represented by one or two species only. The species occurring in Australia and New Zealand but not in Polynesia may have entered Lord Howe Island from either country, and show a latitudinal dispersal in the Temperate Zone independent of that in subtropical regions, indicated by the widely distributed tropical species not extending to New Zealand.

*Moraea* is known only in Africa and Lord Howe Island. It is a remarkable case of discontinuous distribution, and possibly the Lord Howe Island form is a relict species indicating a former wider distribution of the genus.

If we consider only the species which, occurring in Lord Howe Island, extend to one only of the regions named, and also those endemic forms related to species having a similarly restricted distribution, we find that for Polynesia and New Zealand the ratio of endemic to non-endemic species is 2 or 3 to 1, while for Australia it is less than $\frac{1}{2}$ to 1. Here again, therefore, the case for an early migration along a New Caledonia - New Zealand land line is well supported, while for the New Zealand related species the degree of peculiarity is greatest.

*Endemism.*

Among the causes resulting in endemism two only need be considered here: Firstly, there must be effective barriers to the frequent entrance of further members of the same species in order that new variations may not be swamped; secondly, a sufficient time must elapse for the species to alter in accordance with the changed conditions of the new habitat, and thus degree of peculiarity is roughly an index to the period of isolation. It may perhaps, therefore, be laid down as a working hypothesis that those species longest in the land will comprise the largest proportion of endemic forms and the highest degree of peculiarity, while the presence of widely distributed species indicates that dispersal is probably still going on, and this in the case of an oceanic island leads one to conclude that no direct land connection is required to explain their occurrence.

The geographical position of Lord Howe Island indicates a considerable lapse of time since it was directly connected by land with any other place, and species that arrived by a land bridge should show a degree of endemism relatively greater than that exhibited by the whole flora. But it is just those which arrived by land that we are endeavouring to discover. The following table is obtained by combining together the figures already given, the figures in the first column including the non-endemic species plus the number shown in the second column.

| | Total Number of Species. | Endemic Species included in Total. | Percentage of Endemic Forms. |
|---|---|---|---|
| Whole flora .. .. | 209 | 70 | 33 |
| Australia .. .. | 168 | 41 | 24 |
| New Zealand .. | 109 | 38 | 35 |
| Polynesia .. .. | 116 | 39 | 34 |

These figures might be taken as supporting the hypothesis of a land connection between New Caledonia and New Zealand. The proportion of endemic forms in the Australian element is well below that of the other two regions, though the figures for these latter places probably include species which have actually arrived at Lord Howe Island from the Australian Continent. In any case, it may reasonably be inferred from the table that arrivals from Australia are more frequent than from Polynesia and New Zealand, and that therefore oversea migration probably accounts for the preponderance of the continental forms.

*Ecological Groups.*

Dividing the plants into what may be termed ecological groups, and considering these in connection with their geographical relationships and with regard to endemism, brings out some significant facts which will support the conclusions already obtained from other viewpoints. Of fifty-four arborescent and semi-arborescent forest-plants, thirty-eight, or 70 per cent., are endemic. Numerically, Australian forms preponderate, while the New Zealand element is weakest; but their proportion of endemic forms gives the opposite result. On the face of it this might be construed as indicating that the last land connection was with Australia. But judging from the contour of the ocean-floor this could not be, and the conclusion one is forced to is that already stated—namely, the greater number of species of Australian affinities, including a large proportion of them identical in island and continent, proves that trans-oceanic migration has been the chief means of transport for this element. The fact of arborescent forest-plants showing a high degree of endemism follows from their lessened facility for dispersal compared with the other plants.

The coastal plants, twenty-four in number, include eight shrubby species. With the exception of *Coprosma prisca*, *Hymenanthera novae-zelandiae*, *Lepidium howei-insulae*, and *Cassinia tenuifolia*, which are mainly of New Zealand affinities, and of which three are endemic in Lord Howe Island, the whole of them are found in Australia, all but two extending to New Zealand and Polynesia as well. Here, probably, ocean currents have been the chief means of dispersal.

The seeds of orchids, grasses, and sedges are probably distributed mainly by wind. Of the twenty-three species found in Lord Howe Island, four are endemic and related to New Zealand and Australian forms; the remainder occur in New Zealand and Australia, one or both, some extending to Polynesia as well. The Pteridophyta, with their minute spores, probably always owe their wide dispersal to wind. In Lord Howe Island there are forty-nine species, the bulk of which are of wide range. The four tree-ferns and twelve others are endemic and related to widely distributed species. Only one non-endemic species, *Blechnum attenuatum*, is Polynesian but not found in Australia or New Zealand. Taking the last three groups together—that is, coastal plants, orchids and grasses, and Pteridophytes—the suggestion naturally presents itself that as distributing agencies wind and ocean currents in the region of Lord Howe Island act mainly from the Australian Continent eastward. Distribution in a north and south direction is not favoured by these means, and thus the strong New Zealand and Polynesian elements in the Lord Howe Island flora demand land connections. The high percentage of endemic forms in the same elements suggests that such connections were severed a long time ago, while the submarine ridge on which the island is situated indicates the direction in which the land bridges lay. The only evidence for direct land connection between Australia and Lord Howe Island is the fact that a large proportion of the Lord Howe Island species of plants extend to or are related to species in Australia. But a land connection with Australia since one with New Zealand or New Caledonia is disproved by the fact that a deep ocean trough separates the continent from the submarine ridge on which the island stands; while the coastal plants, grasses, and ferns indicate that a stream of migrants is ever crossing the ocean eastwards from Australia. It will thus be seen that speculations based on dynamic and biological facts may lead to opposite conclusions. I have taken the former as of greatest importance in indicating ancient land lines, and endeavoured to explain how the latter do not really conflict with them.

Tate, who considered Lord Howe and Norfolk Islands to form part of the New Zealand region, says, "One is tempted to suggest a modern immigration of Australian species which has dimmed the lustre of the original flora."

Summary: The plants of Lord Howe Island indicate former land connections with both New Zealand and New Caledonia. The greater degree of peculiarity in the New Zealand elements points to the earlier severance of that connection. No closer connection with temperate Australia need be postulated to explain the affinities of the flora of Lord Howe Island and the continent. The last land connection being with New Caledonia. Lord Howe Island ought properly to be considered an outlier of that region. This conclusion conflicts with that I arrived at when considering the birds of Lord Howe Island (*Trans. N.Z. Inst.*, vol. 44, p. 214, 1912), but Iredale has subsequently shown that the flightless rail is more closely related to a New Caledonian form than to the New Zealand *Gallirallus*. In the light of this information the line of reasoning followed in my former article will produce precisely the result here arrived at from a study of the flora.

## IV. LIST OF INDIGENOUS SPECIES.

### 1. LYCOPODIALES.

#### Lycopodium varium R. Br.

*Lycopodium varium* R. Br., *Prodr. Fl. Nov. Holl.* 165, 1810.

Recorded: Bentham, *Fl. Austr.* vii, 674, 1878; Hemsley, *Ann. Bot.* 10, 260, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 27, 351, 1892.

Habitat: On ground in moss forest near summit of Mount Gower.

Distribution: New Zealand, Tasmania, Australia, Pacific islands.

#### Tmesipteris tannensis (Spreng.) Bernh.

*Lycopodium tannensis* Spreng., *Schrad. Journ. Bot.* i, 267, 1799.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26, 1870; Hemsley, *Ann. Bot.* x, 260, 1896.

Habitat: Epiphyte on stems of trees in moss forest, summit Mount Gower.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, New Caledonia, Pacific islands.

#### Psilotum triquetrum Sw.

*Psilotum triquetrum* Sw., *Syn. Fil.* 117, 1806.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* x, 118, 1877; Hemsley, *Ann. Bot.* x, 260, 19, 1896.

Habitat: Rocky places in forest.

Distribution: Norfolk Island, Kermadecs, New Zealand, Australia, New Caledonia, tropical and subtropical regions.

#### Selaginella uliginosa (Lab.) Spring.

*Lycopodium selaginosum* Lab., *Nov. Holl. Pl. Sp.* ii, 104, 1806.

Recorded: Bentham, *Fl. Austr.* vii, 678, 1878; Hemsley, *Ann. Bot.* x, 260, 1896.

Distribution: Tasmania, Australia

### 2. FILICALES.

#### Trichomanes javanicum Bl.

*Trichomanes javanicum* Bl., *Enum. Pl. Java*, 224, 1828.

Recorded: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 146, 1898.

Habitat: Forest in Deep Creek (Maiden).

Distribution: Tasmania, Australia, Polynesia, Malaya, tropical Asia.

### Trichomanes Bauerianum Endl.

*Trichomanes Bauerianum* Endl., *Prodr. Fl. Norf.* 17, 1833.

Recorded : Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*T. meifolium* var. *Bauerianum*) ; F. Muell., *Fragm. Phytogr. Austr.* vii, 121, 1870 (*T. polyanthus*) ; Bentham, *Fl. Austr.* vii, 703, 1878 (*T. apiifolium*) ; Hemsley, *Ann. Bot.* x, 262, 1896 (*T. apiifolium*).

Habitat : On wet banks in ravines in forest from near sea-level to summit of Mount Gower.

Distribution : Norfolk Island, Australia, New Caledonia, Polynesia, Malaya.

### Hymenophyllum tunbridgense (L.) Sm.

*Trichomanes tunbridgense* L., *Sp. Plant.* ii, 1098, 1753.

Recorded : Moore, *Lord Howe Id. Official Visit.* 26, 1870 ; Hemsley, *Ann. Bot.* x, 262, 1896.

Habitat : Epiphyte on stems of trees, ferns, and logs in moss forest, summit of Mount Gower.

Distribution : New Zealand, Tasmania, Australia, Europe, South Africa, tropical America, Chile.

### Hymenophyllum pumilum C. Moore.

*Hymenophyllum pumilum* Moore in Hook. & Bak. *Syn. Fil.* ed. ii, 464, 1874.

Recorded : Baker, *Syn. Fil.* ed. ii, 464, 1874 (*H. Moorei*) ; Bentham, *Fl. Austr.* vii, 706, 1878 ; Hemsley, *Ann. Bot.* x, 262, 1896.

Habitat : Epiphyte on underside of horizontal branches of trees, summit of Mount Gower.

Distribution : New South Wales.

### Hymenophyllum multifidum (Forst. f.) Sw.

*Trichomanes multifidum* Forst. f., *Fl. Austr. Prodr.* 85, 1786.

Recorded : Bentham, *Fl. Austr.* vii, 707, 1878 ; Hemsley, *Ann. Bot.* x, 261, 1896.

Habitat : Epiphyte on stems of trees and tree-ferns in moss forest, summit of Mount Gower.

Distribution : Norfolk Island, New Zealand, Australia, New Guinea, Fiji, Samoa, Celebes.

### Hymenophyllum minimum A. Rich.

*Hymenophyllum minimum* A. Rich., *Fl. Nouv. Zel.* 91, t. 14, f. 2, 1832.

Recorded : Bentham, *Fl. Austr.* vii, 706, 1878 ; Hemsley, *Ann. Bot.* x, 261, 1896.

Habitat : Summit of Mount Gower (Bentham) and Mount Lidgbird (Watts).

Distribution : New Zealand.

### Hymenophyllum flabellatum Lab.

*Hymenophyllum flabellatum* Lab., *Nov. Holl. Pl. Sp.* ii, 101, t. 250, f. 1, 1806.

Recorded : Bentham, *Fl. Austr.* vii, 705, 1878 ; Tate, *Macleay Mem. Vol.* 218, 1893 (*H. nitens*) ; Hemsley, *Ann. Bot.* x, 261, 1896.

Distribution : Kermadecs, New Zealand, Tasmania, Australia, Samoa.

### Cyathea Macarthuri (F. Muell.) Baker.

*Hemitelia Macarthuri* F. Muell., *Fragm. Phytogr. Austr.* viii, 176, 1874.

Recorded: Hook. & Baker, *Syn. Fil.* 26, 1868 (*C. dealbata*); F. Muell., *l.c.*; Baker, *Syn. Fil.* ed. ii, 453, 1874 (*C. Moorei*); Bentham, *Fl. Austr.* vii, 708, 1878; Hemsley, *Ann. Bot.* x, 261, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 144, 1898; Watts, *Proc. Linn. Soc. N.S.W.* 39, 261, 1914.

Habitat: In forest from near sea-level to summit of Mount Gower.

Distribution: Endemic.

### Cyathea brevipinna Baker.

*Cyathea brevipinna* Baker in Benth. *Fl. Austr.* vii, 179, 1878.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* viii, 177, 1874 (*C. medullaris*); Bentham, *l.c.*; Hemsley, *Ann. Bot.* x, 260, 1896; Watts, *Proc. Linn. Soc. N.S.W.* 39, 261, 1914.

Habitat: Abundant in moss forest, summit of Mount Gower.

Distribution: Endemic. This species has been compared with *C. medullaris* of New Zealand.

### Hemitelia Moorei Baker.

*Hemitelia Moorei* Baker, *Gard. Chron.* 252, 1872.

Recorded: Baker, *l.c.*; Bentham, *Fl. Austr.* vii, 709, 1878; Hemsley, *Ann. Bot.* x, 261, 1896; Watts, *Proc. Linn. Soc. N.S.W.* 39, 261, 1914.

Habitat: In wet forest, summit of Mount Gower; not common.

Distribution: Endemic. *Hemitelia* is a tropical genus, mostly American, with one species in New Zealand but none in Australia.

### Alsophila robusta C. Moore.

*Alsophila robusta* C. Moore ex Maiden, *Proc. Linn. Soc. N.S.W.* 23, 144, 1898.

Recorded: Hook. & Baker, *Syn. Fil.* 27, 1868 (*Cyathea affinis*); Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*A. excelsa*); Bentham, *Fl. Austr.* vii, 711, 1878 (*A. australis* var. ? *nigrescens*); Hemsley, *Ann. Bot.* x, 261, 1896 (*A. australis* var. *nigrescens*); Maiden, *l.c.*; Watts, *Proc. Linn. Soc. N.S.W.* 39, 261, 1914.

Habitat: Forest from sea-level to summit of Mount Gower.

Distribution: Endemic. Laing describes a Norfolk Island plant as a variety, *norfolkiana*, of this species (*Trans. N.Z. Inst.* 47, 9, 1915). Bentham and Maiden compare *A. robusta* with *A. australis* of eastern Australia.

### Dryopteris nephrodioides (Baker) Watts.

*Deparia nephrodioides* Baker, *Gard. Chron.* 253, 1872.

Recorded: Baker, *l.c.*; Bentham, *Fl. Austr.* vii, 714, 1878 (*Deparia*); Hooker, *Icon. Plant.* t. 1606, 1886 (*Deparia*); Hemsley, *Ann. Bot.* x, 261, 1896 (*Dicksonia*); Watts, *Proc. Linn. Soc. N.S.W.* 39, 259, 1914.

Distribution: Endemic. A very distinct species, with the sori terminating short lobes of the pinnules.

### Dryopteris apicalis (Baker) O. Kuntze.

*Nephrodium apicale* Baker, *Syn. Fil.* ed. ii, 499. 1874.

Recorded: Baker, *l.c.*; Bentham, *Fl. Austr.* vii, 758. 1878 (*Aspidium*); Hemsley, *Ann. Bot.* x, 265. 1896 (*Aspidium*); Watts, *Proc. Linn. Soc. N.S.W.* 39. 259. 1914.

Habitat: Undergrowth in moss forest, summit of Mount Gower; and on damp bank in forest, Erskine Valley.

Distribution: Endemic.

### Dryopteris parasitica (L.) O. Kuntze.

*Polypodium parasiticum* L., *Sp. Plant.* ii, 1090, 1753.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix. 196. 1875 (*Aspidium molle*); Hemsley, *Ann. Bot.* x. 266. 1896 (*A. molle*); Oliver, *Trans N.Z. Inst.* 42. 159. 1910.

Habitat: Robin's Swamp (Watts).

Distribution: Norfolk Island, Kermadecs, New Zealand, Australia, New Caledonia, tropical and subtropical regions.

### Polystichum Whiteleggei Watts.

*Polystichum Whiteleggei* Watts, *Proc. Linn. Soc. N.S.W.* 39, 258, 1914.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*Aspidium aculeatum*); Bentham, *Fl. Austr.* vii, 758, 1878 (*A. capense*); Hemsley, *Ann. Bot.* x, 265, 1896 (*A. capense*); Watts, *Proc. Linn. Soc. N.S.W.* 39, 397, 1913 (*P. Moorei*); Watts, *l.c.*

Habitat: Undergrowth in forest.

Distribution: Endemic. Related to the widely distributed *Polystichum aculeatum*.

### Polystichum Moorei (Christ) W. R. B. Oliver comb. nov.

*Aspidium aculeatum* var. *Moorei* Christ ex Maiden, *Proc. Linn. Soc. N.S.W.* 23, 146, 1898.

Recorded: Maiden, *l.c.*; Watts, *Proc. Linn. Soc. N.S.W.* 37, 401, 1913 (*Polystichum Kingii*); Watts, *id.* 39, 258, 1914.

Besides the typical form, Mr. Watts describes a variety *tenerum* with a dense cluster of scales at the base of the stipes.

Habitat: In caves near sea-level, and in crevices of the overhanging cliffs, western base of Mount Gower.

Distribution: Endemic.

### Arthropteris tenella (Forst. f.) J. Sm.

*Polypodium tenellum* Forst. f., *Fl. Austr. Prodr.* 81, 1786.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*Polypodium*); Hemsley, *Ann. Bot.* x, 267, 1896 (*Polypodium*).

Habitat: In forest, scrambling over rocks and tree-trunks.

Distribution: Norfolk Island, New Zealand, Australia, New Caledonia.

### Nephrolepis cordifolia (L.) Pr.

*Polypodium cordifolium* L., *Sp. Plant.* ii. 1089. 1753.

Recorded: Moore, *Lord Howe Id. Official Visit.* 26. 1870 (*N. tuberosum*); Hemsley, *Ann. Bot.* x. 265. 1896 (*Aspidium*).

Habitat: Open rocky places on north ridge of Mount Gower.

Distribution: Norfolk Island, Kermadecs, New Zealand, Australia, New Caledonia, Japan, tropical regions.

### Diplazium melanochlamys (Hook.) Moore.

*Asplenium melanochlamys* Hook., *Sp. Fil.* iii. 259. 1860.

Recorded: Hook., *l.c.*: Bentham, *Fl. Austr.* vii. 751. 1878 (*Asplenium*); Hemsley, *Ann. Bot.* x. 264. 1896 (*Asplenium*).

Habitat: Undergrowth in forest from sea-level to summit of Mount Gower.

Distribution: Endemic.

### Asplenium adiantoides (L.) C. Chr.

*Trichomanes adiantoides* L., *Sp. Plant.* ii. 1098. 1753.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix. 78. 1875 (*A. falcatum*); Hemsley, *Ann. Bot.* x. 264. 1896 (*A. falcatum*).

Habitat: Northern Hills (Watts).

Distribution: Norfolk Island, Kermadecs (*A. caudatum*), New Zealand, Australia, New Caledonia, tropical Polynesia, Asia, Africa.

### Asplenium Milnei Carr.

*Asplenium Milnei* Carr. ex Seem., *Flora Vitiensis*, 353. 1873.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26. 1870 (*A. lucidum*); Carr. ex Seem., *l.c.*; F. Muell., *Fragm. Phytogr. Austr.* ix. 78. 1875 (*A. marinum*); Hemsley, *Ann. Bot.* x. 264. 1896 (*A. obtusatum*).

Habitat: Abundant as undergrowth in lowland forest and coastal scrub.

Distribution: Endemic. Allied to *A. remotum* Moore, of Polynesia, New Guinea, and Celebes.

### Asplenium nidus L.

*Asplenium nidus* L., *Sp. Plant.* ii, 1079. 1753.

Recorded: Hook. & Baker, *Syn. Fil.* 190. 1868; Hemsley, *Ann. Bot.* x. 265. 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23. 146. 1898 (*A. Robinsoni*).

Habitat: Rocky places on sea-cliffs and in forest near coast.

Distribution: Norfolk Island, Australia, New Caledonia, tropics from East Africa to Asia and Polynesia.

### Asplenium pteridoides Baker.

*Asplenium pteridoides* Baker, *Jour. Bot.* xi. 17. 1873.

Recorded: Baker, *l.c.*; Bentham, *Fl. Austr.* vii. 749. 1878: Hook., *Icon. Plant.* t. 1649. 1886; Hemsley, *Ann. Bot.* x, 265, 1896.

Habitat: Undergrowth in moss forest, summit of Mount Gower.

Distribution: Endemic. A very distinct species, belonging to the same group as *A. bulbiferum* and *A. flaccidum*.

### Asplenium howeanum (Watts) W. R. B. Oliver comb. nov.

*Asplenium bulbiferum* var. *howeanum* Watts, *Proc. Linn. Soc. N.S.W.* 37, 399, 1913.

Recorded : Watts, *l.c.*
Habitat : Undergrowth in wet rocky places in forest, Erskine Valley to summit of Mount Gower.
Distribution : Endemic. Allied to the widely distributed *A. bulbiferum*.

### Blechnum attenuatum (Sw.) Mett.

*Onoclea attenuata* Sw., *Schrad. Journ.* 1800, 73, 1801.

Recorded : Bentham, *Fl. Austr.* vii, 736, 1878 (*Lomaria*) ; Hemsley, *Ann. Bot.* x, 264, 1896 (*Lomaria*).
Habitat : Climbing up trunks of tree-ferns and trees in wet forest, summit of Mount Gower.
Distribution : Polynesia, Juan Fernandez, South Africa.

### Blechnum capense (L.) Schlecht.

*Osmunda capensis* L., *Mant. Plant.* 306, 1771.

Recorded : Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*Lomaria*) ; Hemsley, *Ann. Bot.* x, 264, 1896 (*Lomaria*).
Habitat : Undergrowth in forest, Erskine Valley to summit of Mount Gower.
Distribution : Kermadecs, New Zealand, Tasmania, Australia, New Caledonia, Polynesia, Malaya, South Africa, tropical and southern America.

### Blechnum Fullagari (F. Muell.) C. Chr.

*Lomaria Fullagari* F. Muell., *Fragm. Phytogr. Austr.* viii, 157, 1874.

Recorded : F. Muell., *l.c.* ; Baker, *Syn. Fil.* ed. ii, 481, 1874 (*Lomaria auriculata*) ; Bentham, *Fl. Austr.* vii, 737, 1878 (*Lomaria*) ; Hemsley, *Ann. Bot.* x, 264, 1896 (*Lomaria*).
Habitat : Undergrowth in moss forest, summit of Mount Gower.
Distribution : Endemic. Mueller compares this species with *Lomaria gibba* from New Caledonia and *L. emarginata* from New Hebrides.

### Doodia aspera R. Br.

*Doodia aspera* R. Br., *Prodr. Fl. Nov. Holl.* 151, 1818.

Recorded : Bentham, *Fl. Austr.* vii, 741, 1878 ; Hemsley, *Ann. Bot.* x, 264, 1896.
Distribution : Norfolk Island, eastern Australia.

### Pellaea falcata (R. Br.) Fée.

*Pteris falcata* R. Br., *Prodr. Fl. Nov. Holl.* 154, 1810.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*Pteris*) : Hemsley, *Ann. Bot.* x, 263, 1896 (*Pteris*).
Habitat : Undergrowth in forest on Northern Hills.
Distribution : Kermadecs, New Zealand, Tasmania, Australia, New Caledonia, Malaya, India.

### Notholaena distans R. Br.

*Notholaena distans* R. Br., *Prodr. Fl. Nov. Holl.* 146. 1810.

Recorded : Bentham. *Fl. Austr.* vii, 774, 1878.
Habitat : Exposed rocky ridge on Northern Hills.
Distribution : Norfolk Island, New Zealand, Australia, New Caledonia, Polynesia, Celebes.

### Hypolepis tenuifolia (Forst. f.) Bernh.

*Lonchitis tenuifolia* Forst. f., *Fl. Austr. Prodr.* 80. 1786.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 ; Hemsley, *Ann. Bot.* x, 263, 1896.
Habitat : Undergrowth in forest.
Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, New Caledonia, Polynesia, Malaya, China.

### Adiantum aethiopicum L.

*Adiantum aethiopicum* L., *Syst. Nat.* ed. x, ii, 1329, 1759.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 79, 1875 ; Hemsley, *Ann. Bot.* x, 262, 1896.
Habitat : Undergrowth in low forest and scrub on Northern Hills.
Distribution : New Zealand, Tasmania, Australia, tropical Africa.

### Adiantum hispidulum Sw.

*Adiantum hispidulum* Sw., *Schrad. Journ.* 1800, 82, 1801.

Recorded : Moore, *Trans. Roy. Soc. N.S.W.* 1871, 30. 1872 ; Hemsley, *Ann. Bot.* x, 262, 1896.
Habitat : Undergrowth in forest, Northern Hills and north ridge of Mount Gower.
Distribution : Norfolk Island, Kermadecs, New Zealand, Australia, New Caledonia, Polynesia, Malaya, India, Africa.

### Pteris comans Forst. f.

*Pteris comans* Forst. f., *Fl. Austr. Prodr.* 79. 1786.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 ; Hemsley, *Ann. Bot.* x, 263, 1896.
Habitat : Undergrowth in forest.
Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, Polynesia, Juan Fernandez.

### Pteris tremula R. Br.

*Pteris tremula* R. Br., *Prodr. Fl. Nov. Holl.* 154, 1810.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*P. arguta*) ; Bentham, *Fl. Austr.* vii, 731, 1878 ; Hemsley, *Ann. Bot.* x, 263, 1896.
Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, Fiji.

### Histiopteris incisa (Thbg.) J. Sm.

*Pteris incisa* Thbg., *Prodr. Fl. Jap.* 171, 1800.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*Pteris*); Hemsley, *Ann. Bot.* x, 263, 1896 (*Pteris*).

Habitat: Undergrowth in moss forest, summit of Mount Gower.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, New Caledonia, tropical and southern extra-tropical regions.

### Pteridium aquilinum (L.) Kuhn var. esculentum (Forst. f.) Hook. f.

*Pteris aquilina* L., *Sp. Plant.* ii, 1075, 1753; *P. esculenta* Forst. f., *Pl. Escul.* 79, 1786.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*Pteris aquilina*); Hemsley, *Ann. Bot.* x, 263, 1896 (*Pteris*).

Habitat: North Head (Watts).

Distribution: Of subspecies—Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, Southern Hemisphere; of species—cosmopolitan.

### Polypodium diminutum Baker.

*Polypodium diminutum* Baker, *Syn. Fil.* ed. ii, 507, 1874.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*P. australe*); Baker, *l.c.*: Hemsley, *Ann. Bot.* x, 266, 1896 (*P. australe*); Watts, *Proc. Roy. Soc. N.S.W.* 49, 388, 1916 (*P. howeanum*).

Habitat: Epiphyte on stems and branches of trees in moss forest, summit of Mount Gower.

Distribution: Endemic. Allied to the widely distributed *P. Billardieri*.

### Polypodium pulchellum Watts.

*Polypodium (Grammitis) pulchellum* Watts, *Proc. Roy. Soc. N.S.W.* 49, 386, 1916.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* vii, 104, 1870 (*P. Hookeri*); Hemsley, *Ann. Bot.* x, 266, 1896 (*P. Hookeri*); Watts, *l.c.*

Habitat: Epiphyte on stems of trees in moss forest, summit of Mount Gower.

Distribution: Endemic. Related to the Australian and Polynesian *P. Hookeri*.

### Polypodium diversifolium Willd.

*Polypodium diversifolium* Willd., *Sp. Plant.* v, 166, 1810.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*P. scandens*); F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*P. Billardieri*); Bentham, *Fl. Austr.* vii, 769, 1878 (*P. pustulatum*); Hemsley, *Ann. Bot.* x, 267, 1896 (*P. pustulatum*).

Habitat: Undergrowth in lowland forest.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, New Caledonia.

### Cyclophorus confluens (R. Br.) C. Chr.

*Polypodium confluens* R. Br., *Prodr. Fl. Nov. Holl.* 146, 1810.

Recorded: Moore, *Lord Howe Id. Official Visit,* 26, 1870 (*Polypodium*); Bentham, *Fl. Austr.* vii, 767, 1878 (*P. confluens*); Hemsley, *Ann. Bot.* x, 266, 1896 (*P. confluens*).

Habitat: Northern Hills (Watts).

Distribution: Norfolk Island, Australia, New Caledonia.

### Platycerium bifurcatum (Cav.) C. Chr.

*Acrostichum bifurcatum* Cav., *Anal. Hist. Nat.* i, 105, 1799.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*P. alcicorne*); Hemsley, *Ann. Bot.* x, 267, 1896 (*P. alcicorne*).

Habitat: On rocks and trees in forest from sea-level to 200 m. alt.

Distribution: Australia, New Caledonia.

### Leptopteris Moorei (Baker) Christ.

*Todea Moorei* Baker, *Journ. Bot.* xi, 16, 1873.

Recorded: Baker, *l.c.*; Bentham, *Fl. Austr.* vii, 700, 1878 (*Todea*); Hooker, *Icon. Plant.* t. 1697, 1887 (*Todea*); Hemsley, *Ann. Bot.* x, 267, 1896 (*Todea*).

Habitat: Summit of Mount Gower (Watts).

Distribution: Endemic. Allied to *L. hymenophylloides* of New Zealand.

### Marattia fraxinea Sm. var. howeana W. R. B. Oliver n. var.

*Marattia fraxinea* Sm., *Pl. Ic.* ined. 2, t. 48, 1790.

Recorded: Moore, *Lord Howe Id. Official Visit,* 26, 1870 (*M. salicina*); Bentham, *Fl. Austr.* vii, 695, 1878; Hemsley, *Ann. Bot.* x, 267, 1896; Watts, *Proc. Linn. Soc. N.S.W.* 37, 396, 1913 (*M. fraxinea* var. *salicina*).

Pinnae oblongae, 30 cm. long., 12 cm. lat. Pinnulae oblongae, obtusae, ad basim oblique cunatae, 70–90 mm. long., 18–20 mm. lat. Sori in venis circa 2 mm. a margine distantes; sporangia 10–16 in omni synangio.

Fronds large, 3–4 m. long, deltoid, 2–3-pinnate. Pinnae oblong, 30 cm. long, 12 cm. broad. Pinnules shortly stalked, oblong, obtuse, obliquely cuneate at the base, margins crenulate, 70–90 mm. long, 18–20 mm. wide. Veins simple or once forked. Sori oblong, 2–3 mm. long, on the veins about 2 mm. from the margin; sporangia 10–16 in each synangium.

Distinguished by the short obtuse pinnules with sori distant from the margin. But for the variation exhibited by *M. fraxinea* I would not have hesitated to set up the Lord Howe Island form as a distinct species.

Habitat: Side of stream in ravine, Deep Creek, in forest; and young plants seen in forest in Erskine Valley. Probably formerly plentiful in forest, but now nearly exterminated by pigs.

Distribution of *M. fraxinea*: Australia, New Caledonia, Polynesia, Malaya, Philippines, India, South Africa.

**Ophioglossum vulgatum** L. var. **Prantlii** (C. Chr.) W. R. B. Oliver comb. nov.

*Ophioglossum vulgatum* L., *Sp. Plant.* ii. 1062, 1753: *O. Prantlii* C. Chr., *Ind. Fil.* 471, 1896.

Recorded: Watts, *Proc. Linn. Soc. N.S.W.* 37, 396, 1913; Watts, *id.* 39, 266, 1914 (*O. vulgatum* var. *lanceolatum*).

Habitat: Track through Johnson's garden (Watts).

Distribution of species: Norfolk Island, Kermadecs, New Zealand, Australia; cosmopolitan.

## 3. Angiosperms.

### Pandanus Forsteri Moore & Muell.

*Padanus Forsteri* Moore & Muell., *Fragm. Phytogr. Austr.* viii, 220, 1874.

Recorded: (Moore, *Lord Howe Id. Official Visit*, 26, 1870, nom. nud.); Moore & Muell., *l.c.*; Moore & Betche, *Handb. Flora N.S.W.* 521, 1893 (*P. Moorei* nom. nud. and *P. Forsteri*); Bentham, *Fl. Austr.* vii. 149, 1878; Hemsley, *Ann. Bot.* x. 256, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 140, 1898.

Habitat: Common in forest in main tier of vegetation from sea-level to 400 m. alt.

Distribution: Endemic. Related to the widely distributed *P. tectorius* Sol. of Polynesia, Australia, and south Asia.

### Halophila ovalis (R. Br.) Gaud.

*Caulinia ovalis* R. Br., *Prodr. Fl. Nov. Holl.* 339, 1810.

Recorded: Bentham, *Fl. Austr.* vii, 187, 1878; Tate, *Macleay Mem. Vol.* 220, 1893 (*H. ovata*); Hemsley, *Ann. Bot.* x, 256, 1896 (*H. ovata*).

Distribution: Tasmania, Australia, shores of Indian and Pacific Oceans.

### Paspalum distichum L.

*Paspalum distichum* L., *Amoen. Acad.* v, 391.

Recorded: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 142, 1898; *id.*, 39, 383, 1914.

Habitat: Ned's Beach, old settlement (Maiden).

Distribution: New Zealand, Australia, tropical and subtropical regions.

### Oplismenus aemulus (R. Br.) Kunth.

*Orthopogon aemulus* R. Br., *Prodr. Fl. Nov. Holl.* 194, 1810.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* viii, 199, 1874 (*Panicum compositum*); Bentham, *Fl. Austr.* vii, 492, 1878 (*Oplismenus setarius*); Hemsley, *Ann. Bot.* x, 258, 1896 (*Opl. compositum*).

Habitat: Undergrowth in lowland forest.

Distribution: Norfolk Island, Kermadecs, New Zealand, Australia, all warm countries.

### Spinifex hirsutus Lab.

*Spinifex hirsutus* Lab., *Nov. Holl. Pl. Sp.* ii, 81, 1806.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*S. sericeus*); F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875; Hemsley, *Ann. Bot.* x, 258, 1896.

Habitat: Sand-dunes and maritime meadow along sea-shore.

Distribution: New Zealand, Tasmania, Australia, New Caledonia.

**Echinopogon ovatus** (Forst. f.) Beauv.

*Agrostis ovata* Forst. f., *Fl. Austr. Prodr.* 8, 1786.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 196, 1875 (*Cinna*).

Habitat: Open spaces in forest, northern slopes Mount Lidgbird and summit Mount Gower.

Distribution: Norfolk Island, New Zealand, Tasmania, Australia.

**Calamagrostis avenacea** (Gmel.) W. R. B. Oliver comb. nov.

*Agrostis avenacea* Gmel., *Syst.* i, 171.

Recorded: Bentham., *Fl. Austr.* vii, 579, 1878 (*Deyeuxia Forsteri*); Hemsley, *Ann. Bot.* x, 259, 1896 (*D. Forsteri*).

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia.

**Dichelachne crinita** (L. f.) Hook. f.

*Anthoxanthum crinitum* L. f., *Suppl.* 90, 1781.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*Stipa micrantha* var. *crinita*); Hemsley *Ann. Bot.* x, 259, 1896.

Habitat: Open rocky ridge on Northern Hills.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia.

**Phragmites communis** Trin.

*Phragmites communis* Trin., *Fund. Agrost.* 134, 1820.

Recorded: Bentham., *Fl. Austr.* vii, 636, 1878; Hemsley, *Ann. Bot.* x, 258, 1896.

Habitat: Tall rush meadow, gap in Northern Hills.

Distribution: Tasmania, Australia; cosmopolitan in tropical and temperate regions.

**Poa caespitosa** Spreng.

*Poa caespitosa* Spreng., *Mant.* i, *Fl. Hal.* 33, 1807.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875; Hemsley, *Ann. Bot.* x, 259, 1896.

Habitat: Abundant on the lower levels as undergrowth in forest, on rocky exposed ridge on Northern Hills, in *Scirpus* meadow and sand-flat.

Distribution: New Zealand, Tasmania, Australia.

**Agropyron scabrum** (Lab.) Beauv.

*Festuca scabra* Lab., *Nov. Holl. Pl. Sp.* i, 22, 1806.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*Festuca Billardieri*); Hemsley, *Ann. Bot.* x, 259, 1896.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia.

**Mariscus haematodes** (Endl.) Laing.

*Cyperus haematodes* Endl., *Prodr. Fl. Norf.* 22, 1833.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* viii, 269, 1874 (*Cyperus congestus*); Bentham, *Fl. Austr.* vii, 285, 1878 (*Cyperus*); Hemsley, *Ann. Bot.* x, 257, 1896 (*Cyperus*).

Habitat: The dominant plant in the tussock-sedge formation in damp places at the lower levels, Northern Hills and talus slope west base of Mount Gower.

Distribution: Norfolk Island. Related to *M. ustulatus* of New Zealand.

### Kyllinga monocephala Rottb.

*Kyllinga monocephala* Rottb., *Desc. et Ic.* 13, t. 4, 1773.

Habitat : Swamp in lowland.

Distribution : Norfolk Island, Australia, New Caledonia, Polynesia, tropical Asia and Africa.

### Scirpus nodosus (R. Br.) Rottb.

*Isolepis nodosus* R. Br., *Prodr. Fl. Nov. Holl.* 221, 1810.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix. 6. 1875 (*Isolepis*) ; Hemsley, *Ann. Bot.* x, 257, 1896.

Habitat : Sand-dunes and maritime meadow : also exposed rocky ridge on Northern Hills.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, southern temperate and subtropical regions.

### Cladium insulare Bentham.

*Cladium insulare* Bentham. *Fl. Austr.* vii, 403, 1878.

Recorded : Bentham, *l.c.* : Hemsley, *Ann. Bot.* x, 257, 1896.

Habitat : In damp open places from sea-level to the summit of Mount Gower. Abundant on the high cliffs of Mount Gower : especially conspicuous where water falls over the cliffs.

Distribution : Endemic. Allied to *C. Sinclairii* Hook. f. of New Zealand.

### Gahnia xanthocarpa Hook. f.

*Lampocarya xanthocarpa*, Hook. f., *Fl. Nov. Zel.* i, 278, 1853.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 13, 1875 (*Cladium*) ; Hemsley, *Ann. Bot.* x, 257, 1896 ; Bentham, *Fl. Austr.* vii, 418, 1878.

Habitat : Undergrowth in forest, usually in open places from near sea-level to summit of Mount Gower.

Distribution : New Zealand.

### Uncina filiformis Boott. var. debilior (F. Muell.) W. R. B. Oliver comb. nov.

*Uncinia filiformis* Boott. in Hook. f., *Fl. Nov. Zel.* i, 286, 1853; *U. debilior* F. Muell., *Fragm. Phytogr. Austr.* viii, 151, 1874.

Recorded : F. Muell., *l.c.* : Bentham. *Fl. Austr.* vii, 435, 1878 (*U. debilior*) ; Hemsley, *Ann. Bot.* x, 257, 1896 (*U. filiformis*).

The Lord Howe Island plant comes nearest to *U. filiformis*, but is a large form with culms 45 cm. tall and glumes usually longer than the utricles.

Habitat : Undergrowth in wet forest, summit of Mount Gower.

Distribution of species : New Zealand.

### Carex breviculmis R. Br. var. stipitata Kükenth.

*Carex breviculmis* R. Br., *Prodr. Fl. Nov. Holl.* 242, 1810 ; *C. breviculmis* var. *stipitata* Kükenth., *Pflanzenreich*. Heft 38, p. 469, 1909.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 ; Hemsley, *Ann. Bot.* x, 257, 1896 ; Kükenth., *l.c.*

Habitat : Summit of Mount Lidgbird : high on Mount Gower (Bentham).

Distribution of species : New Zealand, Tasmania, Australia, China, Japan, Himalayas.

### Carex gracilis R. Br.

*Carex gracilis* R. Br., *Prodr. Fl. Nov. Holl.* 242, 1810.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* viii, 250, 1874 ; Hemsley, *Ann. Bot.* x, 258, 1896.

Habitat : Undergrowth in forest at the lower levels ; abundant.

Distribution : Eastern Australia.

### Howea Forsteriana (F. Muell.) Becc.

*Kentia Forsteriana* F. Muell., *Fragm. Phytogr. Austr.* vii, 100, 1870.

Recorded : F. Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 255, 1896 ; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 138, 1898 (*Kentia*).

The two species of *Howea* are closely related. The more apparent differences are contrasted in the following statement : *H. Forsteriana* (thatch-palm)—Stem stout ; petiole short ; leaflets drooping ; spikes short, 4 to 7 united at base ; fruit elongated. *H. Belmoreana* (curly palm)—Stem slender ; petiole long ; leaflets erect ; spikes long, single ; fruit stout.

Habitat : In forest, chiefly below 150 m. alt., but on northern slopes of Mount Lidgbird ascends to 300 m., mixing with *Hedyscepe canterburyana*. It is often the dominant plant in lowland forest, its foliage-level being below that of *Ficus*.

It has been recorded (Etheridge, *Mem. Austr. Mus.* ii, 6, 1889) that "Wherever the soil is derived from the decomposition of the coral-sand rock the thatch-palm (*K. Forsteriana*) exclusively prevails, whilst the appearance of the curly palm [*K. Belmoreana*] at once indicates a volcanic soil." Maiden also (*Proc. Linn. Soc. N.S.W.* 23, 138, 1898) states that *H. Belmoreana* will not grow on the coral-sandy ground ; it is always found on basalt. I paid particular attention to the distribution of the two species of *Howea* in Lord Howe Island, and consider there is no foundation in fact for the above-quoted statements. *Howea Belmoreana* is common enough in places on the sandy flats, though not nearly so abundant there as *H. Forsteriana*. Conversely, *H. Belmoreana* is the dominant palm on the mountain-slopes up to 300 m., though *H. Forsteriana* on the northern slopes of Mount Lidgbird ascends to that height.

Distribution : Endemic.

### *Hybrids of* Howea.

At the north end of West Bay, Lord Howe Island (19th November, 1913), I examined two specimens of supposed hybrids between *Howea Forsteriana* and *H. Belmoreana*. In their essential characters they were both *H. Forsteriana*, but had some of the habits of *H. Belmoreana*. Although one must be cautious in accepting as hybrids variants in nature, I think the present specimens are best considered as such.

Specimen 1.—Characters of *H. Forsteriana :* Leaves with drooping pinnae, spikes in clusters of three or four, stem stout, fruit long. Characters of *H. Belmoreana :* Spikes long, 1·6 m.

Specimen 2.—Characters of *H. Forsteriana :* Leaves with horizontal or slightly drooping pinnae, spikes in clusters of three or four. Characters of *H. Belmoreana :* Spikes long (much longer than those of *H. Forsteriana* in same locality), pinnae in central leaves with upward tendency, stem slender, fruit robust.

### Howea Belmoreana (Moore & Muell.) Becc.

*Kentia Belmoreana* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 99, 1870.

Recorded: Moore & Muell., *l.c.*; Bentham, *Fl. Austr.* vii, 137, 1878 (*Kentia*); Hemsley, *Ann. Bot.* x, 255, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 138, 1898 (*Kentia*).

Habitat: In forest from sea-level to 300 m. alt., but not plentiful below 100 m. On the mountains it forms a considerable portion of the main tier of vegetation in the forest.

Distribution: Endemic.

### Clinostigma Mooreanum F. Muell.

*Kentia Mooreana* F. Muell., *Fragm. Phytogr. Austr.* vii, 101, 1870.

Recorded: F. Muell., *l.c.*; Bentham, *Fl. Austr.* vii, 139, 1878; Hemsley, *Ann. Bot.* x, 255, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 140, 1898.

Habitat: Plentiful in moss forest on summit of Mount Gower; also on summit of Mount Lidgbird.

Distribution: Endemic. Besides this species, *Clinostigma* contains three or four in New Caledonia and Samoa.

### Hedyscepe canterburyana Moore & Muell.

*Kentia canterburyana* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 101, 1870.

Recorded: Moore & Muell., *l.c.*; Bentham, *Fl. Austr.* vii, 138, 1878 (*Kentia*); Hemsley, *Ann. Bot.* x, 254, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 138, 1898; Maiden, *id.* 24, 382, pl. 32, 33, 1899.

Habitat: In forest on the mountains from 300 m. alt. to summit of Mount Gower. The plants decrease in size as the altitude increases.

Distribution: Endemic. *Hedyscepe* is a monotypic genus related to *Rhopalostylis* of New Zealand and Norfolk Island.

### Flagellaria indica L.

*Flagellaria indica* L., *Sp. Pl.* 333, 1753.

Recorded: Macgillivray, *Kew Journ. Bot.* vi, 353, 1854; Hemsley, *Ann. Bot.* x, 254, 1896.

Habitat: Scandent in forest, ascending to the tops of the highest trees, from near sea-level to about 300 m. alt.

Distribution: Australia, Polynesia, Borneo, tropical Asia and Africa.

### Commelyna cyanea R. Br.

*Commelyna cyanea* R. Br., *Prodr. Fl. Nov. Holl.* 269, 1810.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* viii, 59, 1873 (*C. communis*); Bentham, *Fl. Austr.* vii, 84, 1878; Hemsley, *Ann. Bot.* x, 254, 1896.

Habitat: Undergrowth in lowland forest, Transit Hill, Northern Hills.

Distribution: Norfolk Island, Australia, New Caledonia.

### Juncus pallidus R. Br.

*Juncus pallidus* R. Br., *Prodr. Fl. Nov. Holl.* 258, 1810.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*J. maritimus*); Hemsley, *Ann. Bot.* x, 254, 1896 (*J. maritimus*); Maiden, *Proc. Linn. Soc. N.S.W.* 23, 136, 1898 (*Juncus* sp.). Maiden records that two of the islanders, Robins and King, say this species was introduced to Lord Howe Island.

Habitat: In swamp; a few plants only among *Kyllinga*.

Distribution: New Zealand, Tasmania, Australia.

### Luzula longiflora Bentham.

*Luzula longiflora* Bentham, *Fl. Austr.* vii, 123, 1878.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*L. campestris*); Bentham, *l.c.*; Hemsley, *Ann. Bot.* x, 254, 1896.

Habitat: Undergrowth in wet forest, summit of Mount Gower, and down the slopes for a considerable distance.

Distribution: Endemic. According to Bentham, allied to *L. crinita*, confined to the Subantarctic Islands of New Zealand, and now considered to be a variety of the widely distributed *L. campestris*.

### Dianella caerulea Sims.

*Dianella caerulea* Sims, *Bot. Mag.* 505.

Recorded: Bentham, *Fl. Austr.* vii, 16, 1878; Hemsley, *Ann. Bot.* x, 253, 1896.

Habitat: On open rocky ridge, north spur of Mount Gower, about 450 m. alt.

Distribution: Australia.

### Geitonoplesium cymosum (R. Br.) Cunn.

*Luzuriaga cymosa* R. Br., *Prodr. Fl. Nov. Holl.* 282, 1810.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 196, 1875: Hemsley, *Ann. Bot.* x, 253, 1896.

Habitat: Scandent in lowland forest; common.

Distribution: Norfolk Island, Australia, Borneo, New Caledonia, Polynesia.

### Smilax australis R. Br.

*Smilax australis* R. Br., *Prodr. Fl. Nov. Holl.* 293, 1810.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*S. latifolia*); F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875; Hemsley, *Ann. Bot.* x, 253, 1896.

Habitat: Scandent in lowland forest.

Distribution: Australia.

### Moraea Robinsoniana (Moore & Muell.) Bentham.

*Iris Robinsoniana* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 153, 1871.

Recorded: Moore & Muell., *l.c.*; Anon., *Gard. Chron.* 393, 1872 (*Iris*); Bentham, *Fl. Austr.* vi, 409, 1873; Hemsley, *Ann. Bot.* x, 253, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 136, 1898

Habitat: Occurs from sea-level to the summit of Mount Gower in coastal scrub on cliffs and in rocky places. Always in exposed places, it does not form part of the undergrowth of forest.

Distribution: Endemic. The flowers nearly resemble those of *M. iridioides* (Bentham). With the exception of the Lord Howe Island species, the genus is confined to Africa.

**Microtis unifolia** (Forst. f.) Reichen.

*Ophrys unifolia* Forst. f., *Fl. Austr. Prodr.* 59, 1786.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*M. porrifolia*); Hemsley, *Ann. Bot.* x, 252, 1896 (*M. porrifolia*).

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia.

**Dendrobium gracilicaule** F. Muell. var. **howeanum** Maiden.

*Denrobium gracilicaule* var. *howeanum* Maiden, *Proc. Linn. Soc. N.S.W.* 24, 382, 1899; *D. gracilicaule* F. Muell., *Fragm. Phytogr. Austr.* i, 179, 1859.

Recorded: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*D. gracilicaule*); Maiden, *l.c.*; Hemsley, *Ann. Bot.* x. 252, 1896.

Habitat: Epiphyte on trees in moss forest, summit of Mount Gower.

Distribution: Endemic; of species, east Australia.

**Dendrobium Moorei** F. Muell.

*Denrobium Moorei* F. Muell., *Fragm. Phytogr. Austr.* vii, 29, 1869.

Recorded: F. Muell., *l.c.*; Bentham, *Fl. Austr.* vi, 281, 1873; Hemsley, *Ann. Bot.* x, 252, 1896.

Habitat: On trees in forest.

Distribution: Endemic. Near *D. macranthum* and *D. calcaratum* of Vanikoro, and *D. lancifolium* of Bouru (Mueller).

**Bolbophyllum exiguum** F. Muell.

*Bolbophyllum exiguum* F. Muell., *Fragm. Phytogr. Austr.* ii, 72, 1860.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875; Hemsley, *Ann. Bot.* x, 252, 1896.

Distribution: Australia.

**Cleisostoma erectum** Fitzg.

*Cleisostoma erectum* Fitzg., *Orchid. Austr.* i, pt. 4.

Recorded: Fitzgerald, *l.c.*; Hemsley, *Ann. Bot.* x, 252, 1896.

Habitat: On rocks and trees (Fitzgerald).

Distribution: Endemic. Closely allied to *C. tridentatum* of eastern Australia.

**Macropiper excelsum** (Forst. f.) Miq. var. **psittacorum** (Endl.) Laing.

*Piper psittacorum* Endl., *Prodr. Fl. Norf.* 37, 1833; *Piper excelsum* Forst. f., *Fl. Austr. Prodr.* 5, 1786.

Recorded: Bentham, *Fl. Austr.* vi, 204, 1873 (*Piper excelsum*); Hemsley, *Ann. Bot.* x, 219, 1896 (*Piper excelsum*).

Habitat: Undergrowth in forest from sea-level to summit of Mount Gower.

Distribution: Norfolk Island, Kermadecs, South Pacific islands; of species, New Zealand.

**Peperomia tetraphyllum** (Forst. f.) W. R. B. Oliver comb. nov.

*Piper tetraphyllum* Forst. f., *Fl. Austr. Prodr.* 5. 1786.

Recorded: Moore, *Lord Howe Id. Official Visit*, 25. 1870 (*P. reflexa*); Hemsley, *Ann. Bot.* x. 249. 1896 (*P. reflexa*): Maiden. *Proc. Linn. Soc. N.S.W.* 39. 383. 1914 (*P. affinis*).

Habitat: Among rocks. North ridge. Mount Gower, 300 m. alt., in open rocky places.

Distribution: Norfolk Island. New Zealand, Australia, tropical regions.

**Peperomia Urvilleana** Rich.

*Peperomia Urvilleana* Rich. *Fl. Nouv. Zel.* 356. 1832.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix. 76. 1875; Hemsley, *Ann. Bot.* x. 249. 1896.

Distribution: Norfolk Island. Kermadecs, New Zealand. New Caledonia (*P. Endlicheri*).

**Celtis amblyphylla** F. Muell.

*Celtis amblyphylla* F. Muell., *Fragm. Phytogr. Austr.* ix, 76, 1875.

Recorded: Bentham, *Fl. Austr.* vi. 156. 1873 (*C. paniculata*); F. Muell., *l.c.*; Hemsley, *Ann. Bot.* x. 251, 1896.

Anatomy of leaf from coastal scrub. Ned's Beach: Upper epidermis of single row of cells deeper than, sometimes twice as deep as, wide. Outer walls thickened. Palisade tissue of three or four rows of long narrow cells occupying half the mesophyll. Stomata in the upper epidermis open into large chambers the width of four or five palisade cells. Spongy parenchyma, occupying lower half of mesophyll, of small irregular cells with air-spaces. Lower surface similar to upper, the stomata opening into large chambers in the spongy parenchyma.

Habitat: Forest near sea-coast. West Bay; coastal scrub at Ned's Beach.

Distribution: Endemic. Allied to *C. paniculata* Planch. of Norfolk Island and Australia.

**Malaisa scandens** (Lour.) Planch.

*Caturus scandens* Lour., *Fl. Cochinch.* 612. 1790.

Recorded: Bentham, *Fl. Austr.* vi. 180, 1873 (*M. tortuosa*); Hemsley, *Ann. Bot.* x, 251, 1896 (*M. tortuosa*).

Habitat: Scandent in forest, reaching to the tops of the highest trees. Abundant from sea-level to 300 m. alt.

Distribution: Australia. West Polynesia. Malaya.

**Ficus columnaris** Moore & Muell.

*Ficus columnaris* Moore & Muell., *Proc. Accl. Soc. Vic.* iii. 71. 1874.

Recorded: Moore, *Lord Howe Id. Official Visit*, 25. 1870; Bentham, *Fl. Austr.* vi. 168, 1873 (*F. rubiginosa*); Moore & Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 251, 1896; Maiden. *Proc. Linn. Soc. N.S.W.* 23, 134. 1898.

An immense tree, which from its branches, some 10 m. to 15 m. above the ground, sends down much-branched bunches of aerial roots. One or more of these on reaching the ground takes root and eventually grows into a trunk perhaps as large as the original one, and thus forms a further outpost for the tree to spread from. The head of a large tree, therefore, forms an immense complicated system of branches bearing large leaves which are not usually very dense. Thus in its habit this species is similar to the famous banyan of India.

The bases of the trunks are irregular, as would naturally result from their origin, especially when formed from the union of several descending roots. The bark is reddish-brown, about 10 mm. thick, and when cut discharges copiously a thick white latex. Plank buttresses are formed, usually high ones, beginning 1 m. to 2 m. from the ground and extending out for several metres, twisting and branching the way. The roots or continuations of these buttresses are often more or less exposed above the ground for some distance.

Anatomy of leaf from forest. Transit Hill: Upper surface with cuticle. Upper epidermis of three layers of cells, the outer ones small and flat, then a layer of larger squarish cells, followed by an inner layer of large long cells; no chloroplasts. A few of the inner large epidermal cells are greatly enlarged and contain cystoliths. Palisade parenchyma of three or four rows of small narrow cells densely packed with chloroplasts. Spongy parenchyma of very small cells with few chloroplasts. Lower epidermis of one layer of small flat cells with cuticle.

Habitat: Forms the uppermost tier of vegetation, which is patchy, from sea-level to about 150 m. alt., but odd specimens occur in the Erskine Valley up to 400 m. alt. In the forest on the Northern Hills a young tree was noticed in the fork of a *Hemicyclia australasica* and sending a root to the ground.

Looking over the island from the Northern Hills one may easily note the distribution of *Ficus*. It can always be distinguished by the brown colour of the undersides of the leaves, which show in the wind. It occurs right across the island on the lower ground. It is not found quite near to the water's edge: the wind probably determines its limit in this direction. For a similar reason it does not occur high up on the hills.

It has been recorded that *Ficus* trees on Lord Howe Island have been killed by scale insects. I have concluded that the distribution of *Ficus* on the island is determined by wind. On mentioning this to Mr. Kirby he expressed the opinion that it was the wind that killed the *Ficus* trees when the settlers first cut down the surrounding vegetation. I have little doubt that this explanation is correct—that wind is the primary cause of the death of so many of the large *Ficus* trees. Scale insects may possibly have assisted as the vitality of the trees was lowered.

Distribution: Endemic.

### Elatostema reticulatum Weddell var. grande Bentham.

*Elatostema reticulatum* Weddell, *Ann. Sci. Nat.* (4), i, 188, 1854.
*E. reticulatum* var. *grande* Bentham, *Fl. Austr.* vi, 184, 1873.

Recorded: Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*E. nemorosa*); Bentham, *l.c.*: Hemsley, *Ann. Bot.* x, 251, 1896: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 134, 1898.

Habitat: In wet places from sea-level to summit of Mount Gower; floor of cave under dripping water at base, and in watercourse on summit, of Mount Gower. Common in places inaccessible to pigs.

Distribution: Australia.

**Boehmeria calophleba** Moore & Muell.

*Boehmeria calophleba* Moore & Muell., *Fragm. Phytogr. Austr.* viii, 11, 1872.

Recorded: Moore & Muell., *l.c.*; Bentham, *Fl. Austr.* vi, 184, 1873; Hemsley, *Ann. Bot.* x, 252, 1896.

Habitat: In scrub or low forest from sea-level to about 300 m. alt.

Distribution: Endemic. Very closely allied to *B. australis* Endl. of Norfolk Island. The genus is Polynesian, not extending to either Australia or New Zealand.

**Parietaria debilis** Forst. f.

*Parietaria debilis* Forst. f., *Fl. Austr. Prodr.* 73, 1786.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875; Hemsley, *Ann. Bot.* x, 252, 1896.

Habitat: Among sand-binders on exposed headlands, Ned's Beach.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, Polynesia, temperate and tropical regions.

**Korthalsella articulata** (Burmf. f.) Van Tiegh.

*Viscum articulatum* Burmf. f., *Fl. Ind.* 311, 1768.

Recorded: Moore, *Lord Howe Id. Official Visit*, 24, 1870 (*Viscum opuntioides*, syn. *V. articulatum*); Hemsley, *Ann. Bot.* x, 250, 1896 (*Viscum*); Maiden, *Proc. Linn. Soc. N.S.W.* 23, 134, 1898 (*Viscum*).

Habitat: Parasitic on trees in lowland forest; abundant. The following hosts have been noticed by different observers: *Hemicyclia australasica, Elaeodendron curtipendulum, Coprosma putida, Cryptocarya triplinervis, Ochrosia elliptica.*

Distribution: Norfolk Island, Australia, Polynesia, tropical Asia.

**Exocarpus homaloclada** Moore & Muell.

*Exocarpus homaloclada* Moore & Muell., *Fragm. Phytogr. Austr.* viii, 9, 1872.

Recorded: Moore & Muell., *l.c.*; Bentham, *Fl. Austr.* vi, 230, 1873; Hemsley, *Ann. Bot.* x, 250, 1896.

Habitat: In forest, a shrub in the undergrowth, from near sea-level to summit of Mount Gower.

Distribution: Endemic. Allied to *E. striata* of Tasmania and south-east Australia.

**Rumex Browni** Campd.

*Rumex Browni* Campd., *Monogr. Rum.* 81, 1819.

Recorded: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 133, 1898.

Habitat: Open rocky ridge, Northern Hills.

Distribution: Tasmania, Australia.

**Muehlenbeckia axillaris** (Hook. f.) Walp.

*Polygonum axillare* Hook. f. in *Hook. Lond. Journ. Bot.* vi, 278, 1847.

Recorded: Bentham, *Fl. Austr.* v, 275, 1870; Hemsley, *Ann. Bot.* x, 249, 1896.

Habitat: Scrambling over ground near seashore in West Bay.

Distribution: New Zealand, Tasmania, Australia.

### Rhagodia baccata (Lab.) Moq.

*Chenopodium baccatum* Lab., *Pl. Nov. Holl.* i, 71, t. 96, 1806.

Recorded: Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*R. Billardieri*); Hemsley, *Ann. Bot.* x, 248, 1896 (*R. Billardieri*).

Distribution: Tasmania, Australia.

### Atriplex cinerea Poir.

*Atriplex cinerea* Poir., *Encycl. Suppl.* i, 471.

Recorded: Bentham, *Fl. Austr.* v, 171, 1870; Hemsley, *Ann. Bot.* x, 248, 1896.

Habitat: Among sand-binders on exposed headlands at Ned's Beach.

Distribution: New Zealand, Tasmania, Australia.

### Salicornia australis Sol.

*Salicornia australis* Sol. ex Forst., *Fl. Austr. Prodr.* 88, 1786.

Recorded: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 133, 1898.

Habitat: Coastal rocks at north end of West Bay.

Distribution: New Zealand, Tasmania, Australia.

### Achyranthes aspera L.

*Achyranthes aspera* L., *Sp. Plant.* 204, 1753.

Recorded: Bentham, *Fl. Austr.* v, 246, 1870; Hemsley, *Ann. Bot.* x, 249, 1896.

Habitat: In open rocky places on edge of forest.

Distribution: Norfolk Island, Australia, New Caledonia, Polynesia, tropical and subtropical regions.

### Boerhaavia repens L.

*Boerhaavia repens* L., *Sp. Plant.* 3, 1753.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*B. diffusa*); Hemsley, *Ann. Bot.* x, 248, 1896 (*B. diffusa*).

Distribution: Australia, New Caledonia, Polynesia, tropical and subtropical Asia and Africa.

### Pisonia Brunoniana Endl.

*Pisonia Brunoniana* Endl., *Prodr. Fl. Norf.* 43, 1833.

Recorded: Moore, *Lord Howe Id. Official Visit*, 25, 1870; Hemsley, *Ann. Bot.* x, 248, 1896 (*P. umbellifera*).

Habitat: A small tree in lowland forests.

Distribution: Norfolk Island, Kermadecs, New Zealand, Australia.

### Sesuvium portulacastrum L.

*Sesuvium portulacastrum* L., *Syst. Nat.* ed. x, 1058, 1759.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875; Hemsley, *Ann. Bot.* x, 238, 1896.

Distribution: Australia, Polynesia, tropical and subtropical regions.

### Tetragonia expansa Murray.

*Tetragonia expansa* Murray, *Comm. Gotting.* vi, 13, 1783.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875; Hemsley, *Ann. Bot.* x, 237, 1896.

Habitat: Maritime meadow. Ned's Beach, Admiralty Islets (Maiden).

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, Japan, extra-tropical South America.

### Tetragonia strongylocarpa (Endl.) W. R. B. Oliver comb. nov.

*Tetragonia expansa* Murr. var. *strongylocarpa* Endl., *Prodr. Fl. Norf.* 73, 1833.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*T. implexicoma*); Hemsley, *Ann. Bot.* x, 237, 1896 (*T. implexicoma*).

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia.

### Mesembryanthemum aequilaterale Haw.

*Mesembryanthemum aequilaterale* Haw., *Misc. Nat.* 77, 1803.

Recorded: Moore, *Lord Howe Id. Official Visit,* 24, 1870; Hemsley, *Ann. Bot.* x, 237, 1896.

Habitat: Maritime meadow, Admiralty Islets (Maiden).

Distribution: Norfolk Island, New Zealand, Tasmania, Australia, California, Chile.

### Mesembryanthemum australe Sol.

*Mesembryanthemum australe* Sol. in Ait. *Hort. Kew,* ed. i, ii, 187.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875; Hemsley, *Ann. Bot.* x, 237, 1896.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia.

### Clematis glycinoides DC.

*Clematis glycinoides* DC., *Syst. Veg.* i, 145, 1818.

Recorded: Bentham, *Fl. Austr.* i, 7, 1863; Hemsley, *Ann. Bot.* x, 230, 1896.

Habitat: Lowland forest, trailing over other plants.

Distribution: Norfolk Island, Australia, Polynesia.

### Stephania Forsteri (DC.) A. Gray.

*Cocculus Forsteri* DC., *Syst. Veg.* i, 517, 1818.

Recorded: Moore, *Lord Howe Id. Official Visit,* 24, 1870 (*S. hernandifolia*); Hemsley, *Ann. Bot.* x, 231, 1896 (*S. discolor*).

Habitat: Trailing over shrubs in coastal scrub; also in rush formation in gap in Northern Hills.

Distribution: Australia, New Caledonia, New Guinea, Malaya, Polynesia.

### Drimys howeana F. Muell.

*Drimys howeana* F. Muell., *Fragm. Phtyogr. Austr.*, vii, 17, 1869.

Recorded: F. Muell., *l.c.*; F. Muell., *id.* ix, 76, 1875 (*D. insularis*); Hemsley, *Ann. Bot.* x, 230, 1896.

Anatomy of leaf: Upper epidermis of single row of cells with rather thickened outer walls. Mesophyll of about ten rows of small cells; the upper two rows contain many chloroplasts and represent palisade tissue; the rest of the cells have fewer chloroplasts and there are numerous air-spaces. Lower epidermis similar to upper.

Habitat: Common in forest from sea-level to summit of Mount Gower.

Distribution: Endemic. Closely allied to *D. semicarpifolia* F. Muell., of Queensland.

## Cryptocarya triplinervis R. Br.

*Cryptocarya triplinervis* R. Br., *Prodr. Fl. Nov. Holl.* 402, 1810.

Recorded: Bentham, *Fl. Austr.* v, 297, 1870; Hemsley, *Ann. Bot.* x. 249, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 133, 1898.

Anatomy of leaf of specimen from forest, Transit Hill: Thin cuticle on upper surface. Upper epidermis of single row of oblong or square cells. Palisade tissue, half the mesophyll, of two or three rows of long cells interrupted by large empty cells the width of about four palisade cells. Spongy tissue with air-spaces. Lower epidermis similar to upper, but with thinner cuticle.

Habitat: Common in lowland forest. Transit and Northern Hills.

Distribution: Australia.

## Cryptocarya Gregsoni Maiden.

*Cryptocarya Gregsoni* Maiden, *Proc. Linn. Soc. N.S.W.* 27, 347, 1902.

Recorded: Maiden, *l.c.*; Maiden, *id.* 23, 135, 1898 (black plum).

Anatomy of leaf of specimen from scrub on summit of Mount Gower: Thin cuticle on upper surface. Upper epidermis of oblong cells deeper than wide. Hypoderm of two rows of clear rounded cells. Palisade tissue two-layered, with a few large empty cells among it. Spongy parenchyma of small cells with air-spaces. Lower epidermis similar to upper, but with thinner cuticle. (See fig. 2, *c*.)

Habitat: In forest on mountains from 300 m. alt. to summit of Mount Gower; in scrub on Northern Hills.

Distribution: Endemic.

## Lepidium howei-insulae Thell.

*Lepidium howei-insulae* Thell., *Gatt. Lepid.* 291, 1906.

Recorded: Bentham, *Fl. Austr.* i, 86, 1863 (*L. foliosum*); Hemsley, *Ann. Bot.* x. 231, 1896 (*L. foliosum*); Maiden, *Proc. Linn. Soc. N.S.W.* 23, 123, 1898 (*L. foliosum*); Thellung, *l.c.*; Maiden, *Proc. Linn Soc. N.S.W.* 39, 381, 1914 (*L. foliosum*).

Habitat: Maritime meadow, talus slopes, and sand-flats; Ball's Pyramid and Admiralty Islets (Maiden).

Distribution: Endemic. Nearly allied to *L. oleraceum* of New Zealand.

## Colmeiroa carpodetoides F. Muell.

*Colmeiroa carpodetoides* F. Muell., *Fragm. Phytogr. Austr.* vii, 149, 1871.

Recorded: F. Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 236, 1896.

Habitat: In forest, upper slopes of Mount Gower.

Distribution: Endemic. Allied to *Carpodetus* of New Zealand.

### Pittosporum erioloma Moore & Muell.

*Pittosporum erioloma* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 139, 1871.

Recorded : Moore and Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 232, 1896.

Habitat : In forest from near sea-level to summit of Mount Gower. More common at the higher levels.

Distribution : Endemic. Mueller compares this species with *P. umbellatum* of New Zealand.

### Caesalpinia Bonducella (L.) Fleming.

*Guilandina Bonducella* L., *Sp. Plant.* 545, 1753.

Recorded : Moore, *Lord Howe Id. Official Visit*, 24, 1870 (*Guilandina*) ; Hemsley, *Ann. Bot.* x, 235, 1896 ; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 128, 1898.

Habitat : Coastal scrub.

Distribution : Norfolk Island, Australia, New Caledonia, tropical regions.

### Sophora tetraptera J. Mill. var. howinsula W. R. B. Oliver n. var.

*Sophora tetraptera* J. Mill., *Icon. Plant.* t. 1.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* vii, 26, 1869 (*S. tetraptera*) ; Moore, *Lord Howe Id. Official Visit*, 24, 1870 (*Edwardsia chrysophylla*) ; Hemsley, *Ann. Bot.* x, 235, 1896 (*S. tetraptera*).

Foliolae 8–9 jugae lineari-oblongae. 25–27 mm. longae, 8–10 mm. latae. Racemi 4–8-flori. Flores 35 mm. longi. Legumen inter semina profunde constrictum alis latis undulatis.

A small erect slender tree. Leaflets 8–9 pairs, linear-oblong, 25–27 mm. long, 8–10 mm. broad. Racemes 4–8-flowered. Flowers golden-yellow, 35 mm. long ; standard scarcely shorter than the wings. Pod with 5–9 seeds, wings broad and wavy, each section containing a seed being orbicular in outline.

This variety differs from the New Zealand variety *grandiflora* in its broader leaflets, much smaller flowers, and broader wings to the pods.

Habitat : A small tree in forest, Transit Hill.

Distribution of species : New Zealand, South America.

### Carmichaelia exsul F. Muell.

*Carmichaelia exsul* F. Muell., *Fragm. Phytogr. Austr.* vii, 126, 1871.

Recorded : F. Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 235, 1896 (*C. exul*).

Habitat : In forest and scrub on mountains 300 m. to 600 m. alt.

Distribution : Endemic. In addition to the present species the genus contains about nineteen others, all confined to New Zealand.

### Mucuna gigantea DC.

*Mucuna gigantea* DC., *Prodr.* ii, 405.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 ; Hemsley, *Ann. Bot.* x, 235, 1896.

Habitat : Trailing over sand-dunes in West Bay.

Distribution : Australia, New Caledonia, Polynesia, Malaya, tropical Asia.

### Canavalia obtusifolia DC.

*Canavalia obtusifolia* DC., *Prodr.* ii, 404.

Recorded : Moore, *Lord Howe Id. Official Visit*, 24, 1870 ; Hemsley, *Ann. Bot.* x, 235, 1896.

Distribution : Norfolk Island, Australia, Polynesia, tropical regions.

### Vigna lutea (Sw.) Gray.

*Dolichos luteus* Sw., *Prodr. Veg. Ind. Occ.* 105.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 ; Hemsley, *Ann. Bot.* x, 235, 1896 ; Laing, *Trans. N.Z. Inst.* 47, 27, 1915 (*V. retusa*).

Habitat : Trailing among sand-binders on exposed headlands at Ned's Beach.

Distribution : Norfolk Island, Australia, New Caledonia, tropical regions.

### Pelargonium australe Willd.

*Pelargonium australe* Wild., *Spec. Pl.* iii, 675, 1800.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 ; Hemsley, *Ann. Bot.* x, 233, 1896.

Distribution : Norfolk Island, Tasmania, Australia.

### Oxalis corniculata L.

*Oxalis corniculata* L., *Sp. Plant.* 435, 1753.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 ; Hemsley, *Ann. Bot.* x, 233, 1896.

Habitat : Rocky ridge on top of cliffs, north coast.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, temperate and tropical regions.

### Zanthoxylum pinnata (Forst.).

*Blackburnia pinnata* Forst., *Char. Gen.* 6, 1776.

Recorded : Bentham, *Fl. Austr.* i, 363, 1863 (*Z. Blackburnia*) ; F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*X. howeanum ;* described vii, 141, 1871) ; Hemsley, *Ann. Bot.* x, 233, 1896 (*Z. Blackburnia*).

Habitat : Forest.

Distribution : Norfolk Island, Vavau (Tonga Islands), New Caledonia (Laing).

### Evodia polybotrya Moore & Muell.

*Euodia polybotrya* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 143, 1871.

Recorded : Moore & Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 233, 1896.

Habitat : In forest from near sea-level to upper slopes of Mount Gower, about 600 m. alt.

Distribution : Endemic.

### Melicope contermina Moore & Muell.

*Melicope contermina* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 144, 1871.

Recorded : Moore & Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 233, 1896.

Habitat : In forest, Erskine Valley.

Distribution : Endemic. Very near the New Zealand *M. ternata* Forst.

### Acronychia Baueri Schott.

*Acronychia Baueri* Schott., *Fragm. Rut.* 5, t. 3.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875; Hemsley, *Ann. Bot.* x, 233, 1896; Maiden, *Proc. Linn. Soc.* 23, 124, 1898.

Habitat: In lowland forests, forming part of main tier of vegetation.

Distribution: Australia.

### Dysoxylum pachyphyllum Hemsley.

*Dysoxylum pachyphyllum* Hemsley, *Kew Bulletin*, 1907, 58.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 61, 1875 (*D. Fraserianum*); Hemsley, *Ann. Bot.* x, 234, 1896 (*D. Fraserianum*): Maiden, *Proc. Linn. Soc. N.S.W.* 23, 124, 1898 (*D. Fraserianum*); Hemsley, *l.c.*; Hooker, *Icon. Plant.* t. 2827, 1907; Maiden, *Proc. Linn. Soc. N.S.W.* 39, 382, 1914.

Habitat: In forest, Erskine Valley to summit of Mount Gower.

Distribution: Endemic. Related to *D. Fraserianum* of eastern Australia.

### Hemicyclia australasica Muell. Arg.

*Hemicyclia australasica* Muell. Arg. in DC., *Prodr.* xv, ii, 487.

Recorded: Moore, *Lord Howe Id. Official Visit,* 25, 1870; F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*H. sepiaria*): Hemsley, *Ann. Bot.* x, 250, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 134, 1898.

Anatomy of leaf of specimen from forest, Transit Hill: Upper epidermis of single row of thick-walled cells with thick cuticle. Palisade tissue a single row of cells about $1\frac{1}{2}$ times as long as the thickness of the epidermis, densely packed with chloroplasts. Spongy tissue of irregular cells with many air-spaces. Lower epidermis similar to upper, the cuticle equally as thick. (See fig. 1, *c.*)

Habitat: Common from sea-level to 400 m. alt. A shrub in coastal scrub and on ridge at top of sea-cliffs, Northern Hills; a large tree in forest.

Distribution: Australia.

### Baloghia lucida Endl.

*Baloghia lucida* Endl., *Prodr. Fl. Norf.* 84, 1833.

Recorded: Moore, *Lord Howe Id. Official Visit,* 25, 1870; Hemsley, *Ann. Bot.* x, 251, 1896.

Anatomy of leaf of specimen from Northern Hills: Upper epidermis with thick cuticle, one layer of cells with thick walls. Palisade tissue of two or three rows, the first of long, the second and third of shorter, cells; chloroplasts dense. Spongy tissue occupies about two-thirds of the mesophyll; small cells with a few air-spaces. Lower epidermis similar to upper. Vascular bundles with large sheath of sclerenchymatous tissue, little wider than the bundle above it, but much wider below it. (See fig. 2, *b.*)

Habitat: A shrub in lowland forest, in coastal scrub, and scrub on ridge at top of cliffs, north coast.

Distribution: Norfolk Island, Australia, New Caledonia.

### Homolanthus populifolius Graham.

*Homolanthus populifolius* Graham in Jameson's *Edinb. New Philos. Journ. Sci.* 115, 1827.

Recorded: Moore, *Lord Howe Id. Official Visit,* 25, 1870; F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*Carumbium*); Tate, *Macleay Mem. Vol.* 219, 1893 (*H. Leschenaultianus*); Hemsley, *Ann. Bot.* x, 251, 1896 (*H. Leschenaultianus*).

Habitat: In forest from sea-level to 300 m. alt. A small tree, not reaching main upper-foliage tier. Fairly abundant.

Distribution: Norfolk Island, Australia.

### Euphorbia Sparmanni Boiss.

*Euphorbia Sparmanni* Boiss, *Cent. Euph.* 5, 1860.

Recorded: Bentham, *Fl. Austr.* vi, 46, 1873; Hemsley, *Ann. Bot.* x, 250, 1896.

Habitat: Near the beach (Mueller).

Distribution: Norfolk Island, Australia, Polynesia.

### Elaeodendron curtipendulum Endl.

*Elaeodendron curtipendulum* Endl., *Prodr. Fl. Norf.* 81, 1833.

Recorded: Moore, *Lord Howe Id. Official Visit,* 25, 1870 (*E. australe*); F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*E. australe* var. *melanocarpa*); Moore & Betche, *Handb. Fl. N.S.W.* 518, 1893; Hemsley, *Ann. Bot.* x, 234, 1896 (*E. melanocarpum*); Maiden, *Proc. Linn. Soc. N.S.W.* 23, 125, 1898.

Habitat: In lowland forest.

Distribution: Norfolk Island.

### Guioa coriacea Radlk.

*Atalaya coriacea* Radlkoper *Sitz. Kon. Akad.* p. 326, 1878.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*Cupania anacardioides*); Radlkoper, *l.c.*: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 126, 1898 (*Cupania Howeana*); *id.*, 26, 156, 1901 (synonymy); Hemsley, *Ann. Bot.* x, 234, 1896 (*Atalaya*).

Habitat: Large forest-tree forming part of upper tier of vegetation, Erskine Valley, Transit Hill.

Distribution: Endemic. Nearest allied to *Cupania semiglauca* of Australia (Maiden).

### Dodonaea viscosa Jacq.

*Dodonaea viscosa* Jacq., *Enum. Pl. Carib.* 19, 1760.

Recorded: Moore, *Lord Howe Id. Official Visit,* 24, 1870; F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*D. lanceolata*); Hemsley, *Ann. Bot.* x, 234, 1896 (*D. lanceolata*).

Habitat: In scrub on rocky ridges and exposed outskirts of forest, up to 300 m. alt.

Distribution: Norfolk Island, New Zealand, Tasmania. Australia, New Caledonia, tropical and subtropical regions.

### Lagunaria Patersoni (Andrews) Don.

*Hibiscus Patersonius* Andrews, *Bot. Reposit.* t. 286.

Recorded: Moore, *Lord Howe Id. Official Visit*, 24, 1870 (*Hibiscus*); Hemsley, *Ann. Bot.* x, 232, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 124, 1898.

Anatomy of leaf of specimen from coastal scrub, Ned's Beach: Upper epidermis of single row of cells with thin cuticle. Hypoderm of three rows of large empty cells, the first and second longest in the direction of the lamina, the third longest in a direction transverse to the surface. Palisade tissue of three rows of cells with numerous chloroplasts, in centre of mesophyll. Spongy tissue of irregular cells with few air-spaces. Lower epidermis similar to upper. Lower surface of leaf with covering of stellate hairs.

Habitat: Large tree in forest from sea-level to about 200 m. alt. Small shrub on coastal rocks, and in scrub on exposed ridge on Northern Hills.

Distribution: Norfolk Island, Queensland.

### Hibiscus diversifolius Jacq.

*Hibiscus diversifolius* Jacq., *Ic. Plant. Rar.* t. 551.

Recorded: Moore, *Lord Howe Id. Official Visit*, 24, 1870; Hemsley, *Ann. Bot.* x, 232, 1896.

Distribution: Norfolk Island, New Zealand, Australia, New Caledonia, Pacific islands, South Africa, Madagascar.

### Hibiscus tiliaceus L.

*Hibiscus tiliaceus* L., *Sp. Plant.* 694, 1753.

Recorded: Moore, *Lord Howe Id. Official Visit*, 24, 1870; Hemsley, *Ann. Bot.* x, 232, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 123, 1898.

Habitat: Valley at north end of island (Duff); Middle Beach Road, swamp on King's property (Maiden).

Distribution: Norfolk Island, Australia, New Caledonia, Pacific islands, tropics.

### Hymenanthera novae-zelandiae (A. Cunn.) Hemsl.

*Scaevola ? novae-zelandiae* A. Cunn., *Ann. Nat. Hist.*, ii, 52, 1839.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*H. latifolia*); Hemsley, *Ann. Bot.* x, 231, 1896 (*H. latifolia*); Hemsley, *Kew Bull.* 1908, 96; Maiden, *Proc. Linn. Soc. N.S.W.* 39, 381, 1914.

Habitat: In forest near sea-coast.

Distribution: New Zealand.

### Xylosma ovatum Bentham.

*Xylosma ovatum* Bentham, *Fl. Austr.* i, 108, 1863.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 60, 1875; Hemsley, *Ann. Bot.* x, 231, 1896.

Habitat: In forest. My specimens are not typical, and may represent a distinct species.

Distribution: Australia.

### Passiflora Herbertiana Lindl.

*Passiflora Herbertiana* (Ker Gawl.) in *Bot. Reg.* t. 737.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875; Hemsley, *Ann. Bot.* x, 237, 1896.

Distribution: Australia.

### Pimelea congesta Moore & Muell.

*Pimelea congesta* Moore & Muell., *Fragm. Phytogr. Austr.* viii, 9, 1872.

Recorded: Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*P. prostrata*); Moore & Muell., *l.c.*; Bentham, *Fl. Austr.* vi, 7, 1873 (*P. longifolia*); Hemsley, *Ann. Bot.* x, 250, 1896 (*P. longifolia*).

Habitat: In rocky places in scrub on ridges, Northern Hills; Mount Gower, 400 m. to 600 m. alt.

Distribution: Endemic. This species belongs to the section *Eupimelea*, which includes the whole of the New Zealand species and three or four from Australia.

### Acicalyptus Fullagari F. Muell.

*Acicalyptus Fullagari* F. Muell., *Fragm. Phytogr. Austr.* viii, 15, 1873.

Recorded: F. Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 236, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 129, 1898.

A large forest-tree with sinuous plank buttresses 2 m. above the ground, and rough reddish-grey bark, 7 mm. to 9 mm. thick, which falls off in flakes.

Anatomy of leaf from specimen from forest, Transit Hill: Thick cuticle on upper surface. Upper epidermis of small cells, in length a little more than the thickness of the cuticle. Palisade parenchyma of four rows of cells: the upper row of rectangular cells about as deep as the epidermis and cuticle together; the following three rows of long narrow cells. Spongy tissue of seven or eight rows of rectangular cells, the rows clearly defined especially near the lower surface. Lower epidermis and cuticle similar to that on upper surface. (See fig. 1, *a*.)

Habitat: Abundant everywhere in forest from near sea-level to 500 m. alt. Forms an upper tier of vegetation, equal to *Ficus*, above the palms.

Distribution: Endemic. Four other species of *Acicalyptus* are known, three in Fiji and one in New Caledonia.

### Metrosideros nervulosa Moore & Muell.

*Metrosideros nervulosa* Moore & Muell., *Fragm. Phytogr. Austr.* viii, 15, 1873.

Recorded: Moore & Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 236, 1896.

Anatomy of leaf: Moderately thick cuticle on upper surface. Upper epidermis of single row of cells about the same thickness as the cuticle. Hypoderm of two rows of large oblong cells, some of which are empty. Palisade parenchyma of three or four rows of narrow cells. Spongy parenchyma of small irregular cells with air-spaces. Lower epidermis and cuticle similar to upper.

The chief features of the leaf as seen in cross-section are the vascular bundles and accompanying sclerenchyma, which occupy about half the view. They are long-oval in section, and extend nearly across the lamina, there being only two or three rows of cells between each end and the epidermis. The lower half is narrower than the upper, and contains the vascular bundle. The sclerenchyma cells are clear, pentagonal, with a small central lumina. (See fig. 1, *b*.)

Habitat: In forest from 150 m. alt. to summit of Mount Gower, chiefly above 300 m.

Distribution: Endemic.

### Metrosideros villosa Sm.

*Metrosideros villosa* Sm., *Trans. Linn. Soc.* iii, 268, 1797.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* viii, 14, 1873 (*M. polymorpha*); Hemsley, *Ann. Bot.* x, 236, 1896 (*M. polymorpha*); Gibbs, *Jour. Linn. Soc. Bot.* 39, 146, 1909.

Habitat: In the higher valleys (Mueller).

Distribution: Kermadecs, New Caledonia, Polynesia.

### Leptospermum flavescens Sm.

*Leptospermum flavescens* Sm., *Trans. Linn. Soc.* iii, 262, 1797.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875; Hemsley, *Ann. Bot.* x, 236, 1896.

Habitat: In moss forest on summit of Mount Gower, forming a large portion of the main tier of vegetation.

Distribution: Tasmania, Australia, Malaya.

### Melaleuca ericifolia Sm.

*Melaleuca ericifolia* Sm., *Trans Linn. Soc.* iii, 276, 1797.

Recorded: Bentham, *Fl. Austr.* iii, 159, 1866; Hemsley, *Ann. Bot.* x, 236, 1896: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 129, 1898.

Habitat: A prostrate shrub on coastal rocks and cliffs in exposed places; in wind-swept gap in Northern Hills.

Distribution: Tasmania, Australia.

### Nothopanax cissodendron (Moore & Muell.) W. R. B. Oliver comb. nov.

*Panax cissodendron* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 96, 1870.

Recorded: Moore & Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 238, 1896 (*Panax*).

Habitat: In forest.

Distribution: Endemic. Allied to *Panax Murrayi* F. Muell. of New South Wales (Hemsley).

### Hydrocotyle hirta R. Br.

*Hydrocotyle hirta* R. Br. ex A. Rich, *Ann. Sci. Phys.* vi, 204, 1820.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875; Hemsley, *Ann. Bot.* x, 238, 1896.

Habitat: Scrambling over the ground in fores from sea-level to summit of Mount Gower; plentiful.

Distribution: Tasmania, Australia.

### Apium prostratum (DC.) Thou.

*Petroselinum prostratum* DC., *Prodr.* iv, 102.

Recorded : Bentham, *Fl. Austr.* iii, 372, 1866 (*A. australe*) ; F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 ; Hemsley, *Ann. Bot.* x, 238, 1896 ; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 129, 1898.

Habitat : Coastal rocks and meadow (narrow-leaved form), and as undergrowth in lowland forest.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, antarctic America, South Africa.

### Dracophyllum Fitzgeraldi Moore & Muell.

*Dracophyllum Fitzgeraldi* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 27, 1869.

Recorded : Moore & Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 241, 1896 ; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 120, 1898.

A large spreading tree with leaves in clusters at the ends of the twigs forming a canopy of foliage. Bark reddish-brown, very rough, splitting longitudinally, giving it a peculiar stringy appearance.

Anatomy of leaf of specimen from Erskine Valley : Upper epidermis with cuticle, cells large, one layer, slightly deeper than wide. Hypoderm of two layers of sclerenchymatous cells ; cells about twice as long as broad in cross-section. Palisade tissue of three layers of cells. Spongy tissue of small cells. Lower epidermis of single row of cells, smaller than those of upper epidermis, cuticularized. Vascular bundles surrounded by sclerenchymatous tissue of small pentagonal cells, the sclerenchyma extending as a tissue two to three cells thick to meet the hypoderm. The sclerenchymatous tissue extends to the lower epidermis, or a layer of spongy tissue cells may intervene. (See fig. 3, *b*.)

Habitat : Plentiful in forest on the mountains from 200 m. alt. to summit of Mount Gower. In Erskine Valley it occurs as a large forest-tree, forming with *Acicalyptus* part of the upper tier of vegetation, but is more plentiful in the main tier. On the summit of Mount Gower it occurs singly and in clumps, is very conspicuous, and forms a considerable portion of the vegetation.

Distribution : Endemic. Allied to *D. latifolium* of New Zealand.

### Leucopogon Richei (Lab.) R. Br.

*Styphelia Richei* Lab., *Nov. Holl. Pl. Sp.* i, 44, t. 60, 1806.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*Styphelia*) ; Tate, *Macleay Mem. Vol.* 218, 1893 ; Hemsley, *Ann. Bot.* x, 241, 1896.

Distribution : New Zealand, Tasmania, Australia.

### Aegiceras corniculatum (L.) Blanco.

*Rhizophora corniculatum* L., *Amoen. Akad.* iv, 123, 1760.

Recorded : Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*A. fragrans*) ; F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*A. majus*) ; Hemsley, *Ann. Bot.* x, 242, 1896 (*A. majus*).

Habitat : Near the mouth of Deep Creek.

Distribution : Australia, Malaya, Indian and Pacific Oceans.

### Rapanea myrtillina Mez.

*Rapanea myrtillina* Mez., *Pflanzenreich*, Heft 9, 370, 1902.

Recorded: Mez., *l.c.*; Maiden, *Proc. Linn. Soc. N.S.W.* 27, 349, 1902.
Distribution: Endemic.

### Rapanea platystigma (F. Muell.) Mez.

*Myrsine platystigma* F. Muell., *Fragm. Phytogr. Austr.* viii, 48, 1873.

Recorded: F. Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 242, 1896 (*Myrsine*); Mez., *Pflanzenreich*, Heft 9, 370, 1902; Maiden, *Proc. Linn. Soc. N.S.W.* 27, 349, 1902.

Anatomy of leaf of specimen from scrub on Northern Hills: Upper epidermis of single row of large cells of irregular size, cuticularized. Palisade tissue of one or two rows of cells filled with chloroplasts. Spongy tissue of six or seven rows of small rounded cells. Lower epidermis similar to upper. (See fig. 3, *c*.)

Habitat: In forest from sea-level to upper slopes of Mount Gower, 700 m. alt.; in scrub on ridge at top of sea-cliffs, Northern Hills.

Distribution: Endemic.

### Sideroxylon Howeanum (F. Muell.) Moore & Betche.

*Achras Howeana* F. Muell., *Fragm. Phytogr. Austr.* ix, 72, 1875.

Recorded: Bentham, *Fl. Austr.* iv, 282, 1869 (*A. australis*); Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*A. costata*); F. Muell., *l.c.*; Moore & Betche, *Handb. Fl. N.S.W.* 520, 1893; Hemsley, *Ann. Bot.* x, 242, 1896.

Habitat: In lowland forest; on banks of Deep Creek near the sea.

Distribution: Endemic. Apparently related to *S. novae-zealandiae* of New Zealand.

### Symplocos candelabrum Brand.

*Symplocos candelabrum* Brand, *Pflanzenreich*, Heft 9, 39, 1901.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*S. Stawelli*); Hemsley, *Ann. Bot.* x, 242, 1896 (*S. Stawelli*); Brand, *l.c.*; Maiden, *Proc. Linn. Soc. N.S.W.* 27, 348, 1902.

Distribution: Endemic. Allied to *S. aneityensis* Brand from New Hebrides.

### Notelaea quadristaminea (F. Muell.) Hemsl.

*Chionanthus quadristaminea* F. Muell., *Fragm. Phytogr. Austr.* viii, 41, 1873.

Recorded: F. Muell., *l.c.*; *id.*, x, 89, 1876 (*Mayepa*); Hemsley, *Ann. Bot.* x, 243, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 130, 1898 (blue plum).

Anatomy of leaf of specimen from scrub on Northern Hills: Upper epidermis of single row of small rectangular cells with thin cuticle. Hypoderm of single row of small cells similar to epidermal cells, with no chloroplasts. Palisade tissue of single row of long narrow cells reaching almost to centre of leaf. Spongy tissue of six to eight rows of small irregular rounded cells. Lower epidermis similar to upper, but with thinner cuticle.

Habitat: In forest on the mountains from 200 m. to 600 m. alt. A large tree, forming part of the main tier of vegetation.

Distribution: Endemic.

### Olea paniculata R. Br.

*Olea paniculata* R. Br., *Prodr. Fl. Nov. Holl.* 523, 1810.

Recorded: Moore, *Lord Howe Id. Official Visit,* 25, 1870; Hemsley, *Ann. Bot.* x, 243, 1896.

Habitat: In forest from near sea-level to above 350 m. alt.: plentiful.

Distribution: Australia, New Caledonia.

### Jasminum didymum Forst. f.

*Jasminum didymum* Forst. f., *Fl. Austr. Prodr.* 3, 1786.

Recorded: Moore, *Lord Howe Id. Official Visit,* 25, 1870; Hemsley, *Ann. Bot.* x, 242, 1896.

Distribution: Australia, New Caledonia, Pacific islands, Malaya.

### Jasminum simplicifolium Forst. f.

*Jasminum simplicifolium* Forst. f., *Fl. Austr. Prodr.* 3, 1786.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix. 77. 1875; Hemsley, *Ann. Bot.* x, 243, 1896.

Habitat: Scandent in forest from sea-level to 150 m. alt. Small divaricating shrub in scrub on ridge at top of sea-cliffs, north coast.

Distribution: Norfolk Island, Australia, New Caledonia, Pacific islands.

### Geniostoma petiolosum Moore & Muell.

*Geniostoma petiolosum* Moore & Muell., *Fragm. Phytogr. Austr.* vii. 28, 1869.

Recorded: Moore & Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 244, 1896.

Habitat: Common in forest from sea-level to 300 m. alt. A small tree.

Distribution: Endemic. According to Mueller, allied to *G. australiana* of Queensland.

### Alyxia Lindii F. Muell.

*Alyxia Lindii* F. Muell., *Fragm. Phytogr. Austr.* viii, 46, 1873.

Recorded: F. Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 243, 1896.

Habitat: Moss forest at summit of Mount Gower.

Distribution: Endemic. Mueller compares this species with *A. bracteolata* A. Rich., from Fiji, Tonga, and Samoa.

### Alyxia ruscifolia R. Br.

*Alyxia ruscifolia* R. Br., *Prodr. Fl. Nov. Holl.* 470, 1810.

Recorded: Bentham, *Fl. Austr.* iv, 308. 1869; Moore, *Lord Howe Id. Official Visit,* 25. 1870 (*A. gymnopogon*); Hemsley, *Ann. Bot.* x, 243. 1896.

Habitat: Small shrub in forests near the sea: in scrub on ridge at top of sea-cliffs, north coast.

Distribution: Australia.

### Alyxia squamulosa Moore & Muell.

*Alyxia squamulosa* Moore & Muell., *Fragm. Phytogr. Austr.* viii, 47. 1873.

Recorded: Moore & Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 243, 1896.

Habitat: In scrub on summit and on ridge near summit of Mount Gower.

Distribution: Endemic. Allied to *A. stellata* R. Br., from Fiji, Tonga, and New Caledonia.

### Ochrosia elliptica Lab.

*Ochrosia elliptica* Lab., *Sert. Austr.-Caled.* 25, t. 30. 1825.

Recorded : Moore, *Lord Howe Id. Official Visit*, 25, 1870 ; Hemsley, *Ann. Bot.* x, 243, 1896.

Anatomy of leaf of specimen from coastal scrub, Ned's Beach : Upper epidermis of single row of square cells, with thin cuticle. Hypoderm of single row of large empty cells. Palisade parenchyma of three rows of small elongated cells. Spongy parenchyma of small irregular cells with air-spaces. Lower epidermis of single row of cells with thickened outer walls.

Habitat : In coastal scrub and forest ; abundant.

Distribution : Australia, New Caledonia, Pacific islands.

### Lyonsia reticulata F. Muell.

*Lyonsia reticulata* F. Muell., *Rep. Budek. Exped.* 16.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix. 77. 1875 ; Hemsley, *Ann. Bot.* x, 244, 1896.

Habitat : A woody climber in scrub and forest from the sea-coast to the upper slopes of Mount Gower, 550 m. alt. : trailing over coastal meadow on exposed point, Ned's Beach.

Distribution : Australia.

### Vincetoxicum carnosum (R. Br.) Benth.

*Oxystelma carnosum* R. Br., *Prodr. Fl. Nov. Holl.* 462, 1810.

Recorded : Hemsley, *Ann. Bot.* x, 244, 1896.

Habitat : Trailing over sand-dunes in West Bay.

Distribution : Australia.

### Tylophora biglandulosa (Endl.) A. Gray.

*Hybanthera biglandulosa* Endl., *Prodr. Fl. Norf.* 59, 1833.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix. 70. 1875 (*T. enervis*) : Hemsley, *Ann. Bot.* x. 244. 1896 (*T. enervis*) ; Maiden, *Proc. Linn. Soc. N.S.W.* 28, 710, 1904.

Habitat : Scandent in lowland forest.

Distribution : Norfolk Island.

### Marsdenia rostrata R. Br.

*Marsdenia rostrata* R. Br., *Prodr. Fl. Nov. Holl.* 461, 1810.

Recorded : Bentham, *Fl. Austr.* iv. 339. 1869 : F. Muell., *Fragm. Phytogr. Austr.* ix. 71. 1875 (*M. tubulosa*) ; Hemsley, *Ann. Bot.* x, 244. 1896.

Habitat : Liane in lowland forest, reaching to the tops of the highest trees.

Distribution : Australia.

### Calystegia Soldanella (L.) R. Br.

*Convolvulus Soldanella* L., *Sp. Plant.* 226, 1753.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*Convolvulus sepium* var. *Soldanella*) ; Hemsley, *Ann. Bot.* x, 246, 1896.

Habitat : Sand-dunes.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, temperate and subtropical regions.

### Calystegia marginata R. Br.

*Calystegia marginata* R. Br., *Prodr. Fl. Nov. Holl.* 483, 1810.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 (*Convolvulus*) ; Hemsley, *Ann. Bot.* x, 246, 1896.

Distribution : Norfolk Island, New Zealand, Australia.

### Ipomoea pes-caprae (L.) Roth.

*Convolvulus pes-caprae* L., *Sp. Plant.* 226, 1753.

Recorded : Moore, *Lord Howe Id. Official Visit*, 25, 1870 ; Hemsley, *Ann. Bot.* x, 245, 1896 (*I. biloba*).

Habitat : Sand-dunes and maritime meadow.

Distribution : Norfolk Island, Kermadecs, Australia, New Caledonia, tropical sea-coasts.

### Ipomoea grandiflora Lam.

*Ipomoea grandiflora* Lam., *Tabl. Encyc.* i, 467, 1791.

Recorded : Hemsley, *Ann. Bot.* x, 245, 1896.

Distribution : Norfolk Island (*I. bona-nox*), Australia, New Caledonia, tropical East Africa, Asia, and Polynesia.

### Ipomoea palmata Forsk.

*Ipomoea palmata* Forsk., *Fl. Aegypt-Arab.* 43, 1775.

Recorded : Bentham, *Fl. Austr.* iv, 415, 1869 ; Hemsley, *Ann. Bot.* x, 245, 1896.

Habitat : Near the coast on meadow and *Mariscus*.

Distribution : Norfolk Island, Kermadecs, New Zealand, Australia, New Caledonia, tropical regions.

### Avicennia officinalis L.

*Avicennia officinalis* L., *Sp. Plant.* 110, 1753.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 ; Hemsley, *Ann. Bot.* x, 247, 1896.

Habitat : A few plants on shingle beach between tide-marks at north end of lagoon in West Bay.

Distribution : New Zealand, Australia, tropical regions (rare in Polynesia).

### Westringia rosmariniformis Sm.

*Westringia rosmariniformis* Sm. in *Vet. Acad. Handl. Stockh.* 171, 1797.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875 ; Hemsley, *Ann. Bot.* x, 247, 1896.

Distribution : Australia.

### Plectranthus parviflorus Willd.

*Plectranthus parviflorus* Willd., *Hort. Berol.* t. 65, 1816.

Recorded : Maiden, *Proc. Linn. Soc. N.S.W.* 23, 132, 1898.

Distribution : Australia, New Caledonia, Pacific islands.

### Solanum aviculare Forst. f.

*Solanum aviculare* Forst. f., *Fl. Austr. Prodr.* 18, 1786.

Recorded: Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*S. laciniatum*); F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875; Hemsley, *Ann. Bot.* x, 245, 1896.

Habitat: Undergrowth in forest from sea-level to summit of Mount Gower; a few plants only seen.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia.

### Solanum nigrum L.

*Solanum nigrum* L., *Sp. Plant.* 186, 1753.

Recorded: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 150, 1898 (as introduced).

Habitat: Lowlands in waste places: in forest clearing at summit of Mount Gower.

Distribution: Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia: cosmopolitan.

### Solanum Bauerianum Endl.

*Solanum Bauerianum* Endl., *Prodr. Fl. Norf.* 54, 1833.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix. 74. 1875; Hemsley, *Ann. Bot.* x. 245, 1896.

Distribution: Norfolk Island.

### Tecoma austro-caledonica Burm.

*Tecoma austro-caledonica* Burm., *Bull. Soc. Bot. Fr.* ix, 163, 1862.

Recorded: Bentham, *Fl. Austr.* iv, 537, 1869 (*T. australis*); Hemsley, *Ann. Bot.* x, 246, 1896; Maiden, *Proc. Linn. Soc. N.S.W.* 39, 382, 1914.

Habitat: Scrambling in lowland forest; summit of Mount Gower (Maiden).

Distribution: New Caledonia.

### Negria rhabdothamnoides F. Muell.

*Negria rhabdothamnoides* F. Muell., *Fragm. Phytogr. Austr.* vii, 152, 1871.

Recorded: F. Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 246, 1896.

A small widely branching tree. The foliage consists of clusters of rosettes of large leaves, which with the flowers, three to a pedicel, are borne at the ends of the branches. Bark very soft, rough with large lenticels, light grey, yellow within, 5 mm. thick.

Anatomy of leaf of specimen from moss forest on summit of Mount Gower: Upper epidermis of single row of shallow cells of various sizes. Outer wall scarcely or not thicker than the others. Hypoderm of three or four rows of large empty cells. Palisade tissue of three rows of rather short cells in centre of mesophyll. Spongy tissue of about ten rows of small cells. Scattered simple hairs on under-surface of leaf. (See fig. 3, *a*.)

Habitat: In forest from 150 m. alt. to summit of Mount Gower; at the lower altitudes most abundant near running water.

Distribution: Endemic. Allied to *Rhabdothamnus* monotypic in New Zealand.

### Eranthemum variabile R. Br. var. grandiflorum Benth.

*Eranthemum variabile* R. Br., *Prodr. Fl. Nov. Holl.* 477, 1810.
*E. variabile* var. ? *grandiflorum* Bentham, *Fl. Austr.* iv, 555, 1869.

Recorded: Bentham, *l.c.*; Hemsley, *Ann. Bot.* x, 247, 1896.

Distribution: Australia, New Caledonia.

### Myoporum insulare R. Br.

*Myoporum insulare* R. Br., *Prodr. Fl. Nov. Holl.* 516, 1810.

Recorded: Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*M. acuminatum*): F. Muell., *Fragm. Phytogr. Austr.* vii, 110, 1870; Hemsley, *Ann. Bot.* x, 247, 1896.

Habitat: Near the coast in forest and scrub, and on sand-flat in West Bay.

Distribution: Australia.

### Plantago Hedleyi Maiden.

*Plantago Hedleyi* Maiden, *Proc. Linn. Soc. N.S.W.* 39, 379, 1914.

Recorded: Maiden, *l.c.*

Habitat: Damp rocky places in forest: upper slopes and summit of Mount Gower above 450 m. alt.

Distribution: Endemic. Nearest to *P. aucklandica* Hook. f. of New Zealand.

### Randia stipulosa Moore & Muell.

*Randia stipulosa* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 47, 1869.

Recorded: Moore & Muell., *l.c.*; Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*R. macrophylla*); Moore & Betche, *Handb. Fl. N.S.W.* 519, 1893 (*R. stipularis*); Hemsley, *Ann. Bot.* x, 238, 1896.

Anatomy of leaf of specimen from forest on Transit Hill: Upper and lower epidermis with thin cuticle. Mesophyll little differentiated. Chloroplasts most dense in upper portion, three or four rows of the cells here being elongated in direction transverse to the surface and thus representing palisade tissue. The lower half of the mesophyll has a more open appearance owing to the presence of air-spaces and to there being fewer chloroplasts. Cells rounded, small, about ten rows.

Habitat: A small tree in forest from near sea-level to summit of Mount Gower.

Distribution: Endemic. Closely allied to *R. Fitzalani* F. Muell. of Queensland.

### Psychotria Carronis Moore & Muell.

*Psychotria Carronis* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 49, 1869.

Recorded: Moore & Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 239, 1896.

Habitat: In forest forming part of the main tier of vegetation from sea-level to 200 m. alt.

Distribution: Endemic.

### Coprosma prisca W. R. B. Oliver n. sp.

Recorded: F. Muell., *Fragm. Phytogr. Austr.* ix, 69, 1875 (*C. Baueri*); Hemsley, *Ann. Bot.* x, 239, 1896 (*C. Baueri*).

Frutex vel parva arbor. Foliae angusto-oblongae, obtusae vel subacutae, basibus cuneatis, marginibus reflexis, petiolis brevibus tenuibus, 50–60 mm. longae, 17–25 mm. latae. Flores masculi in capitulis 8–12-floris, calyce minutae 4-dentato, corolla 3 mm. longa 4-lobata. Flores feminei in fasciculis bifloris, limbo calycis obscure 4-dentato, corolla profunde 4-lobata. Drupa ovata, 7 mm. longa.

A shrub 1–2 m. tall, or more rarely a small tree 8 m. tall. Leaves almost fleshy, narrow-oblong, obtuse or subacute, base cuneate, margin recurved, veins conspicuous on the lower surface, petiole short, slender; length (including petiole) 50–60 mm., breadth 17–25 mm. Male flowers in 8–12-flowered heads on axillary peduncles. Calyx minute, 4-lobed. Corolla 3 mm. long, 4-lobed. Female flowers in 2-flowered axiliary fascicles, calyx-limb obscurely 4-toothed, corolla deeply 4-lobed, the lobes longer than the tube. Drupe ovoid, 7 mm. long.

Anatomy of leaf of specimen from coastal scrub, Ned's Beach: Upper epidermis of single row of cells longer than deep, with thickened outer walls. Hypoderm of two rows of large cells with few or no chloroplasts, the first row of rectangular cells, the second of cells elongated in direction to surface of leaf. Palisade tissue of two or three rows of cells in the centre of the leaf. Spongy tissue of small irregular cells with air-spaces. Lower epidermis of single layer of cells longer than deep, with thickened outer walls and a few small hairs.

Habitat: Near the coast in scrub, forest, and on sand-flat (West Bay), and ridge on top of sea-cliffs, north coast.

Distribution: Endemic. The coastal coprosmas inhabitating New Zealand, Chatham, Lord Howe, Norfolk, and the Kermadec Islands form a group of five closely allied species, one confined to each of the places named. The Chatham Island form (*C. chathamica* Cockayne), with rather acute leaves and short petioles, is the most distinct. That from Lord Howe Island approaches it, but has narrower leaves. The Kermadec species (*C. petiolata* Hook. f.) has subacute leaves with slender petioles, and closely approaches the New Zealand species (*C. retusa* Hook. f.), which has broad obtuse leaves with short stout petioles. Finally, the Norfolk Island plant (*C. Baueri* Endl.) has retuse leaves with slender petioles.

In separating the New Zealand form as a species distinct from the Norfolk Island plant I have been obliged to restore Hooker's name *retusa* (*Lond. Journ. Bot.*, vol. 3, p. 415, 1844) for the former, and to restrict Endlicher's familiar name *Baueri* to the latter. This change invalidates Petrie's name *C. retusa* (*Trans. N.Z. Inst.*, vol. 26, p. 268, 1894) for which I now propose to substitute *C. crenulata*.

### Coprosma lanceolaris F. Muell.

*Coprosma lanceolaris* F. Muell., *Fragm. Phytogr. Austr.* ix, 70, 1875.

Recorded: F. Muell., *l.c.*; Hemsley, *Ann. Bot.* x, 239, 1896.

Habitat: Scrub at base of Mount Gower, and in moss forest on summit.

Distribution: Endemic. Very similar to *C. foetidissima* Forst. of New Zealand.

### Coprosma putida Moore & Muell.

*Coprosma putida* Moore & Muell., *Fragm. Phytogr. Austr.* vii, 45, 1869.

Recorded : Moore & Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 239, 1896 ; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 129, 1898.

Anatomy of leaf : Cells of upper epidermis with thick outer walls. Hypoderm of two or three rows of large cells. Palisade parenchyma of two rows of small elongated cells. Spongy parenchyma of about seven rows of small cells, increasing in size towards the lower epidermis. Cells of lower epidermis with thickened outer walls. (See fig. 2, *a*.)

Habitat : Small tree in forest from sea-level to summit of Mount Gower.

Distribution : Endemic. Mueller compares this with *C. grandifolia* from New Zealand.

### Sicyos australis Endl.

*Sicyos australis* Endl., *Prodr. Fl. Norf.* 67, 1833.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 (*S. angulata*); Hemsley, *Ann. Bot.* x, 237, 1896 (*S. angulata*).

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, Pacific islands.

### Wahlenbergia gracilis (Forst. f.) Schrad.

*Campanula gracilis* Forst. f., *Fl. Austr. Prodr.* 15, 1786.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 ; Hemsley, *Ann. Bot.* x, 241, 1896.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, New Caledonia, Tonga, Malaya, tropical Asia, South Africa.

### Lobelia anceps L. f.

*Lobelia anceps* L. f., *Suppl.* 395, 1781.

Recorded : Bentham, *Fl. Austr.* iv, 128, 1869 ; Hemsley, *Ann. Bot.* x, 241, 1896.

Habitat : Coastal rocks and cliffs.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, South Africa, extra-tropical South America.

### Scaevola frutescens (Mill.) Krauss.

*Lobelia frutescens* Mill., *Gard. Dict.* ed. viii, n. 1, 1768.

Recorded : Moore, *Lord Howe Id. Official Visit*, 25, 1870 (*S. Koenigii*) ; Hemsley, *Ann. Bot.* x, 240, 1896 (S. *Koenigii*).

Distribution : Australia, Polynesia, tropical Asia.

### Brachycome segmentosa Moore & Muell.

*Brachycome segmentosa* Moore & Muell., *Fragm. Phytogr. Austr.* viii, 144, 1874.

Recorded : Moore & Muell., *l.c.* ; F. Muell., *id.* ix, 77, 1875 (*B. diversifolia*) ; Hemsley, *Ann. Bot.* x, 239, 1896.

Habitat : In damp rocky places on ground and on cliffs in scrub and forest from sea-level to summit of Mount Gower.

Distribution : Endemic. Allied to *B. multifidum* of Australia.

### Olearia Balli (F. Muell.) Hemsl.

*Aster Balli* F. Muell., *Fragm. Phytogr. Austr.* viii, 143, 1874.

Recorded : F. Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 239, 1896.

Habitat : In scrub on north ridge of Mount Gower above 400 m. alt., and in undergrowth in moss forest on summit of Mount Gower.

Distribution : Endemic.

### Olearia Mooneyi (F. Muell.) Hemsl.

*Aster Mooneyi* F. Muell., *Fragm. Phytogr. Austr.* viii, 144, 1874.

Recorded : F. Muell., *l.c.* ; Hemsley, *Ann. Bot.* x, 239, 1896.

Anatomy of leaf of specimen from moss forest on summit of Mount Gower : Upper epidermis of single row of very small cells with cuticle. Hypoderm of three rows of large empty cells. Palisade tissue of two rows of cells in centre of mesophyll. Under-surface of leaf thickly covered with simple hairs.

Habitat : Small tree in moss forest, summit of Mount Gower.

Distribution : Endemic.

### Gnaphalium japonicum Thunb.

*Gnaphalium japonicum* Thunb., *Fl. Jap.* 311, 1784.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 ; Hemsley. *Ann. Bot.* x, 240, 1896.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania. Australia, Malaya, China, Japan.

### Gnaphalium luteo-album L.

*Gnaphalium luteo-album* L., *Sp. Plant.* 851, 1753.

Recorded : Bentham, *Fl. Austr.* iii, 653, 1866 ; Hemsley, *Ann. Bot.* x, 240, 1896.

Habitat : Open rocky ridge on top of sea-cliffs, north coast.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, New Caledonia ; cosmopolitan (except colder regions).

### Cassinia tenuifolia Bentham.

*Cassinia tenuifolia* Bentham, *Fl. Austr.* iii, 585, 1866.

Recorded : Bentham, *l.c.* ; Hemsley, *Ann. Bot.* x, 240, 1896.

Habitat : Sea-level to summit of Mount Gower, mainly in coastal scrub. A few plants in forest undergrowth on Northern Hills, and elsewhere in exposed places.

Distribution : Endemic. Bentham says this may be a state of *C. laevis* of east Australia, but the inflorescence is different.

### Wedelia uniflora (Spreng.) Oliver W. R. B. comb. nov.

*Buphthalmum uniflorum* Spreng. *Syst.* iii, 605.

Recorded : Bentham, *Fl. Austr.* iii, 539, 1866 (*W. biflora*) ; Hemsley, *Ann. Bot.* x, 240, 1896 (*W. biflora*).

Habitat : Coastal rocks, sand-dunes, and sand-flat.

Distribution : Norfolk Island, Australia, New Caledonia, Pacific islands, tropics of East Africa and Asia.

### Bidens pilosa L.

*Bidens pilosa* L., *Sp. Plant.* 832, 1753.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875.

Habitat : Open places on rocky ridge on top of sea-cliffs, north coast. Maiden states that this species was brought with potatoes by whalers from Sunday Island (*Proc. Linn. Soc. N.S.W.* 23, 150, 1898).

Distribution : Norfolk Island, Kermadecs, New Zealand, Australia, New Caledonia, tropical regions.

### Cotula australis (Sieb.) Hook. f.

*Anacyclus australis* Sieb. ex Spreng., *Syst.* iii, 497.

Recorded : Maiden, *Proc. Linn. Soc. N.S.W.* 23, 130, 1898.

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia, Tristan da Cunha.

### Erechtites quadridentata (Lab.) DC.

*Senecio quadridentata* Lab., *Nov. Holl. Plant. Sp.* ii, 48, 1806.

Recorded : F. Muell., *Fragm. Phytogr. Austr.* ix, 77, 1875 ; Hemsley, *Ann. Bot.* x, 240, 1896.

Habitat : Admiralty Islets (Maiden).

Distribution : New Zealand, Tasmania, Australia.

### Senecio insularis Bentham.

*Senecio insularis* Bentham, *Fl. Austr.* iii, 666, 1866.

Recorded : Bentham, *l.c.* ; Hemsley, *Ann. Bot.* x, 240, 1896.

Habitat : Undergrowth in forest from sea-level to summit of Mount Gower; abundant.

Distribution : Endemic. According to Bentham, approaches in several respects the New Zealand *S. Kirkii* Hook. f.

### Sonchus oleraceus L.

*Sonchus oleraceus* L., *Sp. Plant.* 794, 1753.

Recorded : Macgillivray, *Kew Journ. Bot.* vi, 353, 1854 ; Maiden, *Proc. Linn. Soc. N.S.W.* 23, 130, 1898.

Habitat : Maritime meadow, rocky ridge on top of sea-cliffs, north coast. Admiralty Islets (Maiden).

Distribution : Norfolk Island, Kermadecs, New Zealand, Tasmania, Australia ; cosmopolitan.

## V. Introduced Elements.

### 1. Plants.

A list of all plants recorded as introduced to Lord Howe Island by human agency follows. These occur in waste places among the settlements, and appear where the forest has been disturbed by man. Otherwise, as far as my observations go, they have scarcely entered any of the natural plant formations on the island.

*Imperata arundinacea* Cyr. : Maiden. *Proc. Linn. Soc. N.S.W.* 23, 143, 1898 (as indigenous).

*Panicum sanguinale* L. : F. Muell., *Fragm. Phytogr. Austr.* viii, 153, 1874 (as indigenous).

*Stenotaphrum americanum* Schrank.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 151, 1898.
*Sporobolus indicus* R. Br.: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (*S. elongatus*).
*Polypogon monspeliensis* Desfont.: F. Muell., *Fragm. Phytogr. Austr.* viii, 114, 1873 (as indigenous).
*Cynodon Dactylon* Pers.: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (as indigenous).
*Briza minor* L.: Bentham, *Fl. Austr.* vii, 660, 1878.
*Poa annua* L.: Bentham, *Fl. Austr.* vii, 654, 1878.
*Bromus unioloides* H. B. & K.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 151, 1898.
*Crinum pedunculatum* Br.: Moore, *Lord Howe Id. Official Visit*, 26, 1870 (as indigenous).
*Chenopodium murale* L.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 150, 1898.
*Mirabilis jalapa* L.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 150, 1898
*Portulaca oleracea* L.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 149, 1898.
*Stellaria media* L.: Macgillivray, *Hook. Kew Journ. Bot.* 1854.
*Cerastium vulgatum* L.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 149, 1898.
*Polycarpon tetraphyllum* Loefl.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 149, 1898.
*Lepidium ruderale* L.: Hemsley, *Ann. Bot.* x, 231, 1896 (as indigenous).
*Senebiera didyma* Pers.: Moore, *Lord Howe Id. Official Visit*, 24, 1870.
*Cakile maritima* Scop.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 123, 1898 (as indigenous).
*Capsella bursa-pastoris* Moench.: Moore, *Lord Howe Id. Official Visit*, 24, 1870.
*Cassia laevigata* Willd.: Maiden, *Proc. Linn. Soc. N.S.W.* 23. 149, 1898.
*Medicago denticulata* Willd.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 149, 1898.
*Vicia sativa* L.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 149, 1898.
*Ricinis communis* Willd.: Moore, *Lord Howe Id. Official Visit*, 25, 1870.
*Anagallis arvensis* L.: Maiden, *Proc. Linn. Soc. N.S.W.* 39, 382, 1914.
*Verbena bonariensis* L.: Moore, *Lord Howe Id. Official Visit*, 25, 1870.
*Physalis peruviana* L.: Moore, *Lord Howe Id. Official Visit*, 25, 1870.
*Erigeron linifolius* DC.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 150, 1898.
*Taraxacum dens-leonis* Desf.: Maiden, *Proc. Linn. Soc. N.S.W.* 23, 150, 1898.
*Senecio vulgaris* L.: not hitherto recorded.

## 2. Animals.

Important changes have been wrought in the forest on Lord Howe Island by goats and pigs liberated by the early settlers. These animals have overrun most parts of the island, but are not on Transit Hill, close to the settlement, nor have they been able, thanks to the precipices, to ascend to the summits of the mountains. Throughout the area over which goats and pigs roam the undergrowth has been largely depleted. Goats eat herbage and bark, while pigs uproot the plants on which they feed. Where these animals are found there is little or no undergrowth, where formerly one is forced to believe there must have been a considerable amount. In such places as the summit of Mount Gower, Transit Hill, and the slope at the western base of Mount Gower there is often a dense undergrowth. Over most of Erskine Valley it has almost vanished. Certain species are known to have been common in the forest, but are now very scarce: such are *Marattia fraxinea howeana* and *Boehmeria calophleba. Elatostema reticulatum grande* is recorded by Maiden (*Proc. Linn. Soc. N.S.W.* 23, 135, 1898) as being eaten by pigs, which devour both foliage and tubers. It is impossible now to say what other plants have also been suppressed in the area now overrun by these destructive animals.

## VI. LITERATURE AND HISTORY.

1853. *Proposed New Penal Settlement.* Sydney. Contains a number of reports on Lord Howe Island. That by J. D. Macdonald, "Remarks on the Natural History and Capabilities of Lord Howe Island," contains a short general account of the vegetation. Macdonald visited Lord Howe Island as Assistant Surgeon on H.M.S. "Herald," which surveyed the island in 1853.

1854. J. Macgillivray, Letters from, Naturalist on H.M.S. "Herald," in Hooker's *Kew Journal of Botany*, vi, 353. Gives a short general account of the vegetation. The vascular plants collected by Milne and Macgillivray, naturalists to the "Herald," are included in Bentham's *Flora Australiensis.*

1870. *Lord Howe Island: Official Visit by the Water Police Magistrate and the Director of the Botanic Gardens, Sydney.* Contains reports on Lord Howe Island by members of a party which visited the island on official business in the New South Wales Government steamer "Thetis" in May-June, 1869. The report at page 17, by C. Moore, Director of the Sydney Botanical Gardens, "Sketch of the Vegetation of Lord Howe Island," contains a general account of the vegetation and the first published list of the plants of Lord Howe Island. A hundred and nine names are given, of which twenty-nine are generic names only, and nine are recorded as apparently introduced, thus leaving seventy-one indigenous species. (I have omitted three of Moore's species, transferred two to the list of introduced plants, and consider as indigenous *Sonchus oleraceus*, which he lists as introduced.) In the report by E. S. Hill, "Description of Lord Howe Island," an interesting general account of the island is given, with a description of the vegetation.

1872. "*Iris Robinsoniana* F. v. M.," *Gardeners' Chronicle*, p. 393, 1872. A full account of the species, with two figures.

1872. J. G. Baker, "Ferns of Lord Howe Island," *Gardeners' Chronicle*, p. 253, 1873. Records *Alsophila excelsa*, and describes as new *Hemitelia Moorei* and *Deparia nephrodioides.*

1872. C. Moore, "Remarks on the Botany of Lord Howe's Island," *Trans. Roy. Soc. N.S.W.* 1871, p. 29. Gives a table of the genera of plants, with remarks on the geographical relationships.

1873. J. G. Baker, "New Ferns from Lord Howe Island," *Journ. Bot.* xi, 16. *Todea Moorei* and *Asplenium pteridoides*, collected by the Eclipse Expedition of 1871, are described as new.

1874. J. G. Baker, "Tree-fern from Lord Howe Island," *Journ. Bot.* xii, 279. States that *Hemitelia Macarthuri* F. Muell. is identical with *Cyathea Moorei* Hook. & Baker.

1875. F. v. Mueller, *Fragmenta Phytographicae Australiae*, ix. Melbourne. A list is here given containing 185 names. In addition to these, four other species are mentioned in numbers of the *Fragmenta* between 1873 and 1877. (I have omitted four species from Mueller's list, transferred five to the list of introduced plants, and include his *Marsdenia tubulosa* as not different from *M. rostrata.* Mueller's names include four generically determined only, so that 175 indigenous species are accepted in my list.) In vols. vii to ix of the *Fragmenta*, issued between 1870 and 1875, Mueller, either alone or conjointly with C. Moore, published the descriptions of thirty-two new species of plants from Lord Howe Island.

1863–78. G. BENTHAM, *Flora Australiensis*. London. The first volumes contain very few plants recorded from Lord Howe Island, only twenty appearing in the first five volumes (1863–70), sixteen in vol. vi (1873), and seventy-six in vol. vii (1878). One hundred and twelve names are thus given by Bentham as Lord Howe Island plants, of which four are indicated as being introduced. (I have omitted three species and transferred three to the list of introduced plants, thus leaving 102 indigenous species.)

1882. J. B. WILSON, *Report on the Present State and Future Prospects of Lord Howe Island*. Sydney. The island was visited officially on the 4th April, 1882, by the Hon. J. B. Wilson and a party of observation in the "Thetis." The volume is illustrated by seventeen photographic views and two maps. At page 17 is a "Report on the Geology," by H. Wilkinson. A list of the timbers of the island is given, eighteen specific names being mentioned. At page 28 is a "Report on the Vegetation," by J. Duff. Interesting information is given of twelve of the principal forest-plants of the island.

1889. *Lord Howe Island: its Zoology, Geology, and Physical Characters.* Memoir No. 2, Australian Museum, Sydney. This volume consists of the reports on the collections made by a party, despatched by the Australian Museum to Lord Howe Island, in August-September, 1887. It is illustrated by seven plates and four maps. In Report No. 5, "The Physical and Geological Structure of Lord Howe Island," by R. Etheridge, there is a short general account of the vegetation; while the same author, in Report No. 1, "The General Zoology of Lord Howe Island," makes some remarks about the *Ficus* and four species of palms found on the island.

1893. C. MOORE and E. BETCHE, *Handbook of the Flora of New South Wales*. Sydney. At page 518 there is a "List of Lord Howe and Norfolk Island Plants excluded from the Descriptive Part of the Flora." Lord Howe Island is credited with sixty-seven species, one of which, *Marsdenia tubulosa*, I treat as identical with *M. rostrata*.

1893. R. TATE, "The Geographic Relations of the Floras of Norfolk and Lord Howe Islands," *Macleay Memorial Volume*, p. 205. The author discusses the relationships of the genera and species, regarding "Lord Howe Island as a companion outlier to Norfolk Island of the New Zealand region." Tate's list is a compilation which unfortunately contains many mistakes. Altogether 207 species are listed as occurring in Lord Howe Island. (I reduce his list to 189 indigenous species by transferring four to the list of introduced plants, omitting thirteen, and reducing *Marsdenia tubulosa* to the synonymy of *M. rostrata*.)

1896. J. DAVEAU, "Dichogamie Proterandre chez le *Kentia (Howea) Belmoreana*." *Journ. Botanique*.

1896. W. B. HEMSLEY, "The Flora of Lord Howe Island," *Ann. Bot.* x, p. 22. This is the most complete account of the plants of Lord Howe Island that has yet appeared. Besides a list of the species, giving references and distribution, there is a discussion on the origin of the flora. Hemsley's list contains 210 names, besides *Pandanus* sp. indet. (and, in a supplementary note, two names taken from Tate's list). (I have transferred five of Hemsley's species to the list of introduced plants, omitted eleven altogether, and consider *Marsdenia tubulosa* the same as *M. rostrata*. This leaves 193 indigenous species accepted in my list. Of the two species added from Tate's list I omit *Aspidium decompositum*.)

1898. J. H. MAIDEN, "Observations on the Vegetation of Lord Howe Island," *Proc. Linn. Soc. N.S.W.* 23, 112. Mr. Maiden visited Lord Howe Island in March-April, 1898, in H.M.C.S. "Thetis." His paper only enumerates those plants about which he has some information to add, besides which he gives a list of introduced plants and some bibliographical notes. (Altogether 100 species are dealt with, of which twenty are listed as introduced, four could not be identified, four are Hemsley's names recommended to be removed, three I consider to be introduced, and *Asplenium Robinsoni* I treat as a form of *A. nidus*, thus leaving sixty-eight indigenous species, of which eight are additions to Hemsley's list. Of Maiden's introduced plants I include in my list as indigenous *Bidens pilosa*, *Solanum aviculare*, and *S. nigrum*—this last an addition to Hemsley's list.)

1899. J. H. MAIDEN, "Some Further Observations on the Vegetation of Lord Howe Island," *Proc. Linn. Soc. N.S.W.* 24, 381. Four species are mentioned, including the Lord Howe Island variety of *Dendrobium gracilicaule*, which is described as new (*howeanum*).

1901. J. H. MAIDEN, "On one of the So-called Honeysuckles of Lord Howe Island," *Proc. Linn. Soc. N.S.W.* 26, 156 (*Guioa coriacea* Radlk.).

1902. J. H. MAIDEN, "On a New *Cryptocarya* from Lord Howe Island, together with Notes on other Plants from that Island," *Proc. Linn. Soc. N.S.W.* 27, 347. Seven species are mentioned, including *Cryptocarya Gregsoni* Maiden n. sp., *Rapanea myrtillina* Mez.

1906. A. THELLING, "Die Gattung *Lepidium* (L.)." Zurich. Describes as new *L. howei-insulae.*

1907. W. B. HEMSLEY, *Kew Bulletin*, p. 56. Describes as new *Dysoxylum pachyphyllum.*

1913. W. W. WATTS, "The Ferns of Lord Howe Island," *Proc. Linn. Soc. N.S.W.* 37, 395. Mr. Watts visited Lord Howe Island in July-August, 1911, and made a special study of the ferns. In his paper he admits forty-one species, of which two (*Asplenium howeanum* n. sp. and *Ophioglossum vulgatum*) are additions to the flora.

1914. J. H. MAIDEN, "Further Notes on the Botany of Lord Howe Island," *Proc. Linn. Soc. N.S.W.* 39, 377. Notes are given on sixteen species, including *Plantago Hedleyi*, described as new. There is also a list of twenty-four species collected by Mr. Hedley in September, 1908.

1914. W. W. WATTS, "Additional Notes on the Ferns of Lord Howe Island," *Proc. Linn. Soc. N.S.W.* 39, 257. Notes on eleven species, describing as new *Polystichum Whiteleggei* and *P. Kingii.*

1916. W. W. WATTS, "Two Lord Howe Island Polypodia," *Proc. Roy. Soc. N.S.W.* 49, 385. Two species described as new, *P. pulchellum* and *P. howeanum.*

## VII. SPECIES OMITTED.

In addition to the names relegated to synonymy in the systematic account, the following are omitted altogether, the species with which some are considered to be confused being indicated in parentheses :—

*Aspidium decompositum:* Tate, *Macleay Mem. Vol.* 218, 1893.

*Cheilanthes tenuifolia:* F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875; Bentham; Tate; Hemsley. (= *Notochlaena distans.*)

*Polypodium punctatum:* Bentham, *Fl. Austr.* vii, 764, 1878; Tate; Hemsley. (= *Hypolepis tenuifolia.*)

*Davallia dubia:* Bentham, *Fl. Austr.* vii. 716, 1878; Tate; Hemsley. (= *Hypolepis tenuifolia.*)
*Davallia flaccida:* Moore, *Lord Howe Id. Official Visit*, 26, 1870.
*Pteris Milneanum:* Moore, *Lord Howe Id. Official Visit*, 26, 1870.
*Stipa micrantha:* Hemsley, *Ann. Bot.* x, 258, 1896. (= *Dichelachne crinita.*)
*Chloris pumilio:* Moore, *Lord Howe Id. Official Visit*, 26, 1870; Hemsley.
*Smilax purpurata:* Tate, *Macleay Mem. Vol.* 217, 1893.
*Peperomia leptostachya:* Tate, *Macleay Mem. Vol.* 217, 1893.
*Celtis paniculata:* Tate, *Macleay Mem. Vol.* 219, 1893. (= *C. amblyphylla.*)
*Elaeodendron australe:* Hemsley, *Ann. Bot.* x, 234, 1896. (= *E. curtipendulum.*)
*Calophyllum inophyllum:* Hemsley, *Ann. Bot.* x, 232, 1896.
*Nephelium semiglaucum:* Tate, *Macleay Mem. Vol.* 220, 1893. (= *Guioa coriacea.*)
*Cupania anacardioides:* Hemsley, *Ann. Bot.* x, 234, 1896. (= *Guioa coriacea.*)
*Xanthoxylum howeanum:* Tate, *Macleay Mem. Vol.* 220, 1893.
*Myrsine crassifolia:* F. Muell., *Fragm. Phytogr. Austr.* viii, 48, 1873; Tate; Hemsley (= *Rapanea platystigma.*)
*Sideroxylon australe:* Tate, *Macleay Mem. Vol.* 220, 1893. (= *S. howeanum.*)
*Plantago varia:* F. Muell., *Fragm. Phytogr. Austr.* ix, 78, 1875; Hemsley.
*Ipomoea bona-nox:* F. Muell., *Fragm. Phytogr. Austr.* ix, 74, 1875; Tate; Hemsley. (= *I. grandiflora.*)
*Brachycome diversifolia:* Tate, *Macleay Mem. Vol.* 221, 1893. (= *B. segmentosa.*)

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## ART. IX.—*Botanical Results of an Excursion to the Upper Makarora Valley and the Haast Pass, supported by a List of the Species observed.*

By D. L. POPPELWELL.

[*Read before the Otago Institute, 1st August, 1916; received by Editors, 30th December, 1916; issued separately, 9th July, 1917.*]

DURING the Christmas and New Year holidays of 1915–16 a party of four, consisting of Messrs. G. Biggar, of Gore, O. V. Davies and C. Seelye, of Dunedin, and myself, visited the Upper Makarora Valley and Haast Pass with the object of examining the flora and vegetation of that area. The locality is of special interest from a phytogeographical point of view inasmuch as it was supposed to form the connecting-link between L. Cockayne's Western and Fiord South Island Botanical Districts. (See p. 65 of this volume, where the whole of Cockayne's proposed "districts" are defined.) An investigation of the flora was therefore of great importance from the standpoint of plant-distribution, since up to the present, so far as I know, no botanical work whatever has been undertaken in the above area.

The Haast Pass is situated about seventeen miles from the head of Lake Wanaka, and is reached by following the Makarora River up to the junction of the Fish River with the main stream. The Fish River is then followed until the pass is encountered. The saddle is only about 1,850 ft. above sea-level, and is clothed in forest. It is the watershed between the Fish River and the Haast.

In addition to examining this forest, we climbed the mountains above the east side of the pass, reaching a height of 6,000 ft., noting the plant-covering as we went. The upper line of the forest is about

3,750 ft. above sea-level, and the climbing through the forest is severe. We reached the pass on the 29th December, 1915, and camped beside the headwaters of the Haast for five days, making excursions in different directions. The weather during the last day or two was unfavourable for mountain-climbing, hence our investigation was not as thorough as I should have liked, but the following two conclusions were arrived at, and they appear of considerable moment :—

1. The flora resembles that of the Western Botanical District more closely than that of the Fiord Botanical District, as evidenced by the species as a whole, and especially by the presence of such crucial Western District plants as *Ranunculus sericophyllus* (not *R. Baughani*, nor the varieties of *R. sericophyllus*, if they be varieties rather than species, found in the Humboldt Mountains, &c.), *Anisotome Haastii* (not *A. capillifolium*), *Ourisia macrocarpa* var. *calycina* (not var. *cordata*), and *Celmisia Armstrongii ;* while various common Fiord District plants are wanting—*e.g.*, *Ranunculus Buchanani*, *Ourisia prorepens*, *Veronica catarractae* (the long-leaved var.), *Celmisia verbascifolia*, *C. holosericea*, and *C. Hectori*. All the same, a Fiord District affinity is seen in the presence of *Dracophyllum Menziesii*, *Veronica Hectori*, a var. of *Celmisia Petriei*, and *Olearia moschata*, but the latter is common much farther to the north. Certain characteristic Western District plants also are absent, especially *Dracophyllum Traversii* and *Olearia lacunosa*.

From the above it can be seen that, so far as the flora goes, though more or less intermediate between the two botanical districts under consideration, it seems best to include the Haast Pass, &c., area in the Western Botanical District.

2. With regard to the vegetation, the subalpine forest consists of *Nothofagus Menziesii*, and not of *Podocarpus Hallii* and *Libocedrus Bidwillii* as in the Western Botanical District on the western side. Further, there is no subalpine *Nothofagus cliffortioides* forest, nor montane or lowland *N. fusca* forest. On the other hand, the rain-forest, which commences at the junction of the Rivers Wills and Haast, is of the Western District type, in which *Nothofagus* is absent. So, too, the subalpine fell-field appears to closely resemble Western District fell-field. Thus the vegetation seems to favour the area being included in the Western rather than in the Fiord District.

In the following list of species nothing is said regarding habitat, locality, or comparative rarity, since for any statements of moment a more thorough investigation of the area would have been necessary. A number of other species were noted, but as specimens of such were not secured it has seemed best to include only those species of which the determination is without question.

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## LIST OF INDIGENOUS PLANTS.

### PTERIDOPHYTA.

#### Filices.

*Hymenophyllum sanguinolentum* (Forst. f.) Sw.
*Hemitelia Smithii* (Hook. f.) Hook.
*Alsophila Colensoi* Hook. f.
*Polystichum vestitum* (Forst. f.) Presl.
—— *Richardi* Hook.

#### Filices—*continued.*

*Asplenium bulbiferum* Forst. f. (various forms).
—— *flaccidum* Forst. f. (various forms).
*Blechnum Patersoni* (R. Br.) Mett.
—— *discolor* Forst. f.

PTERIDOPHYTA—*continued.*

Filices—*continued.*

*Blechnum vulcanicum* (Bl.) Kuhn.
—— *lanceolatum* (R. Br.) Sturm.
—— *penna marina* (Poir) Kuhn.
—— *capense* (L.) Schlecht.
—— *fluviatile* (R. Br.) Lowe.
*Hypolepis tenuifolia* (Forst. f.) Bernh.
*Histiopteris incisa* (Thunb.) J. Sm.
*Pteridium esculentum* (Forst. f.) Cockayne.
*Paesia scaberula* (A. Rich.) Kuhn.
*Dryopteris glabella* (A. Cunn.) C. Chr.
*Polypodium Billardieri* (Willd.) C. Chr.

Filices—*continued.*

*Polypodium diversifolium* Willd.
—— *punctatum* Thunb.
*Cyclophorus serpens* (Forst. f.) C. Chr.
*Gleichenia Cunninghami* Hew.
*Leptopteris hymenophylloides* (A. Rich.) Presl.
—— *superba* (Col.) Presl.

Lycopodiaceae.

*Lycopodium Billardieri* Spring.
—— *fastigiatum* R. Br.
—— *scariosum* Forst. f.
—— *volubile* Forst. f.

SPERMOPHYTA.

Taxaceae.

*Podocarpus Hallii* T. Kirk.
—— *totara* D. Don.
—— *ferrugineus* D. Don.
—— *spicatus* R. Br.
—— *nivalis* Hook.
—— *dacrydioides* A. Rich.
*Dacrydium cupressinum* Sol.
*Phyllocladus alpinus* Hook. f.

Potamogetonaceae.

*Potamogeton Cheesemanii* A. Benn.
*Phyllocladus alpinus* Hook. f.

Gramineae.

*Microlaena avenacea* (Raoul.) Hook. f.
*Danthonia Cunninghamii* Hook. f.
—— *flavescens* Hook. f.
—— *Raoulii* Steud.
—— *Buchanani* Hook. f. var.
—— *crassiuscula* T. Kirk.
—— *semiannularis* R. Br. var.
*Arundo conspicua* Forst. f.
*Poa caespitosa* Forst. f. var.
—— *Colensoi* Hook. f. var.
*Festuca novae-zealandiae* (Hack.) Cockayne.
*Agropyron scabrum* (R. Br.) Beauv. var.

Cyperaceae.

*Gahnia procera* Forst.
*Oreobolus pectinatus* Hook. f.
*Uncinia uncinata* (L. f.) Kükenth.
*Carex ternaria* Forst. f.
—— *Gaudichaudiana* Kunth.

Juncaceae.

*Juncus polyanthemus* Buchen.
—— *planifolius* R. Br.
*Luzula campestris* DC. var.

Liliaceae.

*Enargia parviflora* Kunth.
*Cordyline australis* (Forst. f.) Hook. f.
*Astelia linearis* Hook. f.
—— *nervosa* Banks & Sol.
—— *montana* (Kirk) Cockayne.
—— *Petriei* Cockayne.
*Phormium tenax* Forst.
—— *Cookianum* Le Jolis.
*Chrysobractron Hookeri* Col.
*Herpolirion novae-zelandiae* Hook. f.

Orchidaceae.

*Thelymitra longifolia* Forst.
*Microtis unifolia* (Forst. f.) Reichb.
*Prasophyllum Colensoi* Hook. f.
*Caladenia bifolia* Hook. f.
—— *Lyallii* Hook. f.
*Chiloglottis cornuta* Hook. f.
*Corysanthes rotundifolia* Hook. f.
—— *triloba* Hook. f.
—— *macrantha* Hook. f.
*Adenochilus gracilis* Hook. f.
*Gastrodia Cunninghamii* Hook. f.
*Pterostylus Banksii* R. Br.
—— *australis* Hook. f.

Fagaceae.

*Nothofagus Menziesii* (Hook. f.) Oerst.

SPERMOPHYTA—*continued.*

URTICACEAE.

*Urtica incisa* Poir.

LORANTHACEAE.

*Eletranthe Colensoi* (Hook. f.) Engl.
—— *tetrapetalus* (Hook. f.) Engl.
—— *flavidus* (Hook. f.) Engl.

POLYGONACEAE.

*Rumex flexuosus* Sol.
*Muehlenbeckia australis* (Forst. f.) Meissn.
—— *complexa* (A. Cunn.) Meissn. var.
—— *axillaris* (Hook. f.) Walp.

PORTULACACEAE.

*Claytonia australasica* Hook. f.

CARYOPHYLLACEAE.

*Hectorella caespitosa* Hook. f.

RANUNCULACEAE.

*Clematis indivisa* Willd.
*Ranunculus Lyallii* Hook. f.
—— *hirtus* Banks & Sol.
—— *rivularis* Banks & Sol.
—— *lappaceus* Sm. var.
—— *sericophyllus* Hook. f.
*Caltha novae-zelandiae* Hook. f.

MAGNOLIACEAE.

*Drimys colorata* Raoul.

CRUCIFERAE.

*Cardamine heterophylla* (Forst. f.) O. E. Schulz var.

DROSERACEAE.

*Drosera spathulata* Labill.

SAXIFRAGACEAE.

*Carpodetus serratus* Forst.

PITTOSPORACEAE.

*Pittosporum tenuifolium* Banks & Sol. var.
—— *Colensoi* Hook. f.

CUNONIACEAE.

*Weinmannia racemosa* L. f.

ROSACEAE.

*Rubus australis* Forst. var. *glaber* Hook. f.
—— *subpauperatus* Cockayne.
—— *schmidelioides* A. Cunn.
*Geum parviflorum* Smith.
—— *leiospermum* Petrie.
*Potentilla anserina* L. var. *anserinoides* (Raoul) Kirk.
*Acaena novae-zelandiae* T. Kirk.
—— *Sanguisorbae* var. *pusilla* Bitter.
—— —— var. *pilosa* T. Kirk.
—— *microphylla* Hook. f. var.
—— *inermis* Hook. f. var.

GERANIACEAE.

*Geranium microphyllum* Hook. f.
—— *sessiliflorum* Cav. var. *glabrum* Knuth.
*Oxalis magellanica* Forst.
—— *corniculata* L. var.
*Pennantia corymbosa* Forst.

CALLITRICHACEAE.

*Callitriche verna* L.

CORIARIACEAE.

*Coriaria ruscifolia* L. var.
—— *thymifolia* Humb. & Bonpl. var.
—— *angustissima* Hook. f.

LEGUMINOSAE.

*Carmichaelia grandiflora* Hook. f.

ELAEOCARPACEAE.

*Aristotelia racemosa* (A.Cunn.) Hook.f.
—— *Colensoi* Hook. f. ?
—— *fruticosa* Hook. f.
*Elaeocarpus Hookerianus* Raoul.

MALVACEAE.

*Plagianthus betulinus* Forst.
*Gaya Lyallii* (Hook. f.) J. E. Baker.

VIOLACEAE.

*Viola Cunninghami* Hook. f.
*Melicytus lanceolatus* Hook. f.
—— *ramiflorus* Forst.
*Hymenanthera dentata* R. Br. var. *alpina* T. Kirk.

SPERMOPHYTA—*continued.*

THYMELACEAE.

*Pimelea prostrata* Willd. var.
*Drapetes Dieffenbachi* Hook.

MYRTACEAE.

*Leptospermum scoparium* Forst. var.
—— *ericoides* A. Rich. var.
*Metrosideros lucida* (Forst. f.) A. Rich.
—— *hypericifolia* A. Cunn.
*Myrtus pedunculata* Hook. f.
—— *obcordata* Hook. f.

ONAGRACEAE.

*Epilobium pubens* A. Rich.
—— *pictum* Petrie.
—— *melanocaulon* Hook.
—— *microphyllum* A. Rich.
—— *Hectori* Haussk.
*Fuchsia excorticata* L. f.

HALORRHAGACEAE.

*Halorrhagis micrantha* (Thunb.) R. Br.
*Gunnera monoica* Raoul var. *albocarpa* T. Kirk.
—— *dentata* T. Kirk.

ARALIACEAE.

*Nothopanax simplex* (Forst. f.) Seem.
—— *Edgerleyi* (Hook. f.) Seem.
—— *Colensoi* (Hook. f.) Seem.
*Schefflera digitata* Forst.
*Pseudopanax crassifolium* (Sol.) C. Koch. var. *unifoliatum* T. Kirk.

UMBELLIFERAE.

*Hydrocotyle novae-zelandiae* DC.
—— *asiatica* L.
*Schizeilema hydrocotyloides* (Hook. f.) Domin.
—— *Hookeri* (Drude) Domin.
*Anisotome Haastii* (F. Muell.) Cockayne and Laing.
—— *aromatica* Hook. f.
*Aciphylla Colensoi* Hook. f.
—— *Monroi* Hook. f. (or one of Cheeseman's recent segregates from that species).
—— *Lyallii* Hook. f.
*Angelicum montana* (Forst. f.) Cockayne.

CORNACEAE.

*Griselinia littoralis* Raoul.

ERICACEAE.

*Gaultheria antipoda* Forst. f. var. *erecta* Chesm.
—— —— var. *depressa* Hook. f.
—— *perplexa* T. Kirk.
—— *rupestris* R. Br. var.

EPACRIDACEAE.

*Pentachondra pumila* (Forst. f.) R. Br.
*Styphelia acerosa* Sol. var.
—— *Fraseri* (A. Cunn.) F. Muell.
—— *Colensoi* (Hook. f.).
—— *pumila* (Hook. f.) Diels.
*Archeria Traversii* Hook. f.
*Dracophyllum Menziesii* Hook. f.
—— *longifolium* (Forst. f.) R. Br.

MYRSINACEAE.

*Rapanea Urvellei* (A. DC.) Mez.
*Suttonia divaricata* Hook. f.

GENTIANACEAE.

*Gentiana corymbifera* T. Kirk.
—— *bellidifolia* Hook. f.

APOCYNACEAE.

*Parsonsia heterophylla* A. Cunn.

CONVOLVULACEAE.

*Calystegia tuguriorum* (Forst. f.) R. Br.

BORAGINACEAE.

*Myosotis Forsteri* Lehm.

LABIATAE.

*Mentha Cunninghami* Benth.

SCROPHULARINACEAE.

*Veronica salicifolia* Forst. f. var. *communis* Cockayne.
—— *subalpina* Cockayne.
—— *Cockayniana* Cheesem. ?
—— *Hectori* Hook. f.
—— *linifolia* Hook. f.
—— *Lyallii* Hook. f.
—— *lycopodioides* Hook. f. ?

SPERMOPHYTA—*continued.*

SCROPHULARINACEAE—*continued.*

*Veronica monticola* Armst. var.
—— *Thomsoni* Cheesem.
—— *buxifolia* Benth. var.
*Ourisia macrocarpa* Hook. f. var. *calycina* (Col.) Cockayne.
—— *Crosbyi* Cockayne.
—— *caespitosa* Hook. f.
—— *glandulosa* Hook. f.
—— *sessilifolia* Hook. f.
*Euphrasia Monroi* Hook. f. ?
—— *zelandica* Wettst.
*Mazus radicans* Cheesem.

PLANTAGINACEAE.

*Plantago Brownii* Rapin ?

RUBIACEAE.

*Coprosma lucida* Forst. f.
—— *rotundifolia* A. Cunn.
—— *areolata* Cheesem.
—— *parviflora* Hook. f.
*Coprosma propinqua* A. Cunn.
—— *brunnea* (T. Kirk) Cockayne.
—— *linariifolia* Hook. f.
—— *foetidissima* Forst.
—— *repens* Hook. f.
—— *serrulata* Hook. f.
*Nertera depressa* Banks & Sol.
—— *dichondraefolia* (A. Cunn.) Hook. f.
*Galium umbrosum* Sol.

CAMPANULACEAE.

*Pratia angulata* (Forst. f.) Hook. f.
*Wahlenbergia albomarginata* Hook.
—— *gracilis* (Forst. f.) A. DC. var.

STYLIDIACEAE.

*Phyllachne Colensoi* (Hook. f.) Berggr.
*Forstera Bidwillii* Hook. f.

COMPOSITAE.

*Lagenophora pumila* (Forst.) Cheesem.
—— *petiolata* Hook. f.
*Brachycome Sinclairii* Hook. f.
*Olearia lineata* (Kirk) Cockayne.

COMPOSITAE—*continued.*

*Olearia moschata* Hook. f.
—— *arborescens* (Forst. f.) Cockayne and Laing.
—— *ilicifolia* Hook. f.
—— *avicenniaefolia* (Raoul) Hook. f
—— *virgata* Hook. f. var.
*Celmisia Sinclairii* Hook. f. var.
—— *longifolia* Cass. var.
—— —— var. *alpina* T. Kirk.
—— *sessiliflora* Hook. f.
—— *Armstrongii* Petrie.
—— *petiolata* Hook. f.
—— *coriacea* Hook. f.
—— *Walkeri* T. Kirk.
—— *bellidioides* Hook. f.
—— *angustifolia* Cockayne var. with shorter and wider leaves than type.
—— *Haastii* Hook. f.
—— *discolor* Hook. f. var.
—— *Petriei* Cheesem. var.
—— *Lyallii* Hook. f.
—— *glandulosa* Hook. f.
*Gnaphalium trinerve* Forst. f.
—— *luteo-album* L.
—— *collinum* Labill.
—— *Traversii* Hook. f.
—— *paludosum* Petrie.
—— *keriense* A. Cunn.
*Raoulia glabra* Hook. f.
—— *australis* Hook. f. var.
—— *grandiflora* Hook.
*Helichrysum filicaule* Hook. f.
—— *bellidioides* Willd.
*Leucogenes grandiceps* (Hook. f.) Beauv.
*Cassinia Vauvilliersii* Hook. f.
*Craspedia uniflora* Forst. f. var.
*Cotula dioica* Hook. f. var.
—— *squalida* Hook. f.
*Erechtites prenanthoides* (A. Rich.) DC.
—— *scaberula* Hook. f.
*Senecio bellidioides* Hook. f. var.
—— *Lyallii* Hook. f.
—— *scorzoneroides* Hook. f.
—— *lautus* Forst. var. *montanus* Cheesem.
—— *southlandicus* Cockayne.
—— *elaeagnifolius* Hook. f.
*Taraxacum magellanicum* Comm.

# ART. X.—*Notes of a Botanical Excursion to Long Island, near Stewart Island, including a List of Species.*

By D. L. POPPELWELL.

[*Read before the Otago Institute, 1st August, 1916; received by Editors, 30th December, 1916; issued separately, 9th July, 1917.*]

## GENERAL.

LONG ISLAND lies off the south-west of Stewart Island, in latitude 47° 15′ South and longitude 168° 27′ East. It is the largest of a group of small islands in this locality, and is about three miles long by about one mile wide. It is situate a mile and half from the mainland of Stewart Island at its nearest point. This island forms one of the most southerly outliers of the Stewart Island group; it is composed of granitic rock covered with peat. It stands about 800 ft. high, and is fairly steep on the sides, but has an undulating surface. Almost the whole of its steep sides are clothed with scrub and forest, but the top is covered in parts with heath. Some particulars of the various formations will be given later. The island is also known as "Jura," and by the Stewart Island fishermen as "Big South Cape Island." This isolated patch, being practically the nearest land to the Snares, situated sixty miles to the south of it, is scientifically of exceptional interest, so I make no apology for placing upon record some notes as to its plant-covering. During the Easter holidays this year—namely, on the 21st April, 1916—I spent about nine hours on the island noting its vegetation. I was accompanied by Mr. W. A. Thomson, of Dunedin, who is an ardent and experienced plant-collector, and he materially assisted me in my investigations. Owing to the size of the island and the rough nature of its covering, it is obvious that no very exhaustive examination could be made of the flora, and therefore a number of species may have been overlooked. This is the more likely when one considers the late period of the season when our visit was made, and the fact that many plants, such as the Orchidaceae, are then easily passed by.

## ECOLOGICAL CONDITIONS.

Perhaps nowhere in the world can stormier conditions be found than those of these outlying islands off the south coast of Stewart Island. The strong prevailing south-west winds and seas strike these islands with full force. The bare rocks and the wind-shorn plants on the weather side show the effect of this. On the north side, however, there is more shelter, and consequently a less wind-swept vegetation. Heavy rains drench the peaty soil for a great number of days in each year. In common with the rest of Stewart Island there is, I believe, a mild winter climate, and, although at the time of our visit there was a very hot sun and still atmosphere, the average summer temperature is probably low. The soil, as before mentioned, is of a peaty nature, and is much enriched by the droppings of the petrels (*Puffinus griseus*), whose burrows are very plentiful on the steep scrubby sides of the island. These tunnels must also assist materially in draining and aerating the soil.

## Plant Formations.

These can best be described under the headings (1) scrub, (2) rocks and cliffs, (3) heath.

### 1. *Scrub.*

I have chosen the term "scrub" as it best describes the vegetation of the steep sides of the island. Throughout this formation in the more sheltered parts will be found patches which might be called "forest," but as the majority of the plants are of the *Olearia* type, or much stunted, the formation as a whole is best designated "scrub." On approaching the island the general physiognomy is grey-green with yellowish-brown patches, and, higher up, blotches of a darker colour. The grey-green patches are of that peculiar globose appearance so characteristic of the *Olearia* scrub formation of the Stewart Island coast. On a close examination it is at once seen that the scrub consists of *Olearia angustifolia* next the sea, with *O. Colensoi* abundant and *Senecio rotundifolius* behind the first fringe, while the yellowish-brown colour is produced by *Dracophyllum longifolium*, which is fairly plentiful. The darker patches, which usually occupy the sheltered depressions, consist of *Metrosideros lucida.* The whole surface of this formation is smooth and rounded, showing the effect of the strong winds which sweep these islands. Here and there a green patch of *Veronica elliptica* is visible, especially near the sea. This is more marked where there has been some clearing round the mutton-birders' huts. In open places considerable patches of *Poa foliosa* are found, with an occasional tuft of *Carex trifida* or *Microlaena avenacea.* Under the scrub the ground-floor is covered by patches of *Stilbocarpa Lyallii, Asplenium flaccidum, A. scleroprium, A. lucidum, A. obtusatum,* and *Polystichum vestitum,* while *Polypodium diversifolium* climbs over the fallen trees. Among smaller plants I noted *Stellaria parviflora* and *Nertera depressa.* At a higher elevation the following species were added to the formation: *Nothopanax Colensoi, N. Edgerleyi, Metrosideros lucida, Coprosma foetidissima, C. Colensoi, Astelia nervosa,* and the ferns *Histiopteris incisa, Dicksonia squarrosa,* and *Hemitelia Smithii.*

### 2. *Rocks and Cliffs.*

A typical cliff association was noted in a situation where the full force of the wind strikes. The rocks were absolutely bare for a height of between 50 ft. and 60 ft., when a grey-green fringe of *Poa Astoni* altered the physiognomy of the granitic rock wall. On the cliffs *Crassula moschata* was common, while *Myosotis albida, Tetragonia trigyna, Mesembryanthemum australe,* and *Apium prostratum* were sparingly found. This was succeeded by *Olearia angustifolia,* under which the shore-fern *Blechnum durum* was growing in considerable patches. Here and there were tussocks of *Scirpus nodosus.* This association also contained some *Scirpus aucklandicus* and *Anisotome intermedia* var., but gradually merged into the scrub formation above described.

### 3. *Heath.*

On a peaty saddle crossing over the top of the island and forming a wind-funnel there was a most marked heath formation, consisting of *Phormium Cookianum, Leptospermum scoparium, Dracophyllum longifolium* (the two latter fairly abundant), *Olearia arborescens, Styphelia acerosa, S. empetrifolia, Hymenophyllum rufescens, Veronica buxifolia, Gaultheria erecta, Pentachondra pumila, Lycopodium varium* (in large clumps), *Coprosma*

*Colensoi, Enargia parviflora,* with stunted *Olearia Colensoi, Metrosideros lucida,* and *Senecio rotundifolius,* and the bog-plants *Celmisia longifolia* var., *Astelia linearis, Oreobolus pectinatus, O. strictus;* also *Gahnia procera* and *Carex trifida.* The ground was also dotted over with coral moss, and in parts with *Lycopodium ramulosum.* The whole of this formation was very wind-swept. The *Leptospermum* was lying prostrate, and formed a close mat over considerable patches, the plants being rooted right along to the ends of the branches; the ultimate tips were erect and close together, forming a solid mat. Adjoining the above heath there was a low-scrub association consisting of many of the heath-plants above mentioned, but also containing *Dacrydium intermedium* fairly plentifully with *Weinmannia racemosa, Coprosma Colensoi,* and *Griselinia littoralis.* In the wetter parts of the heath I also noted *Donatia novae-zelandiae, Hydrocotyle novae-zelandiae, Drosera spathulata, Gleichenia circinata,* and *Schizaea fistulosa* var *australis;* and, where the ground was drier, *Senecio bellidioides* var., *Cardamine heterophylla, Phormium tenax* (rare), and the ferns *Pteridium esculentum* and *Blechnum capense.*

## Summary.

From the list appended hereto it will be seen that the number of species noted was seventy-five, spread over fifty-three genera and twenty-nine families. I do not think that further investigation will disclose many new species on these outlying islands, the ecological conditions being so much alike. From what I saw of the vegetation of several of the islands near Long Island it does not differ materially from that described above. Most of the other islands are, however, much lower in altitude and smaller in area, and have little or no heath formation.

The most interesting feature of the plant-covering of these islands is the epharmonic relations of its members to climatic and edaphic conditions. The wonderful way in which many of the plants adapt themselves to their environment is most instructive.

If we compare the published list of species from the Solanders, Long Island, and the Breakseas, all of which islands possess much in common in their conditions, it will be seen that they have a considerable percentage of plants in common. Thus out of nineteen species reported from the Solanders* seventeen are found at Long Island, and the other two species, *Thelymitra uniflora* and *Senecio Stewartiae,* will most likely upon further investigation also be found. I think also that further examination of the Solanders will disclose many more species there in common with the island now under review, especially in the heath formations, not yet examined, of the higher parts of the island. Of sixty-nine species reported from Breaksea Islands† forty-three are also included in the list appended hereto. This connection is, if anything, more accentuated when the genera are considered.

So many islands scattered over the ocean at such long distances apart and still having so many genera and species in common certainly suggest land connection at some time. The flora common to all extended areas of that time would, by a process of gradual elimination brought about by the altered ecological conditions of a reduced and lowered land surface, suffi-

* L. Cockayne, On a Collection of Plants from the Solanders, *Trans. N.Z. Inst.*, vol. 41, 1909, p. 404.

† D. L. Poppelwell, Notes on the Plant-covering of the Breaksea Islands, *Trans. N.Z. Inst.*, vol. 48, 1916, p. 246.

ciently account for such slight differences as are now noticeable in the florulas of the various islands. If we compare the florulas of these islands and the Snares we find about seven species common to both the Snares and Long Island. From the list of these—namely, *Crassula moschata, Apium prostratum, Myosotis albida, Veronica elliptica, Hierochloe redolens, Poa foliosa,* and *Asplenium obtusatum*—it will be seen that most of them are fairly widely distributed over the southern islands. The characteristic species of the Snares—viz., *Stilbocarpa robusta, Anisotome acutifolia, Poa litorosa,* and *Colobanthus muscoides*—have not yet been reported from the Stewart Island group, although some closely allied species are found among the latter. One species, *Senecio Stewartiae,* is found only on the Snares, Solanders, and Herekopere Islands. At present, therefore, it appears that the Snares do not belong to the Stewart Botanical District, but rather to the Sub-antarctic Province On the question of plant-distribution on these islands L. Cockayne* and T. F. Cheeseman† have thrown much light in their different papers dealing with the matter.

## LIST OF SPECIES.

### PTERIDOPHYTA.

HYMENOPHYLLACEAE.

*Hymenophyllum rufescens* T. Kirk.

CYATHEACEAE.

*Dicksonia squarrosa* (Forst. f.) Sw.
*Hemitelia Smithii* (Hook. f.) Hook.

POLYPODIACEAE.

*Polystichum vestitum* (Forst. f.) Presl.
*Asplenium obtusatum* Forst. f.
—— *scleroprium* Homb. & Jacq.
—— *lucidum* Forst. f.
—— *flaccidum* Forst. f.
—— *bulbiferum* Forst. f.
*Blechnum durum* (Moore) C. Chr.
—— *capense* (L.) Schlecht.

POLYPODIACEAE—*continued.*

*Histiopteris incisa* (Thunb.) J. Sm.
*Pteridium esculentum* (Forst. f.) Cockayne.
*Polypodium diversifolium* Willd.

GLEICHENIACEAE.

*Gleichenia circinata* Sm.

SCHIZAEACEAE.

*Schizaea fistulosa* Labill. var. *australis* (Gaud.) Hook. f.

LYCOPODIACEAE.

*Lycopodium varium* R. Br.
—— *ramulosum* T. Kirk.

### SPERMOPHYTA.

TAXACEAE.

*Podocarpus ferrugineus* Don.
*Dacrydium intermedium* T. Kirk.

GRAMINEAE.

*Hierochloe redolens* (Forst. f.) R. Br.
*Microlaena avenacea* (Raoul) Hook. f.
*Poa foliosa* Hook. f.
—— *Astoni* Petrie.

CYPERACEAE.

*Scripus aucklandicus* (Hook. f.) Boeck.
—— *nodosus* (R. Br.) Rottb.
*Gahnia procera* Forst.
*Oreobolus pectinatus* Hook. f.
—— *strictus* Berggr.
*Carex lucida* Boott.
—— *trifida* Cav.

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* L. COCKAYNE, A Botanical Excursion during Midwinter to the Southern Islands of New Zealand, *Trans. N.Z. Inst.*, vol. 36, 1904, p. 225. See also L. COCKAYNE, The Ecological Botany of the Subantarctic Islands of New Zealand, *Subant. Islands of N.Z.*, Canterbury Phil. Inst., vol. 1, 1909, pp. 182–235.

† T. F. CHEESEMAN, On the Systematic Botany of the Islands to the South of New Zealand, *Subant. Islands of N.Z.*, Canterbury Phil. Inst., vol. 2, 1909, pp. 389–471.

SPERMOPHYTA—*continued.*

Juncaceae.

*Luzula campestris* DC. var.

Liliaceae.

*Phormium tenax* Forst.
—— *Cookianum* Le Jolis.
*Enargia parviflora* (Banks & Sol.) Hook. f.
*Astelia linearis* Hook. f.
— *nervosa* Banks & Sol.

Urticaceae.

*Urtica australis* Hook. f.

Aizoaceae.

*Mesembryanthemum australe* Sol.
*Tetragonia trigyna* Banks & Sol.

Cruciferae.

*Cardamine heterophylla* (Forst. f.) O. E. Schulz.

Droseraceae.

*Drosera spathulata* Labill.

Crassulaceae.

*Crassula moschata* Forst. f.

Cunoniaceae.

*Weinmannia racemosa* L. f.

Myrtaceae.

*Leptospermum scoparium* Forst.
*Metrosideros lucida* (Forst. f.) A. Rich.

Araliaceae.

*Stilbocarpa Lyallii* J. B. Armst.
*Nothopanax Edgerleyi* (Hook. f.) Seem.
—— —— var. *serrata* T. Kirk.
—— *Colensoi* (Hook. f.) Seem.

Umbelliferae.

*Hydrocotyle novae-zelandiae* DC.
*Apium prostratum* Labill.
*Anisotome intermedia* Hook. f. var. *oblongifolia* Kirk ?

Cornaceae.

*Griselinia littoralis* Raoul.

Ericaceae.

*Gaultheria antipoda* Forst. f. var. *erecta* Cheesm.

Epacridaceae.

*Pentachondra pumila* (Forst. f.) R. Br.
*Styphelia acerosa* Sol. var.
—— *empetrifolia* (Hook. f.) Diels.
*Dracophyllum longifolium* (Forst. f.) R. Br.

Myrsinaceae.

*Suttonia chathamica* (F. Muell.) Mez.

Boraginaceae.

*Myosotis albida* (T. Kirk) Cheesm.

Scrophulariaceae.

*Veronica elliptica* Forst. f.
—— *buxifolia* Benth. var.

Rubiaceae.

*Coprosma lucida* Forst. f.
—— *foetidissima* Forst.
—— *Colensoi* Hook. f.
*Nertera depressa* Banks & Sol.

Stylidiaceae.

*Donatia novae-zelandiae* Hook. f.

Compositae.

*Olearia angustifolia* Hook. f.
—— *Colensoi* Hook. f.
—— —— var. with large leaves, possibly *O. Lyallii* Hook. f.
—— *arborescens* (Forst. f.) Cockayne and Laing.
*Celmisia longifolia* Cass. var.
*Senecio bellidioides* Hook. f. var.
—— *rotundifolius* Hook. f.

## Art. XI.—*Contributions to the Diptera Fauna of New Zealand: Part I.*

By David Miller.

[*Read before the Otago Institute, 5th December, 1916; received by Editors, 30th December, 1916; issued separately, 9th July, 1917.*]

This "contribution" is the first of a series, and comprises a description of seven new forms belonging to the family Stratiomyidae, together with a revision of the nine species included by Hutton in the genera *Beris* and *Exaireta*.* Since commencing this paper several additional new forms have been collected and will be described in a future work on this family.

I have laid stress upon the structure of the wing-neuration, since there are marked differences even amongst species of the one genus; however, in certain cases some forms will no doubt have to be separated later on. Not only the wings, but antennae show distinct peculiarities.

The palpi of some species are peculiar. For example, in *Beris saltusans* n. sp. the 2nd palpal joint shows apparently 5 segments and the 1st joint 3, marked by lateral restrictions. Little has been done in the comparative study of the dipterous palpi, which are believed to vary from 1 to 5 joints. An investigation of these organs would doubtless be of considerable systematic value.

In referring to the tarsal joints I have adopted the following terminology for the 1st to 5th joints respectively, as suggested by Dr. Williston: protarsus, epitarsus, mesotarsus, metatarsus, and onychotarsus.

The wing illustrations of the genus *Exaireta* were drawn to scale from photographs.

I am indebted to Mr. R. Speight, of the Canterbury Museum, for his kindness in allowing me access to the Hutton collection, and to Mr. G. Howes and Mr. G. V. Hudson for various specimens placed at my disposal.

### Family STRATIOMYIDAE.

#### Genus Exaireta Schiner.

If the wings of the various species of this genus, referred to below, be examined, it will be noticed that the 1st submarginal cell varies considerably in form where the 3rd longitudinal vein arises from the 2nd. This feature is due to the position of the anterior cross-vein, and I have indicated in such cases that this cross-vein has either a common origin with the 3rd longitudinal from the 2nd or arises independently from the 3rd. The 3rd longitudinal vein is, according to the species, either strongly or slightly sinuated; accordingly the anterior branch, which may arise from the middle, before the middle, or beyond, is shorter or longer respectively. Again, the distance from the posterior wing-margin of the confluence of the 5th and 6th (anal) longitudinal veins, as compared with the length of the anterior cross-vein, is a feature I consider of importance.

It will be noticed from the illustrations that in the wing of *spiniger* (the type of this genus) the alula is well developed, while in the other species this part of the wing is absent. Also, the general outline of the wings and the position of the discal cell vary considerably.

Of the 4 posterior veins, characteristic of this genus, the 3rd varies considerably in length and may be rudimentary. On the right wing of

* F. W. Hutton, 1901, Synopsis of the *Diptera brachycera* of New Zealand, *Trans. N.Z. Inst.*, vol. 33, pp. 1–95

one male specimen of my new species *seolforalis* this 3rd posterior vein is totally absent, although present on the left wing. The right wing is shown in fig. 7. In all my other specimens of this form the 3rd posterior vein is present. When this vein is absent, as in the above case, one would probably be inclined to place the species in the genus *Beris*—that is to say, if only one specimen were available.

In most cases the antennae of the ♂ are considerably shorter than those of the ♀, and the eyes of the former are slightly closer than those of the latter.

This genus has a distribution throughout New Zealand, most of the species being found both in the North and the South Islands. Only one form, *spiniger*, is common to Australia and New Zealand, while *seolforalis* n. sp. ranges from sea-level to 3,000 ft. altitude.

In his work on the Brachycera,* Hutton describes five species, of which his new form *alpina* I place in the genus *Berismyia* for reasons stated under that division. I also agree with Walker that *E. opposita* of Hutton belongs to the genus *Actina*.

The sexes may be distinguished mainly by the length of the antennae, proximity of the eyes, size of body, and form of the abdomen. In the ♂ the abdomen usually has parallel sides or sides restricted along the middle and is narrower than the thorax, while the ♀, although narrower at the base than the thorax, as a rule becomes wider beyond the middle.

Although both the genera *Exaireta* and *Actina* are very much alike in general appearance, they may be distinguished by the fact than the eyes of the former are bare and those of the latter pubescent, either densely or thinly so.

According to the venation of the wings, I have divided the species of this genus into two main groups—(1) those with the first submarginal cell obtuse, and (2) those with this cell acute. In the one species forming the first group the wing is not clouded or is only faintly coloured, while the anterior branch of the 3rd vein arises before the middle of this vein. The four species of the second group have the wings clouded and the anterior branch of the 3rd vein beyond the middle. This group is further divided into two subgroups by comparing the lengths of the anterior cross-vein and the vein between the discal and 5th posterior cells. To one of these subgroups three species belong, and are themselves distinguished mainly by their coloration.

TABLE OF SPECIES.

| | | |
|---|---|---|
| 1 | First submarginal cell proximally obtuse; wings not clouded, almost clear; 1st abdominal segment deep purple, remainder with dense silvery pubescence .. .. .. .. | *seolforalis* n. sp. |
| | First submarginal cell proximally acute; wings clouded; abdomen without dense pubescence .. .. .. .. | 2 |
| 2 | Vein between discal and 5th posterior cells shorter, never longer, than the anterior cross-vein .. .. .. .. | 3 |
| | Vein between discal and 5th posterior cells distinctly longer than anterior cross-vein .. .. .. .. .. | *spiniger*. |
| 3 | Wings tinged with yellow proximally and brown distally, or also with a distinct transverse cloud .. .. .. .. | 4 |
| | Wings clouded with brown both proximally and distally, and with clear interspaces .. .. .. .. .. | *hoheria* n. sp. |
| 4 | Wings with a distinct transverse median cloud, the distal half lighter brown; abdomen of a uniform purplish-bronze (♀) .. | *straznitzkii*. |
| | Wings without transverse cloud; abdomen tawny, with purple apex | *apicalis*. |

* F. W. HUTTON, 1901, Synopsis of the *Diptera brachycera* of New Zealand, *Trans. N.Z. Inst.*, vol. 33, pp. 1–95.

**E. spiniger Schiner.**

*E. spiniger* Schiner, *Verh. Zool.-Bot. Ges. Wien*, vol. 17, p. 309 (1867); Hutton, *Trans. N.Z. Inst.*, vol. 33, p. 4 (1901). *Xylophagus spiniger* Wied.. *Ausser-Europ. Zweif. Ins.*, 2, p. 618 (1830); Hutton, *Cat. Dipt. N.Z.*, p. 35; Hudson, *Man. N.Z. Entom.*, p. 56, pl. vi, fig. 5. *Beris servillei* Macq., *Dipt. Exot.*, 1, p. 176, pl. 21, fig. 1 (1838). *Diphysa spiniger* Macq., *l.c.*, p. 172.

Walker (*Cat. Dipt. B.M.*. p. 1152) considers *Beris albimacula* to be a probable variety of this species.

A large elongate blue-black fly, the legs with white bands. The head slightly broader than the thorax at the humeri; eyes bare, dichoptic, more so in the ♀, in profile occupying the whole side of head, facets of uniform size, no transverse depression. Front widening toward the antennae, dark shiny blue-black with short and scattered silvery reclinate hairs not affecting the ground-colour; a medio-longitudinal depression and two narrow longitudinal grooves, one on each side toward the orbits; immediately above the antennae and occupying the first third of the front is a dense silvery-white proclinate pile which in certain lights gives a dull-black reflection; there is a distinct transverse line separating the reclinate hairs of the front from the pile. Ocellar triangle circular and bare but surrounded by delicate and small hairs more distinct in the ♂; ocelli brownish-yellow. Occiput with dense silvery hairs, longer below.

Face silvery-white due to tomentum, widening below, with a median fissure, the angles of the epistome bare, bluish-black, and slightly projecting; the silvery tomentum lengthens towards the epistome; facial orbits without hairs but with a dense silvery-white tomentum.

The mouth-parts retracted, of a brownish colour with a few scattered black hairs. The palpi, as far as I am able to discern, are 2-jointed, but Schiner says that they are apparently 3-jointed. The penultimate is elongate and restricted, while the ultimate is clavate; the former is bare but for long and scattered hairs arising from distinct pits, while the latter is clothed by dense and short hairs, among which may be seen innumerable minute pits more distinct in the ♀ palp (fig. 1). In the ♂ the 1st joint is about twice as long as the 2nd, brownish but tawny distally; the 2nd is tawny except for a brown band toward the base, and terminates in 4 distinct and stiff hairs which are apparently hollow. The 1st joint in the ♀ is not much longer than the 2nd, which is without a transverse band and completely tawny. In the ultimate joint of the ♂ palp the hairs are less distinct posterior to the transverse band, and the pits are here absent.

Antennae situated a little below the middle line of head, elongate, being about half the width of head in the ♂ and longer in the ♀, the whole fusiform (fig. 2); 1st and 2nd joints and first third of 3rd joint reddish-brown but with a darker reflection, the remainder of the 3rd joint dark brown; 1st and 2nd joints bristly, the latter about two-thirds the length of the former; 3rd joint bare, about three times the sum of the 1st and 2nd, composed of 8 segments, and terminating in a tuft of apical hairs; the ultimate segment is about one-third the length of the whole; the 1st segment is a little longer than the 2nd joint and broader than any other part of the antenna.

Thorax longer than broad, shiny bluish-black, with short and sparse golden tomentum on the dorsum which becomes longer and silvery on the pleurae; a tubercle before the articulation of the wing and a brown and shiny ridge along the dorso-pleural suture interrupted in the middle; the tomentum on the humeri is denser. Scutellum large, coloured and

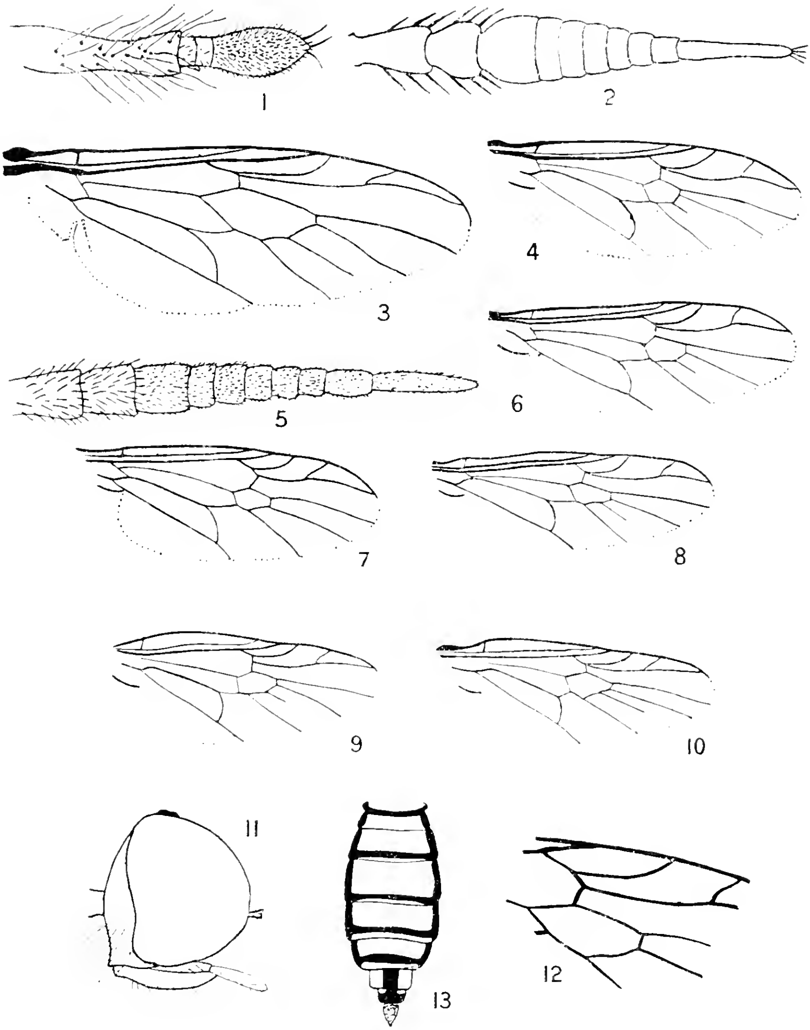

FIG. 1.—Palp of *E. spiniger*.
FIG. 2.—Antenna of *E. spiniger*.
FIG. 3.—Wing of *E. spiniger*.
FIG. 4.—Wing of *E. apicalis*.
FIG. 5.—Antenna of *E. straznitzkii* (♀).
FIG. 6.—Wing of *E. straznitzkii*.
FIG. 7.—Right wing of *E. seolforalis* **n. sp.**
FIG. 8.—Wing of *E. hoheria* **n. sp.**
FIG. 9.—Wing of *A. opposita*.
FIG. 10.—Wing of *A. simmondsii* **n. sp.**
FIG. 11.—Head profile of *B. alpina*.
FIG. 12.—Part of wing of *B. alpina*.
FIG. 13.—Abdomen of *B. alpina*.

clothed as the dorsum; 4 large and hairy spines, black toward the base and reddish-brown distally. In one specimen (♀) close to the base of and beneath both the 2 left-hand spines is a supernumerary spine not much shorter in length. In the ♂ the spines are lighter in colour. Halteres pale grey, sometimes with darker heads.

Posterior legs much longer than the others, their femora club-shaped being distally thickened, bluish-black but for the whitish proximal part; the middle and anterior femora not much more than half the length of the posterior, proximally whitish but otherwise of a more brownish black, the knees tending to brown. Posterior tibiae robust but not distally enlarged, bluish-black and proximally whitish; the remaining tibiae brownish-white, especially distally. Protarsi fully half as long as the whole tarsus; anterior and middle tarsi brownish-white, darker distally, the posterior of a smoky-grey colour. The posterior protarsus of the ♂ is almost white in colour and has a dark spot at the origin; the remaining joints are darker.

Wings deeply clouded with brown between a line through the base of the discal cell and the apex of the wing; axillary angle not sharply curved. The clear spaces are as follow: the articulation; costal cell, except distally at the costa; 1st basal cell, except the spurious vein when present, and 2nd basal cell; a space across the 1st submarginal cell from the costa to the 3rd vein, the proximal edge of which space being in line with termination of 2nd vein and the distal edge in line with origin of anterior branch of 3rd vein; 1st posterior cell slightly lighter along the centre; 2nd to 5th posterior cells distinctly lighter in the centre; discal cell with a faintly lighter space just below the middle line. The anal and axillary cells slightly clouded, the marginal cell very dark, the remainder of the colouring lighter. Costa along the costal cell but slightly outcurved, this cell is thus not widened to any extent; 2nd longitudinal vein gently curved except distally where it meets the costa; anterior cross-vein and 3rd longitudinal having a common origin from the 2nd longitudinal, the 1st section of which being about as long as the anterior cross-vein, which is almost straight and a little posteriorly oblique; 3rd longitudinal distinctly upcurved and in the last section downwards, which is about three-quarters the length of the 1st section (fig. 3); in consequence of the curve of the 3rd vein the anterior branch is comparatively short, being twice as long as the anterior cross-vein; this branch is oblique, arising at an acute angle and more or less distinctly curved to the costa. The 1st submarginal cell is proximally both acute and narrow. Vein between discal and 5th posterior cells straight and about one and a half times the length of anterior cross-vein. A spurious longitudinal vein, sometimes represented by a delicate cloud, along the middle of the 1st basal cell. Of the 4 posterior veins from the discal cell the 3rd reaches three-quarters of the distance to the posterior margin of the wing. The confluence of the 5th and 6th longitudinal veins about three times the length of the anterior cross-vein from the margin.

The abdomen is elongate, fusiform in the ♀, linear and restricted along the middle in the ♂; in the former as broad as thorax beyond the middle, but not broader or as broad as the thorax in the latter; the whole deep shiny-blue with a faint tinge of purple in certain lights. There is a short vestiture of silvery hairs, longer laterally, and so arranged on the posterior margin of each segment as to present a banded appearance. In the ♂ those bands are more or less brown. The abdomen is 7-segmented.

The ♀ genital organs are represented by a pair of 2-jointed tawny styles projecting slightly upwards and arising from the sides of a central dome-shaped tawny plate.

The ♂ genitalia consist above of a pair of short tawny claw-like hairy styles arising from a plate as in the ♀. and beneath this plate is a pair of stout claws being opposed to each other and each arising from a protuberance upon which they apparently articulate.

♂. Length, 7–12·5 mm.; wing, 6–10 mm.

♀. Length, 14 mm.; wing, 12 mm.

*Habitat.*—Throughout New Zealand, but more abundant in Auckland than elsewhere. It is by no means often found as far south as Otago, and is not as common in the South Island as in the North Island, except at Nelson, where the climate is exceptionally warm. The principal localities are Auckland, Napier, Wellington, and Nelson; and it is seen in the months of December, January, and February.

This species is common to Australia and New Zealand.

## E. apicalis Hutton.

*E. apicalis* Hutton, *Trans. N.Z. Inst.*, vol. 33, p. 4 (1901). *Beris apicalis* White, *Voy. "Erebus" and "Terror."* pl. 7, fig. 17; Walker, *Cat. Dipt. B.M.*, p. 126. *Diphysa apicalis* Walker, *l.c.*, p. 1151 (1849); Hutton, *Cat. Dipt. N.Z.*, p. 34. *Exaireta analis* Nowicki, *Mem. Krak. Akad. Wissen.*, 2, p. 11 (1875).

A medium-sized fly with clouded wings and a tawny abdomen dark at the apex.

Head a little broader than the thorax at the humeri; eyes bare, dichoptic, more so in the ♀; a faint emargination above the antennae, very distinct in the ♂. In profile the eyes occupy the whole side of the head. Front shiny black with a tinge of blue and a patch of silvery tomentum just above the antennae, which are situated a little below the middle line of head; about three-quarters the width of the head in ♂ and fully one and a quarter times the head-width in ♀, being characteristically elongated. As a rule the antennae project in front of the head, but in one ♀ they are erect. First and 2nd joints bristly with a shorter pubescence, the 3rd with a dense vestiture of short and stiff pubescence obscuring the segmentation; this joint is linear and almost of equal width throughout. The 2nd joint and proximal portion of 3rd are tawny, the remainder dark brown. The apex of the 3rd joint is of unique form: the penultimate segment is truncated, from one corner of which some short and stiff hairs project; the opposite corner and the adjoining half of the anterior edge of this segment are occupied by the base of the ultimate segment, which is short and oval, terminating in some stiff hairs. Face with a silvery pubescence, darker in certain lights, and with a dark medio-longitudinal stripe. Mouth-parts tawny and withdrawn, the palpi apparently 2-jointed. Occiput shiny black with a silvery tomentum.

Dorsum dark violet-black, faintly purple in certain lights, and dusted with a golden tomentum; humeri tawny; in some cases the dorsum is more or less dark tawny, with a dark violet-black spot posterior to the humeri and extending as a narrow stripe to the transverse suture. Pleurae shiny violet-black, except the sternopleurae which are pitch-black. Scutellum either tawny or dark tawny, tomentose, and with 4 tawny spines. Halteres pale tawny.

Legs tawny, the anterior tarsi fuscous except the proximal portion of the protarsi which is tawny; posterior femora thickened. The anterior and middle protarsi are equal to the sum of the remaining tarsal joints, but the posterior protarsus is only about one-half the sum of the remainder, its epitarsus being but a little shorter.

Wings (fig. 4) clouded with brown distally of the posterior angle of discal cell, across which from the costa and through the marginal cell the coloration is darker; proximally the wing is faintly yellow, with veins of a similar colour, but distally the veins are brown; a clear space in the marginal cell along the 2nd vein and a slightly clearer space in the 1st submarginal cell. The anterior branch of the 3rd vein may be either clouded or unclouded. Axillary angle distinctly rounded. Anterior cross-vein and 3rd vein having a common origin from the 2nd longitudinal, the 1st submarginal cell proximally acute. Anterior branch of 3rd vein arising almost at right angles and gently curved to the costa, and a little longer than the anterior cross-vein, which is anteriorly oblique and slightly curved. Third longitudinal vein angulated at the origin of the anterior branch, and the last section almost straight. Of the 4 posterior veins from the discal cell the 3rd is short, reaching only one-quarter of the distance to the posterior margin. Length of vein between discal and 5th posterior cells but little more than half the anterior cross-vein. The confluence of the 5th and 6th longitudinals about twice the length of the anterior cross-vein from the margin.

Abdomen linear in the ♂ but broadening beyond the middle in the ♀, where it is wider than the thorax. In the ♂ the abdomen may or may nor be restricted along the middle of the sides. There are 7 visible segments; the 1st four and a triangular spot on the anterior margin of the 5th tawny, the remainder iridescent-violet; the 1st is slightly darker. Just before the posterior margin on the 2nd to 4th segments is a darker narrow band not extending to the sides.

The genital organs of both ♀ and ♂ are tawny.

♂. Length, 7 mm.; wing, 6 mm.

♀. Length, 8 mm.; wing, 7 mm.

*Habitat.*—Throughout New Zealand; not rare. Principal localities: Bay of Islands, Auckland, Wellington, Nelson, and Otago. To be found from October to February.

## E. straznitzkii Nowicki.

*E. straznitzkii* Nowicki, *Mem. Krak. Akad. Wissen.*, 2, p. 14 (1875); Hutton, *Trans. N.Z. Inst.*, vol. 33, p. 4, and *Cat. Dipt. N.Z.*, p. 36.

A moderate-sized fly, purplish in colour, with tawny scutellum and legs and a transverse cloud on wing.

♀. Head broader than the thorax at the humeri; eyes bare and dichoptic, occupying almost the whole of the head in profile; a delicate restriction across the eye from just above the antennae, becoming faint toward the occiput; facets of uniform size. Front depressed, of a shiny blackish-blue colour, with a dense silvery pubescence just above the antennae, otherwise with minute scattered hairs; on the front above the antennae is a circular depression from which runs a central groove to the base of the antennae.

Antennae elongate, about one and a half times the width of head and situated a little below the middle line; dark brown, except the 2nd joint and the 1st segment of the 3rd which are brownish yellow; 1st joint about one and a half times the length of the 2nd, and with a vestiture of delicate black bristles; 2nd joint with stronger bristles; 3rd joint pubescent, densely so distally concealing the segmentation. When cleared and examined under a high power 8 segments may be distinguished (fig. 5). Many sensory pits may be seen on these segments, especially toward the outside.

Face silvery tomentose except for a nude and black medio-longitudinal stripe; upon the tomentum, in certain lights, are a few black spots. Mouth-parts tawny, completely withdrawn except for the apices of the palpi. A few hairs around the oral aperture and longer posteriorly.

Thorax on the dorsum shiny and dark reddish-purple, dusted with a tawny tomentum; humeri tawny; pleurae shiny pitch-black with a faint purplish reflection and short silvery down at times indistinct. Scutellum and the 4 spines tawny. Halteres light yellow.

Legs tawny, posterior femora thickened; tarsi darker at the apex, especially those of the anterior and middle legs, almost the whole of the former velvet-brown. Length of tarsal joints as in preceding species.

Wings (fig. 6) with costa straight along the costal cell; anterior cross-vein and 3rd longitudinal not having a common origin from the 2nd vein but nearly so, the 1st submarginal cell being thus proximally acute. Anterior cross-vein curved a little and slightly anteriorly oblique but not short. The remainder of venation practically identical with that of *apicalis*. A dark-brown band across the wing covering the marginal and discal cells and becoming lighter toward the posterior margin; both sides of this band are irregular, and the apex of the marginal cell may be clear. Proximal of the band the wing is faintly tinged with yellow, darker in the costal cell, and the veins yellow; between the band and apex the wing is faintly brown, with brown veins.

Abdomen beyond the middle broader than the thorax, of a shiny-cupreous colour, with a distinct purplish tint, dusted with tawny, and bearing yellow hairs at the sides.

Genital organs represented by a pair of tawny and styliform appendages.

♀. Length, 8 m.m.; wing, 7·5 mm.

Hutton gives the length, apparently of both sexes, as 8–11 mm., and wing 7-8 mm. I have not seen the male, and there are no specimens of the species in Hutton's collection.

*Habitat.*—Auckland (Hutton) and Southland, January (Philpott).

### E. seolforalis n. sp.

A fly of moderate size. Wings unclouded and more or less pellucid. Thorax of a brilliant green, and abdomen—except for the first deeply purple segment—covered by a dense silvery pubescence. The abdomen is characteristic.

Head broader than the thorax at the humeri; eyes bare, dichoptic, more so in ♀, occupying most of head in profile, orbits angulated above the antennae (more marked in ♂), facets of uniform size, no transverse depression in either sex but in the ♂ a narrow bronzy belt; in both sexes lower two-thirds of eye darker than the upper third. Front hairy, narrow, of about equal width throughout, shiny black with a faint bluish tinge and a patch of silvery tomentum just above the antennae, which are situated a little below the middle line of head and not quite as long as the width; 1st to 3rd joints dark brown with a thick pubescence; 1st and 2nd joints short, bristly, and of about equal length; 3rd elongate, club-shaped, and composed of 8 segments terminating in apical delicate hairs.

Face hairy, silvery-tomentose with darker longitudinal reflections. Proboscis hairy and tawny; palpi darker with delicate hairs, the pen-ultimate joint elongate and narrow, tawny, and about as long or a little longer than the ultimate, which is fusiform, and broader than the former, the first quarter tawny, the remainder dark brown caused by a dense pubescence amongst which are one or two delicate hairs. Occiput depressed, shiny black, with no reflections.

Thorax and scutellum brilliant bluish-green, the 4 scutellar spines short and tawny, those of the ♂ longer than in the ♀; dorsum thinly dusted with tawny, humeri slightly tawny. Halteres greyish-white, but darker at the head.

Legs very minutely clothed with stiff hairs, on the whole dark tawny, anterior tarsi fuscous; apex of middle protarsi and remaining 4 joints fuscous; posterior tarsi greyish in certain lights. Protarsi longer than sum of remaining joints, more so the anterior; posterior epitarsi slightly longer than those of the other legs; posterior femora thickened.

Wings (fig. 7), except for the tawny subcostal and marginal cells, unclouded, being either clear or slightly coloured; costal cell normal, not widened; anal angle but distinctly curved; anterior cross-vein and 3rd longitudinal not having a common origin from the 2nd vein, the cross-vein leaving the 3rd vein about half its length from the 2nd vein so that the 1st submarginal cell is more or less proximally truncated or obtuse; cross-vein not short, anteriorly oblique. Third vein not angulated but gently curved, the anterior branch arising at a slightly acute angle and bisinuated to the costa, the 1st sinuation the stronger; this branch is about twice the length of anterior cross-vein. Vein between the discal and 5th posterior cells not quite as long as the anterior cross-vein. Of the 4 veins from the discal cell the 3rd may be absent, rudimentary, or short (absent in the figure). The distance from the posterior margin of the confluence of the 5th and 6th longitudinals equal to the length of the anterior cross-vein.

Abdomen with 7 segments, of uniform width in the ♂ and not as broad as the thorax; in the ♀ broader than the thorax and but little narrower at the base. First segment of a deep shiny purple, the remainder clothed with a dense silky and silvery pubescence which in certain lights shows a darker band on the posterior margin of each segment, due to a slight depression. There are longer silvery hairs at the sides. At times the silvery vestiture may be thinner, showing the ground-colour of the segments (except the 1st) to be tawny. This last feature was noticed in a male.* The 8th segment, when visible, is bare and of a deep purple, the genital organs tawny.

♂. Length, 9·5 mm.; wing, 7·5 mm.

♀. Length, 10 mm.; wing, 8·25 mm.

*Habitat.*—Wellington (Howes); Mount Arthur Tableland, taken in hot sunshine, January, 1889 (Hudson); Kaitoke, November, 1910 (Hudson); Arthur's Pass, 3,000 ft., December, 1914 (Hudson).

This species, on account of abdomen, is unique. Although I have not yet met with specimens, it is apparently a common species.

### E. hoheria n. sp.

A medium-sized slender and dark-coloured fly, with tawny bands on legs and clouded wings with clear spaces.

♀. Head broader than thorax at humeri; eyes bare, dichoptic more so toward the vertex, occupying most of head in profile, no transverse depression, facets of uniform size lower two-thirds darker than upper third; front shiny black with short hairs and a patch of white, slightly yellow,

* Since writing the above I have found this species in large numbers in the bush on the banks of the Manawatu River during December. It abounded in the open glades in sunshine. Most of these specimens had the pubescence of the abdomen very thin.

pubescence above antennae and extending over the face, which has a black medio-longitudinal stripe and longer hairs than on the front. Mouth-parts tawny, proboscis light in colour; palpi completely tawny, the penultimate joint narrow and slightly restricted along middle of sides, bearing long and delicate hairs and about one and a half times the length of the ultimate which is clavate, bare on proximal half but with dense stiff and short hairs and numerous pits on distal half, terminating in at least 1 terminal and 1 subterminal stiff hair.

Antennae dark brown, situated about the middle line and not as long as width of head: 1st joint about twice the length of 2nd, and both bristly; 3rd joint with 8 segments, the first of which is the largest; terminal segment a little longer than the 1st and notched at apex, on one side of which is a tuft of hairs; the whole joint has a dense and stiff pubescence.

Occiput depressed, shiny black with a yellowish-grey tomentum.

Dorsum of thorax greenish-black with violet reflections and dusted with a yellowish-grey tomentum; pleurae coppery with a violet reflection, excepting the sterno-pleurae which are black; scutellum bluish-green but narrowly margined with tawny at the apex, the 4 tawny spines small or indistinct.

Halteres pale yellow with dark-brown heads.

Legs banded with tawny and fuscous, the latter separated by the former, which lies in the middle; posterior femora (which are enlarged) and their tibiae distinctly banded, the middle femora faintly banded being mostly tawny, the anterior tawny; middle and anterior tibiae tawny but for proximal fuscous bands; posterior protarsi and epitarsi light brown, the remainder dark; middle protarsi light brown with a dark distal spot, the remainder dark brown; practically all joints of anterior tarsi dark brown. In form the tarsi resemble the preceding species.

Wings (fig. 8) clouded, axillary angle strongly curved; costal cell widened; 1st submarginal cell proximally acute, the anterior cross-vein and 3rd longitudinal vein having a common origin from the 2nd vein. Third vein strongly sinuated, the anterior branch arising acutely beyond the centre, sinuated slightly, and nearly twice as long as anterior cross-vein, which is slightly anteriorly oblique. Third posterior vein reaching about half-way to the posterior margin. Vein between the discal and 5th posterior cells a little more than half the anterior cross-vein. Distance from the margin of the confluence of the 5th and 6th veins about twice the length of the anterior cross-vein. Veins brown; submarginal cell clouded with dark brown; costal cell clear; 1st submarginal cell clear except proximally and along the branch of 3rd vein; 2nd submarginal cell brown; 1st posterior cell brown, except for a narrow elongate space near the middle; 2nd posterior cell brown except for a space toward the margin; 3rd and 4th posterior cells brown except for a large and square space on distal half into which runs the 3rd posterior vein; 5th posterior cell clear proximally the brown cloud being triangular in form; axillary lobe distinct, with a slightly clear space proximally along the 6th vein; anal cell clear but for a small cloud along the 6th vein near the confluence of the 5th; 1st and 2nd basal cells clouded on proximal half and clear distally; discal cell clouded.

Abdomen with 7 segments, narrower than the thorax at the base but becoming wider at the middle, tapering to a point and terminating in the bifid tawny and styliform appendage. The whole almost blackish-bronze, the 3 apical segments lighter; 1st segment faintly tawny in the middle; 2nd almost all tawny but for sides and posterior margin; the 3rd with a broad tawny spot toward the anterior margin. Ventrally the colour is bright yellow margined with black-bronze, except the 2 apical segments which are coloured below as above.

The ♂ is smaller than ♀. Thorax black-bluish-green; scutellum bright bluish-green, the spines short and tawny. Wings with no clear spot in 2nd posterior cell; space in the 3rd and 4th posterior cells smaller; 3rd posterior vein in one specimen not reaching this space but in another entering it—that is, the 3rd posterior vein of former specimen not reaching half-way to the margin and not more than half-way in the wing of the latter.

Abdomen long and linear, slightly restricted along the middle sides and not quite as broad as thorax; 1st segment without a tawny spot; spot of 2nd smaller than that of ♀ and with a faintly darker central stripe; the 3rd segment with a clear tawny spot on the anterior margin, and the 4th with a similar but smaller spot.

The ♀ and smaller ♂ were bred by Mr. Philpott from pupae found under the bark of a dead ribbonwood-tree at Wallacetown, while a larger ♂ was captured by him on a tree-trunk at night on the West Plains.

Another ♂ captured by him in Otago measures only 7 mm., and wing 5 mm. The tawny spots of the abdomen are here indistinct, only to be faintly seen in certain lights, and the wings are not so deeply clouded with brown; in this case the 3rd posterior vein barely reaches half-way to the margin.

♂. Length, 8–9 mm.; wing, 6·25–6·75 mm.

♀. Length, 8 mm; wing, 7 mm.

*Habitat.*—West Plains (Otago), February; Wallacetown, October.

## Genus Actina Meigen.

This genus, as has been said, differs from *Exaireta* in the eyes being pubescent, but on reviewing the wings we find further differences. In *Actina* the costal cell is distinctly widened by a curve of the costa: this is characteristic of six other new forms obtained after the following were described, but which will form part of a future "contribution." The costal cell is not widened in *Exaireta*. Again, the 3rd longitudinal vein is not so strongly sinuated in *Actina* as in *Exaireta*.

The two species mentioned below may be distinguished by the following table:—

(*a*.) First submarginal cell proximally obtuse; abdomen tawny, with blackish-brown bands widening laterally .. .. *opposita*.
(*b*.) First submarginal cell proximally acute; abdomen brownish-black, 3rd to 5th segments with anterior tawny band .. *simmondsii* n. sp.

## A. opposita Walker.

*Exaireta opposita* Hutton, *Trans. N.Z. Inst.*, vol. 33, p. 5 (1901).
*Actina opposita* Walker, *Cat. Dipt. B.M.*, pt. 5, Supp., p. 13 (1854); Hutton, *Cat. Dipt. N.Z.*, p. 35.

♂. A medium-sized fly with brilliant green thorax and tawny, banded abdomen.

Eyes with delicate scattered and yellow hairs, cupreous with no transverse markings, closely approximated below middle line of front and occupying side of head in profile. Ocellar triangle Prussian blue, more or less prominent, situated well in front of the posterior eye-corners—that is, as if upon the front—the eye-corners at the vertex being well behind the triangle, which bears some long hairs, apparently not arranged in series; posterior to the triangle the vertex is rounded, carrying long hairs, and of a brilliant greenish-blue, this colour extending across the occiput to the foramen as an elongate triangle; occiput rounded, violet-black, and hairy especially below where they are silvery; front blue-black with delicate brown hairs, narrow especially toward the antennae, above which it suddenly widens to form a triangular area of silvery ash-grey pubescence, along which is a narrow and darker medio-longitudinal stripe.

Antennae about half the width of head or a little more, and situated at the middle line; 1st and 2nd joints bristly, the latter about three-quarters the length of the former, both yellow, but the 1st, owing to the denser bristles, darker than the 2nd; 3rd joint composed of 8 segments, densely pubescent and with 2 terminal hairs, the penultimate segment also having some longer hairs apically; all the 1st and undersides of 2nd and 3rd segments yellow, the remainder fuscous. The dorsal edge of this joint is straight, the ventral approaching the dorsal toward the apex.

Face strongly widening below, hairy, the hairs longer and denser below, shiny blue-black with a greyish pubescence at epistome; facial orbits densely greyish-pubescent; oral margin violet-black and densely hairy, slightly produced downwards posteriorly; proboscis and palpi pale yellow, the latter small and indistinct.

Dorsum of thorax and scutellum brilliant bluish-green, with a vestiture of minute and delicate hairs, each hair arising from a minute depression, giving, on the whole, a delicate punctured appearance. The scutellum is, if anything, bluer than the dorsum, the 4 strong spines being yellow but darker at the base. Humeral and post-alar calli dark tawny, the former with distinct yellow hairs. In certain lights the dorsum may be bronzy-green, violet-blue, or golden. Pleurae with silvery hairs, coloured as the dorsum but the reflections more pronounced.

Anterior and middle femora and tibiae pale yellow; posterior femora thickened, darker than the others and fuscous at the apex; posterior tibiae thickened but not strongly so, darker than the others, slightly fuscous at the knees but strongly fuscous on apical quarter. Anterior tarsi fuscous, the middle pale yellow but darker apically, the posterior thickened, darker than the middle and slightly fuscous toward the apex. All the protarsi longer than the following joint.

Wings yellowish, the veins yellow, the marginal cell clouded with yellow; costal cell strongly widened; auxiliary vein sinuated at apex; 1st submarginal cell proximally obtuse; the 3rd vein apparently arising from anterior cross-vein; 1st section of 3rd vein about half the length of the anterior cross-vein, which is perpendicular; 3rd vein slightly sinuated, the anterior branch fully twice as long as anterior cross-vein, arising almost at right angles and bisinuated to the costa (fig. 9); 3rd posterior vein not reaching half-way to margin of wing; vein between the discal and 5th posterior cells a little longer than anterior cross-vein; distance from the margin of the confluence of the 5th and 6th veins nearly three times the length of anterior cross-vein. Anal angle strongly curved.

Halteres pale yellow.

Abdomen with 7 segments, of equal width throughout, almost as wide as thorax, with a vestiture of dense pale-yellow hairs along the sides and short hairs on dorsal surface; 1st segment blackish-brown but for a central tawny part extending on to the posterior margin and not separated from the colour of following segment; 2nd to 4th segments tawny, each with a narrow posterior blackish-brown band widening laterally to form a triangular spot on the sides at the posterior corners. Although along the middle this band is separated from the posterior margin by a narrow and tawny fusiform area, it extends on to the margin at the sides; 5th and 6th segments with the blackish-brown band not produced as a triangle at the sides, and in the latter not extending completely across the segment; 7th segment small, the brown band occupying almost the whole surface, only a slight tawny area on each side. The genital organs are tawny and withdrawn.

In the ♀ the abdomen is oval, broader than the thorax, and dark tawny with dark-brown bands as in the ♂. The legs are also dark tawny but without fuscous markings, while the thorax is not so brilliant in colour.

♂. Length, 8 mm.; wing, 6·5 mm.

♀. Length, 8 mm.; wing, 6·5 mm.

*Habitat.*—Wellington, December (Howes), November (Hudson); Auckland (Bolton and Broun); Otago (Hutton).

### A. simmondsii n. sp.*

♂. A medium-sized fly with green thorax and dark-brown abdomen with tawny markings.

Eyes holoptic just below middle of front, distinctly pubescent; front bluish-green with silvery reflections toward the ocellar triangle, which is prominent and bears long and erect stiff hairs.

Antennae dark-brown almost black, situated a little below middle line but not as long as the width of head; 1st and 2nd joints bristly, the latter about a third as long as the former, which is comparatively elongate; 3rd joint about twice the sum of the 1st and 2nd, composed of 8 segments, and clavate in form; ultimate segment almost a third as long as the whole joint.

Face with long brownish-grey hairs, darker in certain lights, and an indistinct and darker medio-longitudinal stripe. Proboscis and palpi tawny. Occiput flat, black with a silvery tomentum.

Dorsum, pleurae, and scutellum bright bluish-green, with a vestiture of erect and tawny scattered hair; the 4 scutellar spines tawny and short, indistinct on account of vestiture. Halteres pale tawny.

Legs tawny, tarsi fuscous more so apically; the posterior pair lost on my only specimen.

Wings very faintly tinged with brown, the veins brown; marginal cell clouded with brown but lighter apically; 1st submarginal cell proximally acute; costal cell enlarged; 3rd vein almost straight, the anterior branch about three times length of anterior cross-vein which is slightly anteriorly oblique; 3rd posterior vein reaching more than half-way to the margin; vein between the discal and 5th posterior cells longer than but not twice as long as anterior cross-vein. Distance from the margin of the confluence of the 5th and 6th veins about four times length of anterior cross-vein. Anal angle strongly rounded.

Abdomen brownish-black, not quite as broad as thorax, rectilinear and of a uniform width throughout, in profile swollen at the apex, consisting of 7 visible segments, the apical bearing an extruded and down-turned tawny appendage; 3rd to 5th segments margined anteriorly by a tawny band broader at the sides, except on the 3rd, where the band is uniformly thin throughout; apical segment tawny; ventral side dull tawny bordered by brownish-black; apical segments coloured ventrally as dorsally. The whole coverd by long tawny hairs longer at the sides and shortening apically.

♂. Length, 8 mm.; wing, 6·5 mm.

*Habitat.*—Runanga, January (Howes); Titahi Bay, December (Simmonds).

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* I have taken the liberty to name this species after Mr. Simmonds, of Auckland, who collected the first specimens at Titahi Bay.

Genus BERISMYIA Giglio-Tos.

I have placed the following species, *Exaireta alpina* of Hutton, in this genus on account of the position of the antennae below the middle line of head and the presence of only three posterior veins in the wing. I have no specimens of this species at my disposal beyond Hutton's type species, which is a female.

B. alpina.

*Exaireta alpina* Hutton, *Trans N.Z. Inst.*, vol. 33. p. 5 (1901).

♀. A moderately large fly with bluish-green thorax and the abdomen dark tawny, the sides of which and the posterior margin of each segment dark green; legs tawny and wings yellowish. At first sight this species resembles in colour the female of *A. opposita*, but its much larger size and margined abdomen, as well as the position of the antennae and number of posterior veins, at once place it as a distinct species.

Eyes dichoptic, bare, occupying side of head in profile, a faint depression a little above the antennae. Ocellar triangle and front blue-black and shiny, the former more or less prominent and the latter with a patch of silvery-grey tomentum above the antennae, which are elongate, being longer than width of head, and situated below the middle line (fig. 11); black in colour but for base and underside of 1st segment of the 3rd joint, which is dark tawny; 1st and 2nd joints bristly, the latter half as long as the former; 3rd joint composed of 8 segments, densely pubescent, and terminating in several short and delicate hairs.

Face shorter than front and strongly receding, covered by a silvery-white tomentum (black in certain lights), along which is a dark medio-longitudinal and narrow stripe Proboscis pale tawny palpi large and projecting in front of proboscis; penultimate joint elongate and narrow, longer than the ultimate, and pale tawny with delicate hairs; ultimate joint fusiform, about two-thirds length of preceding, tawny at base and on inner side, otherwise black. Occiput shiny black, more or less rounded, with some scattered silvery tomentum above but hairy below, and produced backward at the oral margin.

Thorax brilliant bluish-green, especially the pleurae, the sterno-pleurae a darker green; the dorsum with a scattered greyish tomentum, the pleurae with silvery hairs. Humeral and post-alar calli dark tawny, the latter golden in certain lights. Scutellum brilliant bluish-green margined with tawny, the 4 spines short and dark tawny.

Wings tinged with yellow, deeper at the base and in costal and marginal cells; veins yellow; costal cell broadened slightly; 1st submarginal cell proximally obtuse, the 1st section of 3rd vein not quite as long as anterior cross-vein, which is slightly oblique anteriorly (fig. 12); 3rd vein slightly sinuated, the anterior branch arising at right angles from the middle and strongly bent to the costa; only 3 posterior veins, there being no sign of a 4th; vein between discal and 4th posterior cells not quite twice length of anterior cross-vein. Distance from the margin of the confluence of the 5th and 6th veins not twice the length of anterior cross-vein. Anal angle strongly rounded. Halteres yellow.

Legs tawny, the femora and tibiae stout, the posterior femora thickened; anterior tarsi fuscous, especially the protarsi.

Abdomen with 7 visible segments about as wide as thorax, oval or almost rectangular excluding the 6th and 7th segments (fig. 13). The whole tawny, but segments 1 to 5 bordered along the sides by deep shiny-green which is continued across the middle of the 1st segment; the 2nd to 5th segments with a transverse dark-green band near the posterior margin; the 6th segment has a broad fuscous stripe in the middle, while the 7th and terminal appendage are more or less totally fuscous. The ventral side is yellow.

What I have called the 6th and 7th abdominal segments are probably a portion of the extruded ovipositor, since they differ not only in colour but are abruptly smaller than the 5th. However, at present I am unable to place this species in any of the genera which have 5 visible segments as their character.

♀. Length, 10 mm.; wing, 9 mm.

*Habitat.*—Mount Arthur, 3,600 ft. (Hudson).

## Genus Beris Latreille.

Captain Hutton (*l.c.*, pp. 5–7) described four species of this genus, three of which were new forms; of the fourth—*B. substituta* Walk.—neither Hutton nor I have representatives, though I am inclined to think that the female of *violacea* Hutton may be a *substituta*.

To those already recorded I add four other new species, bringing the total to eight; but, since some possess features markedly different from those characteristic of this genus, it may be found necessary later on to place them in other genera. A notewothry example is *cuprea* of Hutton; in this form the 1st and 2nd posterior veins arise from a common pedicle from the apex of the discal cell, which is thus apically acute, the 1st and 3rd posterior cells being here contiguous. Curiously enough, this is the only species of the eight which has holoptic eyes in the male, a feature peculiar to *Beris*. However, all but two of the following forms have the eyes more or less characteristically hairy, but the flagellum of the antennae, which should have 8 segments, has only 7 in all the species but one—*caliginosa* n. sp.—while at least the 1st and 2nd segments of the flagellum in *saltusans* n. sp. are distinctly hairy. Moreover, in these two forms, the 1st, 3rd (except anterior branch), 5th, and 6th longitudinal veins are distinctly bristly.

The anterior cross-vein arises from the 3rd longitudinal, but in none of the following do both have a common origin from the 2nd, though the 1st section of the 3rd vein varies in position and length.

According to the following table the species fall into two chief divisions, according as to whether the eyes be hairy or bare; in the former the legs are banded, but in the latter of a uniform colour.

Table of Species.

| | | |
|---|---|---|
| 1 | Eyes hairy and legs banded* .. | 2 |
| | Eyes bare and legs not banded | 6 |
| 2 | Eyes distinctly hairy; 1st, 3rd (except anterior branch), 5th, and 6th longitudinal veins bristly | 3 |
| | Eyes minutely or indistinctly hairy; veins not bristly | 4 |
| 3 | Flagellum minutely pubescent .. | *caliginosa* n. sp. |
| | Flagellum hairy on first two segments at least | *saltusans* n. sp. |
| 4 | First section of 3rd vein longer than, or equal to, anterior cross-vein | 5 |
| | First section of 3rd vein shorter than anterior cross-vein .. | *micans*. |
| 5 | Wings clear but for a transverse band; thorax brilliant bluish-green | *lacuans* n. sp. |
| | Wings clouded but clearer at apex; thorax dull-bronzy .. | *violacea*. |
| 6 | First and 2nd posterior veins arising from a common pedicle | *cuprea* |
| | First and 2nd posterior veins normal .. | *refugians* n. sp. |

* *Substituta* is not included in this table, but it falls into the first division owing to colour of legs; as has been said, it may equal *violacea*. The legs of *micans* are not as distinctly banded as the other species of this division.

### B. substituta Walker.

*B. substituta* Walker, *Cat. Dipt. B.M.*, Supp., 5, p. 12 (1854); Hutton, *ib.*, p. 6. *Actina substituta* Hutton, *Cat. Dipt. N.Z.*, p. 34.

"Dull green or aeneous green. Antennae black. Palpi testaceous. Scutellum with 4 tawny spines. Abdomen purplish-cupreous. Legs tawny, femora and tibiae with brown bands. Wings greyish, the stigma and veins black.

"This species has 3 externo-medial veins, and the 1st branch of the cubital vein is very short, proceeds almost directly to the border, and thus forms an unusually large angle with the second branch.

"Length, 2 lines: wings, $3\frac{3}{4}$ lines.

"Auckland (Colonel Bolton)."—Walker, *l.c.*

### B. violacea Hutton.

*B. violacea* Hutton, *Trans. N.Z. Inst.*, vol. 33, p. 6 (1901).

♀. Eyes broadly dichoptic with minute and scattered hairs; front broad, shiny blackish-brown with short scattered greyish hairs, and, above the antennae, a patch of greyish pubescence dead-black in certain lights and notched on the posterior margin. Antennae below middle line of head, long but not as long as width of head; 1st joint shiny black, the 2nd light brown, and both bristly (fig. 14); flagellum linear, covered by a dense stiff and black pubescence giving a tawny reflection in certain lights, composed of 7 almost equal segments except the ultimate which is about twice the length of the penultimate, both of which having terminal hairs. Face broad, shiny black with a few scattered silvery hairs; proboscis tawny and thinly hairy, palpi (fig. 15) 2-jointed, both of about equal length and projecting beyond the proboscis; 1st joint blackish and hairy, the 2nd brown with a darker apex, fusiform, minutely pubescent, and terminating in 3 bristle-like hairs. Occiput shiny black and depressed, hairy below.

Dorsum of thorax dull-bronzy with dull-greenish reflections and a finely punctured appearance; pleurae shiny blue-black and slightly hairy. Scutellum coloured as dorsum, with 4 light-brown but not large spines.

Wings clouded with greyish-brown but clear toward the apex: veins brown; stigma dark brown; base of the wing and anterior part of the costal cell clearer. First section of 2nd longitudinal vein about twice as long as anterior cross-vein, the 2nd section but slightly bent into the 1st submarginal cell; 1st section of 3rd vein a little longer than anterior cross-vein, which is perpendicular; 3rd vein curved upward to the bifurcation and thence sinuated downwards to the costa, the anterior branch arising almost at right angles and but very slightly bent to the costa (fig. 16); basal cells closed behind by an oblique transverse vein, the vein separating those cells represented by a furrow and clear line along which the membrane easily splits; confluence of the 5th and 6th longitudinal veins distant from the margin about three times the length of anterior cross-vein. Halteres with greyish-white heads and darker stalks.

Legs banded with dark and light brown, the proximal portions of each joint being of the latter colour, less distinct on the middle and anterior legs and more especially the latter, the tibiae of which have also a light-brown marking in the middle; posterior tibiae dark brown. The protarsi barely one-half as long as the whole joint, mostly light brown but for the apex, the remaining tarsal segments dark brown except for a light-brown band (sometimes indistinct) at the origin of each, but the anterior and middle tarsi vary from light to dark according to the light.

Abdomen broader than the thorax at the widest part, apically truncated, and shiny Prussian blue; the genital appendages paired, tawny, 2-jointed, and hairy.

♂. Antennae a little longer than those of the ♀ owing to the elongation of the flagellar segments; 2nd joint more or less black. Apex of palpi darker than ♀ and the hair beneath the eyes longer. Wings and legs also darker in colour. Thorax dull black and slightly shiny.

♂ and ♀. Length, 5 mm.; wing, 4 mm.

*Habitat.*—Abundant in swarms about bushes and flowers in the sunlight. Christchurch and Otago (Hutton): Christchurch, December; Manawatu, November and December (Miller): Wellington (Atkinson).

### B. cuprea Hutton.

*B. cuprea*, Hutton, *l.c.*, p. 6.

♀. Eyes bare, broadly dichoptic; front brilliant shiny black; antennae not slender, situated below middle line, barely half length of head-width and comparatively shorter than those of *violacea;* 2nd joint black and bristly; flagellum blackish-brown—except for the first segment, which is tawny and broader than the others—composed of 7 segments of about equal length* covered by a dense stiff pubescence and terminating in 3 apical hairs; the ultimate segment, though short, is about twice the length of the penultimate, which bears longer hairs on the anterior margin. Occiput depressed.

Thorax humped and rounded above, brilliant bronze sometimes with a deep bluish-green sheen; scutellum coloured as dorsum, the 4 spines brownish-yellow but not large.

Legs tawny, not banded; onychotarsi black, protarsi about half the length of whole joint; posterior femora not thickened.

Wings faintly tinged with yellow, the stigma and veins yellow; anterior branch of 3rd vein arising at right angles and slightly curved to the costa (fig 17), the 1st section of the 3rd vein shorter than anterior cross-vein; discal cell apically acute; 3 posterior veins, but the 1st and 2nd arise from a common pedicle, the 1st and 3rd posterior cells being thus contiguous at apex of the discal cell; 3rd posterior vein distinctly separated from the 2nd basal cell; 5th and 4th vein evanescent toward their origin, the latter somewhat indistinct. Halteres tawny.

Abdomen ovate, broader than the thorax at the widest part, shiny blackish-brown. From the apical segment project a pair of short, 2-jointed appendages, the 1st joint tawny and longer than the 2nd, which is black, ovate, and terminates in long hairs.

♂. "Eyes contiguous; abdomen narrow and linear; the 2nd posterior cell petiolate" (Hutton).

There is now no male specimen in Hutton's collection, and as I have no representatives of this species beyond Hutton's female type above described a fuller description is at present impossible.

♀. Length, 4 mm.; wing, 3 mm.

*Habitat.*—Auckland and Maketu (Broun).

* As Hutton's type, described above, is attached to a card, the first antennal joint, face, and proboscis are not visible; and, since the wings are incumbent, the venation cannot be accurately determined without damaging the specimen.

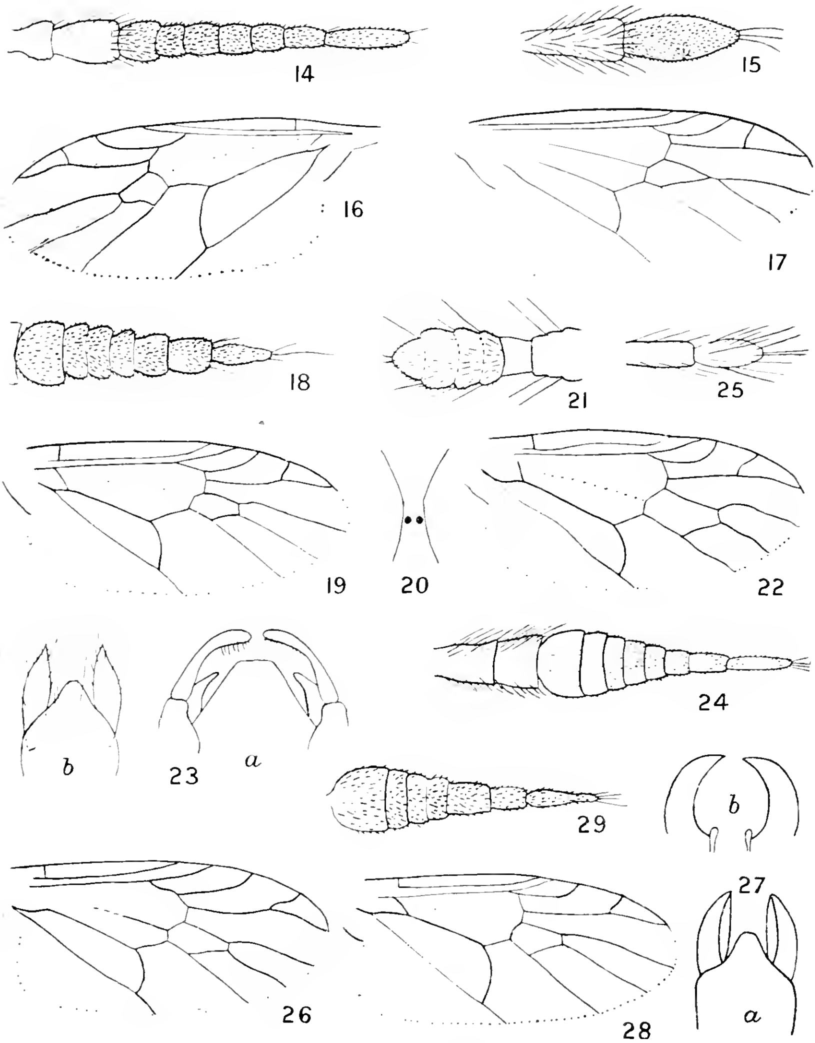

FIG. 14.—Antenna of *B. violacea.*
FIG. 15.—Palp of *B. violacea.*
FIG. 16.—Wing of *B. violacea.*
FIG. 17.—Wing of *B. cuprea.*
FIG. 18.—Flagellum of *B. micans.*
FIG. 19.—Wing of *B. micans.*
FIG. 20.—Showing eye-margins of *B. saltusans* n. sp
FIG. 21.—Palp of *B. saltusans* n. sp.
FIG. 22.—Wing of *B. saltusans* n. sp.
FIG. 23.—Genitalia of *B. saltusans* n. sp.
FIG. 24.—Antenna of *B. caliginosa* n. sp.
FIG. 25.—Palp of *B. caliginosa* n. sp.
FIG. 26.—Wing of *B. caliginosa* n. sp.
FIG. 27.—Genital appendages of *B. caliginosa* n. sp.
FIG. 28.—Wing of *B. lacuans* n. sp.
FIG. 29.—Flagellum of *B. refugians* n. sp.

### B. micans Hutton.

*B. micans* Hutton, *ib.*, p. 6.

♀. Eyes broadly dichoptic, with delicate and indistinct scattered hairs; front shiny black with a patch of silvery pubescence above the antennae; this patch is dull black in certain lights and notched on posterior margin. Antennae situated below middle line, somewhat short and stout; 1st and 2nd joints bristly, the former black and about as long as the latter, which is brownish and square in shape; flagellum black with a dense and stiff pubescence obscuring the segmentation—however, the ultimate segment is not quite twice as long as the penultimate, both of which have distinct terminal hairs (fig. 18). Face shiny black with a greyish tomentum and a few black delicate hairs, while scattered over the surface are several circular black spots. Proboscis pale tawny; palpi testaceous or tawny, 2-jointed, the 1st hairy and the 2nd minutely pubescent with an indistinct terminal bristle. Occiput flat but not depressed.

Dorsum of thorax rounded, of a brilliant greenish-blue with darker bronzy reflections, the humeri testaceous; scutellum coloured as dorsum but narrowly margined with tawny, the spines large and tawny; halteres pale tawny.

Legs tawny, the posterior femora and tibiae with darker reflections; the tarsi (except protarsi and proximal part of epitarsi) fuscous; all the protarsi longer than the epitarsi but not half as long as the whole joint.

Wings yellow or faintly tinged with yellow, stigma light yellow and veins yellow; 3rd vein almost straight, the anterior branch arising at right angles and but slightly curved to the costa; 1st section of 3rd vein not as long as anterior cross-vein, which is perpendicular; vein between the basal cells obsolete and represented by a limpid line; basal cells closed posteriorly by an oblique cross-vein (fig. 19).

Abdomen brownish-black and shiny, beyond the middle broader than the thorax.

The ♂ differs from the ♀ only in length, and perhaps in the colour of the thorax, which is of a more brilliant bluish-green. Hutton's type is a male, the antennae of which are lost.

♂. Length, 4 mm.; wing, 3·75 mm.

♀. Length, 5 mm.; wing, 4·5 mm.

*Habitat.*—♂, Colac Bay, December (Howes); Auckland (Broun). ♀, West Plains, Otago, October (Philpott).

### B. saltusans n. sp.

♂. Black. Head black; eyes distinctly hairy, dichoptic, the margins angulated just above the antennae (fig. 20); front slightly narrowing toward the antennae, shiny black, and distinctly hairy. Antennae blackish-brown, situated below middle line and, if anything, a little longer than half the width of head; 1st joint elongated, the 2nd about two-thirds as long as the 1st, and both bristly on the upper side; all but the first 2 segments of flagellum missing; 1st segment nearly as long as 2nd antennal joint but broader, the 2nd segment shorter, and both distinctly hairy. Face dull black with distinct brownish hairs except beneath the antennae where it is bare and shiny black; oral margin shiny bluish-black; proboscis brownish; palpi 2-jointed and blackish-brown, and both presenting a peculiar segmented appearance; 1st joint bristly, the sides notched (fig. 21), from which notches arise long bristle-like hairs; 2nd joint more or less clavate, apparently divided into 5 segments from the anterior corners of which (except of the 1st) arise bristle-like hairs; the 1st of these segments is bare and brown in colour, the remainder having a vestiture of dense light-brown pile, the apical terminating in a pair of indistinct and short brown bristles. Posterior orbits broad, black, and hairy; occiput shiny black and flat.

Dorsum and scutellum shiny black with a covering of greyish hairs; scutellar spines black, short, and indistinct; pleurae brownish and slightly hairy; halteres brownish.

Wings shorter and blunter than preceding species, clouded with brown, but darker anteriorly than posteriorly with clear intercellular spaces; stigma darker brown but a clear space separating the pigment from the 2nd vein; veins brown; all the veins on posterior half excepting the 5th longitudinal weaker than those on anterior half; subcostal cell more or less clear except for a cloud along auxiliary vein as far as bend at apex; a clear space at the anterior apical corner of 1st basal cell, the colour also being separated from the 1st vein; in the 2nd basal cell is a more or less clear space apically, while these two basal cells are separated by a clear line, the vein being here obsolete; clearer spaces at apex of anal cell, in discal cell, in the posterior cells (that of the 1st posterior cell being in the form of a median line), and in the 1st submarginal cell at the costa. Costa curved outwards along costal cell, which is thus somewhat widened; auxiliary vein sinuated, 1st section of 3rd vein about twice as long as anterior cross-vein; 3rd vein slightly down-curved along posterior branch; the anterior branch arising at right angles and strongly curved to the costa (fig. 22); apex of discal cell slightly beyond the line of end of 2nd longitudinal vein; the 1st, 3rd (except anterior branch), 5th, and 6th longitudinal veins distinctly bristly.

Legs hairy, slightly stouter than in preceding species; femora and tibiae dark brown, their tarsi brown except proximal portions of protarsi and epitarsi which are greyish-brown; protarsi not quite half as long as the whole joint; posterior femora, tibiae, and protarsi perceptibly thickened; middle and anterior legs more hairy than the posterior, and the lighter portions of the tarsi of these legs somewhat darker than the posterior.

Abdomen ovate, composed of 7 segments, broader than the thorax, apically truncated, and brown in colour. Genitalia (fig. 23) more or less withdrawn; composed of an outer pair of 2-jointed, hairy, claw-like styles (*a*), while toward the base of each on the inner side is a small pointed and bare chitinous structure; between these outer claws is a pair of shorter, flat, and pointed hairy structures arising from a dome-shaped piece (*b*). The genitalia were damaged when mounting, so that a fuller account cannot be given

♂. Length, 4 mm.; wing, 4 mm.

*Habitat.*—Wallacetown. October. Captured in the bush by Mr. A. Philpott.

The chief characters which separate *saltusans* from the preceding species are the angulated eye-margin, hairy flagellum, and hairy legs, the 4 bristly veins, and the position of the apex of the discal cell beyond the end of the 2nd longitudinal vein. Doubtless it will have to be placed in another genus.

### B. caliginosa n. sp.

♂. Eyes distinctly hairy, not broadly dichoptic; front shiny black and distinctly hairy; antennae blackish-brown, about the length of the width of one eye and situated on the middle line; 1st joint not much longer than the 2nd, both bristly above and below (fig. 24); flagellum clavate, distinctly 8-segmented, minutely pubescent, and terminating in short hairs; face with a dense and brownish tomentum, covered with long black hairs except on the lower part, there being only a few very short ones at the epistome; proboscis and palpi tawny, the latter projecting beyond the former; 1st palpal joint longer than the 2nd (fig. 25), both bearing long and stiff bristle-like hairs; posterior orbits not broad, of about equal width throughout, and with long black hairs below; there are distinct postorbital bristle-like hairs; occiput black, depressed, and hairy.

Dorsum of thorax violet-black, slightly shiny with short and delicate greyish hairs; pleurae black, shiny, and hairy; scutellum bare, shiny violet, the 4 spines distinct and brown; halteres pale brown.

Legs stouter than usual, indistinctly banded with brown and dark brown, the latter colour on the distal half of each joint; posterior femora club-shaped, their tibiae slightly thickened, and tarsi light brown except apex of the slightly thickened protarsi, epitarsi, and the whole of the remaining joints, which are dark brown: the tarsi of the other legs are also darker distally, but their protarsi are not so light in colour as the posterior; all the protarsi are barely half the length of the whole joint.

Wings faintly tinged with brown: veins brown, the auxiliary vein paler; the stigma brown but the pigment separated from the 1st longitudinal vein; 1st section of 2nd longitudinal vein—that is, the part between the origin and the orgin of the 3rd vein—sinuated and about twice the length of the anterior cross-vein; 1st section of 3rd vein shorter a little than the anterior cross-vein, which is more or less anteriorly oblique; 3rd vein distinctly sinuated, the anterior branch forming an acute angle and strongly sinuated; apex of discal cell behind the line of end of second vein; vein separating the two basal cells obsolete only along proximal half; 1st, 3rd (except anterior branch), 5th, and 6th longitudinal veins bristly (fig. 26).

Abdomen brown (except the 1st segment, which is black) and darker at the sides, with 7 segments, about as wide as the thorax, not apically truncated but more or less pointed, and terminating in the tawny genital organs (fig. 27, *a* and *b*). The apical segment, slightly down-turned and projecting backward, is a pair of short hairy boat-shaped appendages separated by a cone-shaped structure (*a*), beneath which is a pair of strong inner claws (*b*), and outside these long claw-like bristles.

♂. Length, 6 mm.; wing, 5 mm.

*Habitat.*—Dunedin, November (Howes).

## B. lacuans n. sp.

♂ (?). Eyes minutely hairy and dichoptic; front shiny bluish-black, with a few delicate hairs and a patch of silvery tomentum just above the antennae: this tomentum is darker in certain lights and notched along posterior margin; antennae situated about the middle line of head or perhaps a little below, not elongate, not as long as width of an eye, blackish-brown, the base of the flagellum dark testaceous; 1st and 2nd joints short, of about equal length, and bristly: flagellum with a dense pubescence, 7-segmented, the 1st broad, the ultimate about twice as long as the penultimate and terminating in a tuft of hairs. Face black, thinly hairy and with a delicate greyish tomentum; proboscis pale yellow; palpi tawny pubescent, and 2-jointed, projecting beyond the proboscis; 1st joint hairy, lighter in colour than the 2nd, which is fusiform and terminates in a pair of black stiff hairs. The arrangement of the vestiture of both palpal joints gives an indistinct segmented appearance; in the 2nd joint there appears to be 7 such segments, the 1st distinct and forming a neck. Occiput depressed and indistinctly hairy; posterior orbits much narrowed above but slightly widened below, with long hairs at lower end and beneath the eyes; posterior orbital hairs present, short and bristle-like—a character of all the species described in this genus.

Dorsum brilliant bluish-green, the humeri and post-alar calli tawny; pleurae shiny blackish-brown with a tuft of greyish hairs below the humeri; scutellum brilliant bluish-green margined with tawny, the 4 spines large and tawny.

Anterior and middle legs tawny with darker markings on femora and tibiae, metatarsi and onychotarsi fuscous, protarsi about half as long as the whole joint. The posterior legs, halteres, and abdomen lost.

Wings clear but for the dark-brown stigma and a broad transverse median brown cloud; veins dark brown; auxiliary vein not sinuated (fig. 28); 1st section of 3rd vein, if anything, a little longer than the anterior cross-vein; anterior branch of 3rd vein arising at right angles and slightly curved forward to the costa, the posterior branch almost straight; anterior cross-vein nearly perpendicular. Apex of discal cell posterior to line of end of 2nd longitudinal, which runs almost straight from the 1st vein before turning up to the costa; vein between the basal cells obsolete and represented by a clear line and furrow; an oblique vein closing the basal cells behind.

Length of wing, 5 mm.

This type, though incomplete, is quite distinct from the other species.

*Habitat.*—Wallacetown, January (Philpott).

### B. refugians n. sp.

♀. Eyes bare, moderately dichoptic; front narrow and greyish-yellow, due to a dense tomentum; ocellar triangle blackish-brown; antennae situated about middle line of head, blackish-brown with a testaceous band in the middle, in length about half the width of head; 1st and 2nd joints bristly, the former slightly elongated, the latter shorter and basin-shaped; flagellum (fig. 29) pubescent, clavate, and composed of 7 segments, the first 4 testaceous and semi-diaphanous, the remainder blackish-brown; the ultimate segment terminates in distinct hairs.

Face with a silvery tomentum darker in certain lights, a few scattered yellow hairs and a dark spot beneath the antennae; there are also a few longer yellow hairs beneath the eyes; proboscis and palpi a delicate pale yellow, the former with yellow hairs; palpi not reaching in front of proboscis, 2-jointed; the 1st densely pubescent with longer yellow hairs and a slightly darker reflection, the 2nd about as long as the 1st, minutely pubescent, fusiform, and ending in a distinct blackish-brown bristle; oral margin shiny blackish-brown with an anterior tubercle. Posterior orbits pubescent, narrowed toward the vertex, and with a tuft of long hairs below; posterior orbital hairs distinct; occiput depressed at the vertex, but slightly convex below, and of a greenish-yellow colour.

Thorax comparatively small considering the abdomen, shiny and bare but for a minute and scattered tomentum on the dorsum; humeri pale green with a dark mark beneath; dorsum tawny with darker reflections, the margins of the transverse suture and the anterior margin between the humeri blackish-brown ; in certain lights may be seen 2 lighter longitudinal stripes anterior to the transverse suture, while posterior to it are 2 black stripes, the edges of the dorsum also being here margined with black ; those 4 stripes posterior to the suture do not extend to the scutellar suture ; pleurae pale yellowish-green with brownish markings on the pteropleurae and mesopleurae ; the lower half of the pteropleurae and sternopleurae dark brown ; metapleurae hairy ; scutellum apple-green with a darker brownish base, the spines short and pale yellow ; halteres dark tawny.

Legs tawny but paler than the coxae ; tarsi fuscous from the apex of the epitarsi to the onychotarsi (inclusive) : in certain lights the posterior protarsi with a darker mark at the apex ; posterior tibiae with a darker tawny colour above ; posterior femora slightly thickened ; the protarsi of all legs a little more than half the length of the whole joint.

Wings very faintly tinted with yellow ; stigma pale yellow ; veins brownish-yellow ; auxiliary vein not sinuated ; 1st section of 2nd vein about three times the length of the anterior cross-vein and almost parallel to the costa ; 1st section of 3rd vein shorter than anterior cross-vein, the 2nd section slightly sinuated to the bifurcation, the anterior branch arising at a slightly acute angle and distinctly curved forward to the costa, the posterior branch curved downward and forming an obtuse angle with the 2nd section ; apex of discal cell distinctly posterior to apex of 2nd vein ; anterior cross-vein anteriorly oblique ; vein separating the basal cells present ; both basal cells closed toward the base, the 2nd of those cells being considerably narrower than the 1st.

Abdomen covered with delicate minute and bristle-like hairs, fusiform, about twice as long as the thorax and distinctly broader, composed of 7 segments, the apex upturned and bearing the 2 styliform appendages ; the whole tawny but semi-diaphanous on basal half, while at the base is a blackish spot ; each segment except the 1st and 6th margined posteriorly with blackish-brown, which on the 2nd, 3rd, and 4th segments extends to and along the lateral margins in the form of a triangular spot ; in the middle, at the anterior margin of the 4th segment is a circular black spot ; on the 5th the black margin hardly extends to the posterior corners, on the 6th it is confined more or less to the centre of the posterior margin, while on the apical segment it forms a broader and wider marking. The 1st joint of the styliform appendages is tawny, hairy, and equal in length to the 2nd, which is elongate, fusiform, and tawny on proximal half but black distally, carrying long hairs. The apical segment of the abdomen is hairy.

♀. Length, 6 mm. ; wing, 5·75 mm.

*Habitat.*—Dunedin, in the bush, January (Miller) ; Ranfurly, February (Howes).

# ART. XII.—*A List of the Lepidoptera of Otago.*

By ALFRED PHILPOTT.

Communicated by Dr. W. B. Benham, F.R.S.

[*Read before the Otago Institute, 7th December, 1915; received by Editors, 30th December 1916; issued separately, 16th July, 1917.*]

IN 1901 I published a "Catalogue of the Lepidoptera of Southland" (*Trans. N.Z. Inst.*, vol. 33, p. 167). In 1904 this was supplemented by "Notes on Southern Lepidoptera" (*Trans. N.Z. Inst.*, vol. 36, p. 161), which added many species to the list and extended its scope to Otago. Since that date work on our Lepidoptera has been steadily carried on, many more species have been recorded and a large number of new forms described. There remains, however, a great deal of work still to be done. The rugged and forest-clad country of Fiordland has, so far, been almost entirely neglected, and Stewart Island has received very little attention. Owing to the facilities which rail and steamer afford, the neighbourhood of Lake Wakatipu has received an undue share of attention, and it will probably be found that when entomologically explored the vast block of mountainous country lying between the Waiau River and the western coast will prove as rich in species as the better-known Lakes district.

I am indebted to other workers for much valuable information, freely supplied. It is to be understood, however, that where I have used such data I have had an opportunity of examining the species referred to, so that the responsibility for any errors rests with myself. To Messrs. W. G. Howes, F.E.S., C. C. Fenwick, M. O. Pasco, Charles E. Clarke, and F. S. Oliver my most cordial thanks are due. Mr. G. V. Hudson, F.E.S., has placed me under a debt of gratitude for his advice and interest in the carrying-out of the work. Lastly, the authoritative series of "Revisions" by Mr. E. Meyrick, F.R.S., which have appeared in the later volumes of the *Transactions*,* have enabled me, I hope, to complete my task with a minimum of synonymical error.

The list deals with a total of 671 species, comprised in 159 genera.

METACRIAS HUTTONI (Butl.). *Cist. Ent.* 2, 487; Huds., *N.Z. M. & B.* 4, pl. 4, 6.

Wakatipu. November to February. From 3,000 ft. to 5,000 ft. The form occurring on the Remarkables is much larger but otherwise identical.

M. STRATEGICA Huds., *Entom.* (1889), 53; Meyr., *Trans. N.Z. Inst.* 22, 216.

Generally distributed in mountainous regions, and descending to the lowland plains round Invercargill. It is somewhat remarkable that though occurring on Flagstaff Hill (about 1,000 ft.) it does not appear to be found on the less elevated country in the vicinity of Dunedin. The perfect insects appear about the middle of November and are over by the end of January. The larvae feed on various grasses, both indigenous and introduced; during the winter they hibernate, and may be found under logs and at the base of tufts of grass. The species frequents open country, but penetrates into the forest wherever there are grassy tracks.

* Vol. 43, p. 78; vol. 44, p. 88; vol. 45, p. 30; vol. 47, p. 205.

NYCTEMERA ANNULATA (Boisd.), *Voy. Astr.* 5, 197, pl. 5, 9; Meyr., *Trans N.Z. Inst.* 22, 218.

Generally distributed in open country. October to May. The species is now less common than formerly, owing to the destruction of much of the food-plant (*Senecio jacobaea*) of the larva.

HELIOTHIS ARMIGERA Hubn., *Samml. Eur. Schmett.* 370; Meyr., *Trans. N.Z. Inst.* 19, 34.

Invercargill; Dunedin. March. Rare. Apparently occasional stragglers only reach the neighbourhood of Invercargill.

EUXOA RADIANS Guen., *Noct.* 1, 261.

Dunedin; Alexandra. October and November. Invercargill, a single specimen at blossom of *Rubus australis* in October.

E. ADMIRATIONIS (Guen.), *Ent. Mo. Mag.* 5, 38; Huds., *N.Z. M & B.* 31, pl. 5, 37.

Dunedin; Wakatipu; Alexandra; Ida Valley. December to April.

AGROTIS YPSILON (Rott.), *Naturf.* 9, 141; Meyr., *Trans. N.Z. Inst.* 19, 32.

Generally distributed. October to April.

A. INNOMINATA Huds., *N.Z. M. & B.* 31, pl. 5, 39.

Dunedin. August to October. Found in plenty by Mr. C. C. Fenwick on the lupin-covered sandhills near St. Clair. This is the only known southern locality.

GRAPHIPHORA COMPTA (Walk.), *Cat.* 10, 404; *immunis* Meyr., *Trans. N.Z. Inst.* 19, 30.

Invercargill; Tuatapere. Probably generally distributed in lower forest districts. Much more common in the autumn.

AUSTRAMATHES PURPUREA (Butl.), *Cist. Ent.* 2, 490; *ceramodes* Meyr., *Trans. N.Z. Inst.* 19, 31.

Dunedin. October to June. Common.

ANDESIA PESSOTA (Meyr.), *Trans. N.Z. Inst.* 19, 29.

Wakatipu. February to April. Fairly common.

HOMOHADENA FORTIS Butl., *Cist. Ent.* 2 549; *iota* Huds., *Trans. N.Z. Inst.* 35, 243, pl. 30, 3.

Invercargill, rare, October; Wakatipu, to 3,000 ft., common, August to April.

ICHNEUTICA CERAUNIAS Meyr., *Trans. N.Z. Inst.*, 19, 13.

Woodend (Invercargill); Tuturau; Waipori; Wakatipu and Hunter Mountains, to 5,000 ft. November and December. Not common.

I. CANA Howes, *Trans. N.Z. Inst.* 46, 96.

Hector Mountains. A single example in November.

I. DIONE Huds., *N.Z. M. & B.* 14.

Hunter Mountains. Not uncommon at flowers of *Dracophyllum longifolium* at about 3,250 ft.

LEUCANIA PURDII Frdy., *Trans. N.Z. Inst.* 15, 195.

Dunedin; Routeburn. December to March. Larva on *Astelia nervosa* var. *montana.*

L. ACONTISTIS Meyr., *Trans. N.Z. Inst.* 19, 9.

Generally distributed; rare near Invercargill.

L. UNICA Walk., *Cat.* 9, 112; Meyr., *Trans. N.Z. Inst.* 19, 10.

Dunedin; Wakatipu; Alexandra. November and December. Dunedin examples are darker and have the veins less clearly marked with blackish than the mountain forms. There seems also to be a more frequent tendency to the presence of a subterminal series of black points across the wing.

L. LISSOXYLA Meyr., *Trans. N.Z. Inst.*, 43, 70.

Several taken on Flagstaff Hill, Dunedin, in March, by Mr. C. E. Clarke.

L. PHAULA Meyr., *Trans. N.Z. Inst.*, 19, 10.

Invercargill; Waipapa; Dunedin. November to February. Not common.

L. ALOPA Meyr., *Trans. N.Z. Inst.*, 19, 10.

Invercargill; Flagstaff Hill; Wakatipu. November to March. Common. Wakatipu examples are usually paler and have the stigmata more clearly defined.

L. BLENHEIMENSIS Frdy., *Trans. N.Z. Inst.* 15, 196.

Dunedin; Paradise; Routeburn. November to March.

L. SEMIVITTATA Walk., *Cat.* 32, 628; Meyr., *Trans. N.Z. Inst.* 19, 12.

Generally distributed in forest districts. November to March.

L. SULCANA Frdy., *Trans. N.Z. Inst.* 12, 267, pl. 9, 3.

Generally distributed. February to April.

L. STULTA Philp., *Trans. N.Z. Inst.* 37, 330, pl. 20, 1.

Invercargill; Tuturau. October to December.

ALETIA MICRASTRA (Meyr.), *Trans. Ent. Soc. Lond.* 1897, 383; Huds., *N.Z. M. & B.* 12, pl. 4, 10.

Invercargill; Gore. March. A scarce insect.

A. NULLIFERA (Walk.), *Cat.* 11. 742; Meyr., *Trans. N.Z. Inst.* 19, 7.

Riversdale; Wakatipu; Waipori; Dunedin. January to March.

A. MODERATA (Walk.), *Cat.* 32, 705; *griseipennis* Huds., *N.Z. M. & B.* 9, pl. 4, 8

Generally distributed. November to March. The note on *griseipennis* (*Trans. N.Z. Inst.* 33, 168) refers to this species.

A. GRISEIPENNIS (Feld.), *Reis. Nov.* 109, 22; *moderata* Meyr., *Trans. N.Z. Inst.* 19, 7.

Wakatipu; Orepuki; Dunedin. November to March.

A. FALSIDICA (Meyr.), *Trans. N.Z. Inst.* 43, 70; *hamiltoni* Hamps., *Ann. & Mag. Nat. Hist.* 12, 594.

Bold Peak. February.

A. LATA Philp., *Trans. N.Z. Inst.* 47, 192.

Vanguard Peak; Bold Peak. December and January. I think it probable that this form should be under *Ichneutica*.

A. TEMENAULA (Meyr.), *Trans. N.Z. Inst.* 39, 107.

Dunedin; Wakatipu; Omakau (Central Otago). March and April.

A. PACHYSCIA (Meyr.), *Trans. N.Z. Inst.* 39, 107.

Wakatipu. January.

A. LONGSTAFFI (Howes), *Trans. N.Z. Inst.* 43, 128, pl. 1, 3.

Generally distributed, but rare near Invercargill. February and March.

A. OBSECRATA Meyr., *Trans. N.Z. Inst.* 46, 101.

Ben Lomond, 2,000 ft. to 3,000 ft.; Remarkables; Kinloch. November to February. Not uncommon. Flying swiftly by day over rough herbage.

A. SMINTHISTIS (Hamps.), *Cat.* 5, 280, pl. 86, 17.

Waipori. November to January. I take *sollennis* Meyr. (*Trans. N.Z. Inst.* 46, 101) to be a faded or discoloured specimen of this species.

PHYSETICA COERULEA (Guen.), *Ent. Mo. Mag.* 5, 38; Meyr., *Trans. N.Z. Inst.* 19, 5.

Mataura; Orepuki; Wakatipu; Alexandra. October to April.

PERSECTANIA DISJUNGENS (Walk.), *Cat.* 15, 1681; Meyr. *Trans. N.Z. Inst.* 19, 15.

Mataura; Wakatipu; Dunedin; Wedderburn. Ascends to 5,500 ft. November to January.

P. STEROPASTIS (Meyr.), *Trans. N.Z. Inst.* 19, 22.

Generally distributed. November to March. Larva on *Phormium tenax* and *Arundo conspicua*, to which plants it does much injury. It is also sometimes found on *Cordyline australis*. When full-grown the larva is 37–40 mm. in length. It is dull-brownish-yellow, faintly tinged with pink, and slightly fusiform in shape. The anal third is darker owing to the suffused fuscous bordering of the lines. The dorsal and subdorsal lines are thin and pale yellow. The head is flesh-coloured. During the day the larvae hide away in the old sheaths at the base of the plants, coming out after dark and feeding along the margin of the leaves, in which they cut deep V-shaped incisions.

P. EWINGII (Westw.), *Proc. Ent. Soc.* 2, 55; *composita* Meyr., *Trans. N.Z. Inst.* 19, 22.

Generally distributed. November to May.

P. AROTIS (Meyr.), *Trans. N.Z. Inst.* 19, 11.

Invercargill; Dunedin. September to November. Hampson calls this species *aulacias* Meyr., but in uniting the two forms Hudson selected the name *arotis*, which must stand in accordance with article 28 of the International Rules of Zoological Nomenclature.

P. ATRISTRIGA (Walk.), *Cat.* 33, 756; Meyr., *Trans. N.Z. Inst.* 19, 8.

Generally distributed. January to April.

P. PROPRIA (Walk.), *Cat.* 9, 111; Meyr., *Trans. N.Z. Inst.* 19, 9.

Generally distributed. February to April.

ERANA GRAMINOSA Walk., *Cat.* 11, 605; Meyr., *Trans. N.Z. Inst.* 19, 28.

Dunedin. September to April.

MELANCHRA MEYRICKI (Hamps.), *Ann. & Mag. Nat. Hist.* 8, 8, 421; *pictula* Meyr., *Trans. N.Z. Inst.* 19, 18.

Wakatipu. November to April. The figure in Taylor's *Te Ika a Maui* evidently refers to *rhodopleura* of Meyrick. There is no trace of the white reniform of *meyricki*, neither are the hindwings even tinged with scarlet.

M. EXQUISITA Philp., *Trans. N.Z. Inst.* 35, 246, pl. 32, 2.

Invercargill; Queenstown; Alexandra; Ida Valley. October to February.

M. PLENA (Walk.), *Cat.* 33, 744; Meyr., *Trans. N.Z. Inst.* 19, 17.

Generally distributed. August to April, and occasionally during the winter months also.

M. PAUCA Philp., *Trans. N.Z. Inst.* 42, 544.
Invercargill. March. Very rare.

M. OCTANS Huds., *N.Z. M. & B.* 25, pl. 5. 1.
Orepuki; Orawia; Dunedin. September to March.

M. GRANDIOSA Philp., *Trans. N.Z. Inst.* 35, 246, pl. 32, 1.
Invercargill. May. Since the two type specimens (♂ and ♀) were taken in 1901 the species has not been met with.

M. MAYA Huds., *N.Z. M. & B.* 17, pl. 4, 31.
Wakatipu. September to March.

M. DECORATA Philp., *Trans. N.Z. Inst.* 37. 329, pl. 20, 2.
Generally distributed. August to March.

M. DIATMETA Huds., *N.Z. M. & B.* 21, pl. 5, 5.
Generally distributed. September to March.

M. INSIGNIS (Walk.). *Cat.* 33, 724; *polychroa* Meyr., *Trans N.Z. Inst.* 19, 16.
Generally distributed. Common from September to May, and often to be met with during the winter months. In so very varied a species it is difficult to draw any satisfactory conclusions, but it may be noted that Invercargill specimens are shorter-winged than those from other localities, and that the males are more pink-tinged. Mountain forms appear to tend more to purplish in the males and cinereous-grey in the females.

M. MUTANS (Walk.). *Cat.* 11, 602, Meyr.: *Trans. N.Z. Inst.* 19, 17.
Generally distributed. August to May.

M. BEATA Howes, *Trans. N.Z. Inst.* 38, 509, pl. 44, 2.
Invercargill; Dunedin. September and October.

M. USTISTRIGA (Walk.). *Cat.* 11. 630; Meyr., *Trans. N.Z. Inst.* 19. 26.
Generally distributed. August to March. Larva on *Muehlenbeckia australis.*

M. PARACAUSTA (Meyr.). *Trans. N.Z. Inst.* 19. 15.
Generally distributed. September to January. The mountain form of this species is usually without the blackish-brown median stripe, the basal streak only being present. The white areas of the lowland variety are also wanting, the ground-colour tending to a uniform ochreous-grey.

M. COELENO Huds., *N.Z. M. & B.* 26, pl. 4, 39.
Generally distributed; rare in the neighbourhood of Invercargill, fairly common at Queenstown. October to December.

M. INFENSA (Walk.), *Cat.* 11. 748; *arachnias* Meyr., *Trans. N.Z. Inst.* 19, 23.
Generally distributed. October to December.

M. OMAPLACA (Meyr.), *Trans. N.Z. Inst.* 19, 24.
Invercargill; Dunedin; Wakatipu; Ida Valley. September to March.

M. ALCYONE Huds., *N.Z. M. & B.* 24, pl. 5, 14.
Invercargill; Dunedin; Queenstown. August to October. Rare.

M. RUBESCENS (Butl.), *Cist. Ent.* 2. 489; Meyr., *Trans. N.Z. Inst.* 19, 25.
Generally distributed. October to March. Not common in the neighbourhood of Queenstown, where its place seems to be taken by the following species.

M. PASCOEI (Howes), *Trans. N.Z. Inst.* 44, 205.
Orepuki; Queenstown; Flagstaff Hill. August to December

M. MOLLIS Howes, *Trans. N.Z. Inst.* 40, 533.
Invercargill. December. Rare.

M. CHRYSERYTHRA (Hamps.), *Cat. 3rd Suppl.* 1668A.
Orepuki; Gore; Bold Peak; Routeburn. December.

M. LIGNANA (Walk.), *Cat.* 11, 758; Meyr., *Trans. N.Z. Inst.* 19, 26.
Dunedin; Wakatipu. February to April.

M. PANISCOLOR (Howes), *Trans. N.Z. Inst.* 44, 204.
Dunedin. October and November.

M. STIPATA (Walk.), *Cat.* 33, 753; Meyr., *Trans. N.Z. Inst.* 19, 25.
Generally distributed. September to May, and occasionally during the winter.

M. MEROPE Huds., *N.Z. M. & B.* 19, pl. 5, 2.
Orepuki; Ben Lomond; Dunedin. October to April.

M. DOTATA (Walk.), *Cat.* 11, 522; Meyr., *Trans. N.Z. Inst.* 19, 24.
Orepuki; Wakatipu. October to April.

M. ASTEROPE Huds., *N.Z. M. & B.* 24, pl. 5, 15.
Bold Peak; Routeburn. December.

M. TARTAREA (Butl.), *Proc. Zool. Soc. Lond.* 1877, 384, pl. 42, 2; Meyr., *Trans. N.Z. Inst.* 19, 21.
Generally distributed. December to April.

M. AGORASTIS (Meyr.), *Trans. N.Z. Inst.* 19, 18.
Generally distributed. December to April. Fairly common at Queenstown, rare in other localities.

M. VITIOSA (Butl.), *Proc. Zool. Soc. Lond.* 1877, 384, pl. 42, 3; Meyr., *Trans. N.Z. Inst.* 19, 20.
Generally distributed. August to April. In *Trans. N.Z. Inst.* 33, 170, and 36, 163, this and the following species are dealt with under the names *proteastis* and *vitiosa* respectively.

M. OCHTHISTIS (Meyr.), *Trans. N.Z. Inst.* 19, 20.
Generally distributed. A few in August, and apparently a second brood from February to April.

M. MOROSA (Butl.), *Cist. Ent.* 2, 513; *pelistis* Meyr, *Trans. N.Z. Inst.* 19, 20.
Generally distributed. January to June. Specimens taken at Broad Bay, Otago Peninsula, are without any pink tinge, and have the hind-wings of a very dark fuscous. Dark examples of this species are difficult to separate from *agorastis*, but the latter is somewhat shorter-winged and has a broad blunt anterior thoracic crest in place of the pronounced bifid one of *morosa*.

M. LEVIS Philp., *Trans. N.Z. Inst.* 37, 330, pl. 20, 4.
Invercargill; Dunedin. September to February. Rare.

M. LITHIAS (Meyr.), *Trans. N.Z. Inst.* 19, 17.
Wedderburn (Central Otago); Hunter Mountains, in January, at 3,000 ft.

M. HOMOSCIA (Meyr.), *Trans. N.Z. Inst.* 19, 21.
Invercargill; Dunedin; Wakatipu. September to May.

M. PRIONISTIS (Meyr.), *Trans. N.Z. Inst.* 19, 27.
Generally distributed. September to May, and occasionally during the winter.

M. PHRICIAS (Meyr.), *Trans. N.Z. Inst.* 20, 46; *temperata* Meyr. (*nec* Walk.), *Trans. N.Z. Inst.* 19. 27.
Wakatipu. October to April. A variety is not uncommon in which the dorsum is strongly margined with black.

M. PRAESIGNIS (Howes), *Trans. N.Z. Inst.* 43, 128, pl. 1, 4.
Orepuki; Wakatipu. September to March.

M. OLIVERI (Hamps.), *Ann. & Mag. Nat. Hist.* 8, 424.
Ben Lomond; Routeburn. December.

BITYLA DEFIGURATA (Walk.), *Cat.* 33, 756; Meyr. *Trans. N.Z. Inst.* 19, 31.
Generally distributed. September to May. Worn hibernating specimens may frequently be found during the winter under loose flakes of bark or in crevices of trees.

B. SERICEA Butl., *Proc. Zool. Soc. Lond.* 1877, 387, pl. 42, 12; Meyr., *Trans. N.Z. Inst.* 19, 31.
Queenstown. March to May.

ARIATHISA COMMA (Walk.), *Cat.* 9, 239; Meyr., *Trans. N.Z. Inst.* 19, 30.
Generally distributed. November to March.

HYPENODES COSTISTRIGALIS Steph., *Ill. Brit. Ent.* 4, 20; *exsularis* Meyr., *Trans. N.Z. Inst.* 20, 46.
Invercargill. March.

OPHIDERES MATURNA (L.). Huds., *Trans. N.Z. Inst.* 40, 105, pl. 15, 5.
One taken at Dunedin in March by Mr. G. Howes. Probably introduced in a consignment of bananas.

DASYPODIA SELENOPHORA Guen., *Noct.* 3, 174; Meyr., *Trans. N.Z. Inst.* 19, 38.
Invercargill. November to February. Occasional examples.

RHAPSA SCOTOSIALIS Walk., *Cat.* 34, 1150; Meyr., *Trans. N.Z. Inst.* 19, 38.
Generally distributed. October to May.

TATOSOMA LESTEVATA (Walk.), *Cat.* 1416; Meyr., *Trans. N.Z. Inst.* 16, 67.
Wakatipu; Cape Saunders (Otago Peninsula). November and December.

T. TRANSITARIA (Walk.), *Cat.* 1419; Meyr., *Trans. N.Z. Inst.* 43, 71.
Humboldt Range, in December. A single worn example of what appears to be this species was secured by Mr. C. C. Fenwick.

T. AGRIONATA (Walk.), *Cat.* 1417, Meyr., *Trans. N.Z. Inst.*, 43, 71.
Generally distributed. November to May. Frequents dense forest and also more open situations, and, in common with the two following species, is much attracted to the flowers of indigenous plants, such as species of *Rubus*, *Parsonsia*, and *Weinmannia*.

T. TIPULATA (Walk.), *Cat.* 1417; Meyr., *Trans. N.Z. Inst.* 43, 71.
Generally distributed. September to December. Larva on *Nothofagus cliffortioides* and *Weinmannia racemosa*. The palpi in the ♀ of this form are fully twice as long as in the ♀ of *agrionata*.

T. TIMORA Meyr. (*agrionata nec* Walk.), *Trans. N.Z. Inst.* 16, 68.
Generally distributed. October to May.

T. ALTA Philp., *Trans. N.Z. Inst.* 45, 76.

The Hump; Wakatipu. From 2,500 ft. to 4,500 ft. November to December.

T. TOPIA Philp., *Trans. N.Z. Inst.* 35, 246, pl. 32, 3 and 4.

Generally distributed in bush districts. November to March. A variety of the ♀ occurs in which the forewing, from $\frac{1}{4}$ to $\frac{4}{5}$, is almost wholly white.

T. FASCIATA Philp., *Trans. N.Z. Inst.* 46, 118.

Lake McKenzie, in November; Hunter Mountains, in December, at 3,500 ft.

T. APICIPALLIDA Prout, *Trans. N.Z. Inst.* 46, 122.

Ben Lomond; Bold Peak. November and December.

PARADETIS PORPHYRIAS (Meyr.), *Trans. N.Z. Inst.* 16, 59.

Not uncommon in the neighbourhood of Lake Wakatipu, where it is usually found near the banks of the mountain streams. Occasional examples occur near Invercargill, and it has been met with at about 3,000 ft. on the Hunter Mountains. December to February.

CHLOROCLYSTIS SEMIALBATA (Walk.), *Cat.* 1708; *indictataria* Huds., *N.Z. M. & B.* 44, pl. 6, 17 ♂, 17A ♀.

Generally distributed in both forest and open scrub lands. October to March. Very variable; it is possible that two species are confused under this name.

C. SANDYCIAS Meyr., *Trans. Ent. Soc. Lond.* 1905, 219; *plinthina* Huds., *N.Z. M. & B.* 41, pl. 6, 8.

Generally distributed. October to January. Extremely abundant in some localities. The remarks under *plinthina* (*Trans. N.Z. Inst.* 33, 172) refer to this species.

C. PLINTHINA (Meyr.), *Trans. N.Z. Inst.* 20, 49.

Invercargill, July and August; Hunter Mountains, a worn specimen in December at an elevation of 3,500 ft. Apparently a winter form at low elevations, and emerging at a later date in the mountains.

C. MUSCOSATA (Walk.), *Cat.* 1246; *bilineolata* Huds., *N.Z. M. & B* 41, pl. 6, 9 and 10.

Generally distributed. October to May. Fairly common.

C. BILINEOLATA (Walk.), *Cat.* 1246; *antarctica* Huds., *N.Z. M. & B.* 42, pl. 6, 20.

Generally distributed. November to January.

C. PARALODES Meyr., *Trans. N.Z. Inst.* 45, 23.

Wakatipu. This species is very similar to *bilineolata*, but if only a variety of that species it does not appear to occur in the vicinity of Invercargill.

C. LACUSTRIS Meyr., *Trans. N.Z. Inst.* 45, 24.

Wakatipu. Also closely resembling *bilineolata*.

C. LUNATA Philp., *Trans. N.Z. Inst.* 44, 115.

Invercargill; Dunedin; Wakatipu. December and January. Variable: mountain forms are more strongly marked. The white mark in the middle of the wing of the ♀ is frequently absent. Larva on *Veronica salicifolia*.

C. aristias Meyr., *Trans. Ent. Soc. Lond.* 1897, 385; Huds., *N.Z. M. & B.* 42, pl. 6, 21 and 22.

Ben Lomond. December and January.

C. halianthes Meyr., *Trans. N.Z. Inst.* 39, 108.

Wakatipu. November to January.

C. rubella Philp., *Trans. N.Z. Inst.* 47, 193.

Ben Lomond; Bold Peak. December and January.

C. modesta Philp., *Trans. N.Z. Inst.* 47, 193.

Ben Lomond and Bold Peak, at altitudes of from 3,000 ft. to 4,000 ft. December and January.

C. luminosa Philp., *Trans. N.Z. Inst.* 47, 192.

Routeburn; Ben Lomond, at 2,000 ft. December.

C. magnimaculata Philp., *Trans. N.Z. Inst.* 47, 193.

Queenstown; Flagstaff Hill, at about 1,000 ft. November to January. Specimens from Flagstaff are smaller and darker than Wakatipu examples.

C. maculata Huds., *N.Z. M. & B.* 44, pl. 6, 18.

Bluff; Queenstown. October to January. Rare.

C. malachita Meyr., *Trans. N.Z. Inst.* 45, 25.

Wakatipu.

C. lichenodes (Purd.), *Trans. N.Z. Inst.* 19, 70.

Generally distributed. December to February.

C. sphragitis (Meyr.), *Trans. N.Z. Inst.* 20, 51.

Generally distributed. November to February. Not common.

C. neries (Meyr.). *Trans. N.Z. Inst.* 20, 51; *minima* Huds., *Trans. N.Z. Inst.* 37, 356.

The Hump; Hunter Mountains; Wakatipu; Flagstaff Hill. From 1,000 ft. to 4,000 ft. December and January. The species varies greatly in size, ranging from 15 mm. to 24 mm. in wing-expanse, but the variation does not appear to be climatic or seasonal, and is probably connected with the food-supply of the larva. Mr. Hudson now regards his *minima* as an unusually small specimen of this species.

Microdes epicryptis Meyr., *Trans. Ent. Soc. Lond.* 1897, 384.

Generally distributed. September to March.

M. villosata Guen.

Stewart Island. April. A pair obtained by Mr. R. Fisher, and now in the collection of Mr. G. Howes.

Phrissogonus denotatus (Walk.), *Cat.* 1361; Meyr., *Trans. N.Z. Inst.* 20, 53.

Dunedin. September to February.

Elvia glaucata Walk., *Cat.* 1431; Meyr., *Trans. N.Z. Inst.* 15, 65.

Generally distributed. November to July. Attached to dense and damp portions of the forest. Near Invercargill a tendency is shown towards a darkening of the ground-colour, the normal green giving place to dark-bluish-fuscous.

EUCYMATOGE ANGULIGERA (Butl.), *Cist. Ent.* 2, 507; Meyr., *Trans. N.Z. Inst.* 41, 5.

Generally distributed. October to March. Some varieties strongly resemble *E. gobiata*, but the present species can always be separated from that species by the pronounced blunt projection in middle of outer edge of median band, and the marked pink flush of the undersides.

E. GOBIATA (Feld.), *Reis. Nov.* 131, 2; Meyr., *Trans. N.Z. Inst.* 16, 70.

Generally distributed. September to June.

HYDRIOMENA DELTOIDATA (Walk.), *Cat.* 1321; Meyr., *Trans. N.Z Inst.* 16, 70.

Generally distributed. December to March.

H. HEMIZONA Meyr., *Trans. Ent. Soc. Lond.* 1897, 385; Huds., *N.Z. M. & B.*, 48, pl. 7, 10.

Longwood Range, to 2,500 ft.; Wakatipu. December to February. Some specimens have the median band strongly marked; in others it is hardly traceable.

H. SUBOCHRARIA (Dbld.). *Dieff. N.Z.* 2, 285; Meyr., *Trans. N.Z. Inst.* 16, 73.

Stewart Island; Invercargill; Queenstown. February. Rare.

H. RIXATA (Feld.), *Reis. Nov.* 132, 1; Meyr., *Trans. N.Z. Inst.* 16, 75.

Generally distributed. December to February. Particularly attached to the banks of streams. The species appears to become progressively more dull and suffused in colour towards the southern limits of its distributional area, Invercargill specimens being darker than those from the neighbourhood of Dunedin, and these in turn being less bright than those from farther north.

H. PURPURIFERA (Frdy.), *N.Z. Journ. Sci.* 1883; Meyr., *Trans. N.Z. Inst.* 16, 119.

Generally distributed in forest to about 3,000 ft. December and January. Wakatipu specimens have the hindwings much lighter in colour than those from lower elevations.

H. SIMILATA (Walk.), *Cat.* 1413; Meyr., *Trans. N.Z. Inst.* 16, 76.

Generally distributed. November to May. A striking variety, with the median band wholly black, occurs occasionally in the Invercargill area.

H. CALLICHLORA (Butl.), *Cist. Ent.* 2, 509; Meyr., *Trans. N.Z. Inst.* 16, 76.

Generally distributed. September to March.

H. ARIDA (Butl.), *Cist. Ent.* 2, 505; *chaotica* Meyr., *Trans. N.Z. Inst.* 16, 76.

Generally distributed. September to March.

H. SUBRECTARIA (Guen.), *Phal.* 10, 411.

Queenstown, in November. An occasional example. Found also in Australia, where, I learn from Mr. G. Lyell, it is widespread but not very common. New Zealand specimens are somewhat darker than those which I have seen from Australia.

H. TRIPHRAGMA (Meyr.), *Trans. N.Z. Inst.* 16, 74; *siris* Hawth., *Trans. N.Z. Inst.* 29, 283.

Otago Peninsula. Common from September to November.

H. SIRIA (Meyr.), *Trans. N.Z. Inst.* 16, 93.

Invercargill. Very local. October and November. The specimens from which the species was described are said to have been obtained at Dunedin by the late Captain Hutton prior to 1883, but no subsequent collector has found the species in that locality.

EUCHOECA RUBROPUNCTARIA (Dbld.), *Dieff. N.Z.* 2, 287; Meyr., *Trans. N.Z. Inst.* 16, 60.

Generally distributed, but not common, in the southern portion of Otago. November to February.

ASTHENA PULCHRARIA (Dbld.), *Dieff. N.Z.* 2, 286; Meyr., *Trans. N.Z. Inst.* 16, 69.

Table Hill (Stewart Island); Fiordland; Wakatipu. November to March. The species does not occur at elevations much below 1,000 ft.

A. SCHISTARIA (Walk.), *Cat.* 782; Meyr., *Trans. N.Z. Inst.* 16, 69.

Generally distributed. October to April.

VENUSIA VERRICULATA (Feld.), *Reis. Nov.* 131. 20; Meyr., *Trans. N.Z. Inst.* 16, 62.

Generally distributed. October to June. The larva feeds on *Cordyline australis.* It is pale-greenish with chocolate-brown markings; a subdorsal chain of spots, two on each segment; a supra-lateral line of spots, one on each segment; a strong lateral line; several spots on each segment below lateral line. It eats freely of the young leaves of its food-plant, cutting irregular indentations. It is subject to the attacks of an ichneumon fly, which pupates within the skin of the dead caterpillar, and, when ready to emerge, gnaws a circular hole through the dorsal surface of the anal segments.

V. XANTHASPIS (Meyr.), *Trans. N.Z. Inst.* 16, 61.

Wakatipu. December to February.

V. CHARIDEMA Meyr., *Subant. Isl. N.Z.* 70.

Kinloch; Ben Lomond; Flagstaff Hill (Dunedin). From 1,000 ft. to 2,500 ft. November and December. Originally described from Auckland Island specimens. Four other species from these islands, discovered at the same time, have since been obtained on the mainland, in all cases in southern Otago. This leaves five species from the Subantarctic Islands still unknown on the mainland.

V. UNDOSATA (Feld.), *Reis. Nov.* 128, 2; Meyr., *Trans. N.Z. Inst.* 16, 60.

Generally distributed in forest to 3,000 ft. October to March. The ochreous and brown forms seem to be restricted to the lower levels, the mountain specimens belonging to the very pale yellow varieties.

V. DISSIMILIS Philp., *Trans. N.Z. Inst.* 46, 118.

Ben Lomond, 3,000 ft. December to February.

ASAPHODES ABROGATA (Walk.), *Cat.* 1075; Meyr., *Trans. N.Z. Inst.* 16, 61.

Generally distributed in open uncultivated situations, particularly those of a damp marshy nature. February to April.

A. MEGASPILATA (Walk.), *Cat.* 1198; Meyr., *Trans. N.Z. Inst.* 16, 63.

Generally distributed in lowland forest districts, but does not appear to extend to the Wakatipu. October to March. Easily separated from all varieties of *A. rufescens* by the yellow hindwings and the more strongly sinuate termen of forewings.

A. RUFESCENS (Butl.), *Cist. Ent.* 2, 502; *cymosema* Meyr., *Trans. N.Z. Inst.* 16, 63.

Common everywhere at low elevations, frequenting forest, plantations, and hedges. It is particularly attached to *Cupressus macrocarpa*. October to March.

A. PARORA (Meyr.), *Trans. N.Z. Inst.* 17, 63; *humeraria* Meyr. (*nec* Walk.), *Trans. N.Z. Inst.* 16, 64.

Invercargill, in May; Dunedin; Queenstown. Rare in most localities, but more common at Queenstown, where it may be taken from September to February.

A. STEPHANITIS Meyr., *Trans. N.Z. Inst.* 39, 108.

Invercargill. February and March. The close superficial resemblance between this species and *Xanthorhoe clarata* does not appear to possess any special significance.

XANTHORHOE ROSEARIA (Dbld.), *Dieff. N.Z.* 2, 285; Meyr., *Trans. N.Z. Inst.* 16, 71.

Generally distributed. March to December, but much more common during autumn and winter. In cabinet specimens the green colour rapidly fades to pale-ochreous.

X. OROPHYLLA (Meyr.), *Trans. N.Z. Inst.* 16, 71.

Generally distributed in open mountainous districts, ascending to about 4,000 ft. November to January.

X. SEMIFISSATA (Walk.), *Cat.* 1320; Meyr., *Trans. N.Z. Inst.* 16, 72.

Generally distributed. Frequents more wooded situations than the preceding species, and found at lower elevations only. August to April.

X. CHLAMYDOTA (Meyr.), *Trans. N.Z. Inst.* 16, 72.

Invercargill; Queenstown; Cromwell; Dunedin. Rare near Invercargill, but fairly common in other localities. October to December.

X. STINARIA (Guen.), *Ent. Mo. Mag.* 5, 92; Meyr., *Trans. N.Z. Inst.* 16, 78.

Invercargill; Dunedin; Queenstown; Lake Wanaka. November and December. Frequents rough herbage in the vicinity of forests.

X. PRAEFECTATA (Walk.), *Cat.* 781; Meyr., *Trans. N.Z. Inst.* 16, 78.

Bluff; Pahia (Wallace County); Routeburn; Dunedin. November to February. Probably generally distributed, the food-plant of the larva being *Phormium*.

X. CATAPHRACTA (Meyr.), *Trans. N.Z. Inst.* 16, 79.

Hunter Mountains; Wakatipu. January and February. A purely mountain form, occurring at about 3,500 ft.

X. CLARATA (Walk.), *Cat.* 1197; Meyr., *Trans. N.Z. Inst.* 16, 79.

Occurs generally throughout open country and frequents the outskirts of forest. November to March. The specimens from the higher altitudes are larger and distinctly lighter in colour.

X. DECLARATA Prout, *Trans. N.Z. Inst.* 46, 122.

Ben Lomond; Takitimu Mountains. November to February. Common from 1,000 ft. to 3,000 ft. Very variable in point of size and, in the ♀ especially, in markings. The species appears to have been derived from *clarata* and to be convergent with *cataphracta*.

X. BEATA (Butl.). *Proc. Zool. Soc. Lond.* 1877, 397, pl. 43, 6.

There is no description of this species in any New Zealand publication: those by Meyrick (*Trans. N.Z. Inst.* 16, 79) and Hudson (*N.Z. M. & B.* 63) refer to the following form. The points of distinction between the two are pointed out by Meyrick in *Trans. N.Z. Inst.* 46, 102.

Invercargill; Wakatipu. December. Occurs in forest to about 3,000 ft., but is somewhat local in distribution.

X. BENEDICTA Meyr., *Trans. N.Z. Inst.* 46, 102.

Common from August to April in all lowland forest districts.

X. ADONIS, Huds., *N.Z. M. & B.* 63, pl. 7, 49.

Generally distributed. In forest to about 2,500 ft. November to March.

X. EXORIENS (Prout), *Trans. N.Z. Inst.* 44 (*Proc.* 54).

Wakatipu. March.

X. DIONYSIAS Meyr., *Trans. N.Z. Inst.* 39, 109.

Old Man Range (Central Otago); 4,000 ft., in December.

X. AEGROTA (Butl.), *Cist. Ent.* 2, 499; Meyr., *Trans. N.Z. Inst.* 16, 80.

Generally distributed. October to April.

X. CHIONOGRAMMA (Meyr.), *Trans. N.Z. Inst.* 16, 82.

Lake Harris, 3,600 ft., in January.

X. VENIPUNCTATA (Walk.), *Cat.* 1666.

Generally distributed, but not common. January and June. This is the species treated under *X. lucidata* Walk. by Meyrick and Hudson: Prout regards the latter name as belonging to a smaller and more strongly marked insect.

X. CEDRINODES Meyr., *Trans. N.Z. Inst.* 43, 72; *undulata* Philp., *Trans. N.Z. Inst.* 45, 76.

Stewart Island; Bluff; Invercargill; Dunedin. August to February. An examination of Mr. C. E. Clarke's long series of this species has shown me that my *undulata* is not specifically distinct. The latter variety is characterized by the median band being almost obsolete, and the dots on veins being, in several instances, prolonged into dashes.

X. HELIAS (Meyr.), *Trans. N.Z. Inst.* 16, 81.

Dunedin; Hunter Mountains, amongst *Veronica buxifolia* var., at 3,500 ft., in January.

X. RECTA Philp., *Trans. N.Z. Inst.* 37, 331.

Ida Valley.

X. PRASINIAS (Meyr.), *Trans. N.Z. Inst.* 16, 81.

Generally distributed in forest to about 2,000 ft. November to January. At the higher elevations the yellow of the hindwings is not infrequently replaced by reddish.

X. OBARATA (Feld.), *Reis. Nov.* 132, 33; Meyr., *Trans. N.Z. Inst.* 16, 82.

Dunedin; Queenstown; Bold Peak. December and January. A rarity.

X. CHORICA (Meyr.), *Trans. N.Z. Inst.* 20, 58.

Invercargill; Queenstown. Not common. December.

X. SUBOBSCURATA (Walk.), *Cat.* 1358; *petropola* Meyr., *Trans. N.Z. Inst.* 16, 82.

Bold Peak, in February.

X. CINEREARIA (Dbld.), *Dieff. N.Z.* 2, 286; Meyr. *Trans. N.Z. Inst.* 16, 83 (part).

Generally distributed. November to July. Near Invercargill spring examples are rare, but in the autumn the species becomes plentiful. This difference becomes less marked in localities farther north. The following two species are included in the notes on this form in *Trans. N.Z. Inst.* 33, 176, and 36, 165.

X. INVEXATA (Walk.), *Cat.* 1199.

Queenstown, in December. Usually at rest during the day on dry shaded rock-faces from 1,000 ft. to 2,000 ft. Occasional stragglers occur near Invercargill.

X. SEMISIGNATA (Walk.), *Cat.* 1200; Meyr., *Trans. N.Z. Inst.* 16, 83 (part).
Common everywhere at low altitudes. November to March.

X. PLUMBEA Philp., *Trans. N.Z. Inst.* 47, 194.
Queenstown, in November. Not very common.

X. BULBULATA (Guen.), *Ent. Mo. Mag.* 5, 94; Meyr., *Trans. N.Z. Inst.* 16, 84.

Invercargill; Ben Lomond; Takitimu Mountains. August to March. Amongst rough herbage in open situations. On the lower slopes only of the hills.

X. CINNABARIS (Howes), *Trans. N.Z. Inst.* 44, 203.
Garvie Mountains. November.

X. OCCULTA Philp., *Trans. N.Z. Inst.* 35, 247, pl. 32, 5.
Generally distributed. September to March.

X. ORARIA Philp., *Trans. N.Z. Inst.* 35, 247, pl. 32, 6.

New River (Invercargill), abundant on the coastal sandhills; Ben Lomond and Mount Earnslaw, at 4,000 ft. September to April. The female has not yet been discovered, and is probably apterous. Ben Lomond specimens are longer-winged than the coastal form, and those from Mount Earnslaw are still longer.

X. SERICODES Meyr., *Trans. N.Z. Inst.* 47, 202.
Mount Earnslaw, 4,000 ft., in January.

X. IMPERFECTA Philp., *Trans. N.Z. Inst.* 37, 331, pl. 20, 6.
Invercargill, in swampy forest. Rare and local. December and January.

X. FRIVOLA Meyr., *Trans. N.Z. Inst.* 45, 26.

The type specimen is said to have been taken at Invercargill by myself, but I am quite unable to identify the species.

X. PERIPHAEA Meyr., *Trans. Ent. Soc. Lond.* 1905, 220.
Macetown; Ben Lomond; Humboldt Range. February. Not common.

X. ALBALINEATA Philp., *Trans. N.Z. Inst.* 47, 194.
Table Hill, Stewart Island, at about 2,000 ft., in December.

X. STRICTA Philp., *Trans N.Z. Inst.* 47, 195.
Bold Peak, in February.

LYTHRIA CATAPYRRHA (Butl.), *Proc. Zool. Soc. Lond.* 1877, 392, pl. 43, 2; Meyr., *Trans. N.Z. Inst.* 16, 64.

Generally distributed to about 3,500 ft. in all open situations. October to May. On the mountains a very striking form occurs in which the median band is wholly black; a second well-marked variety is much suffused with reddish. These varieties do not appear to be represented in the lower part of the habitat of the species.

L. SIRIS Huds., *Trans. N.Z. Inst.* 40, 106, pl. 15, 1.
Old Man Range (Central Otago), at about 4,000 ft., in February.

DASYURIS TRANSAUREA Howes, *Trans. N.Z. Inst.* 44, 203.
Garvie and Humboldt Mountains; Greenstone Flat; Flagstaff Hill (Dunedin). November to January.

D. LEUCOBATHRA (Meyr.), *Trans. N.Z. Inst.* 43, 59.
Bold Peak; Hunter Mountains. From 3,500 ft. to 4,000 ft. December.

D. ANCEPS (Butl.), *Proc. Zool. Soc. Lond.* 1877, 392, pl. 43, 3; Meyr., *Trans. N.Z. Inst.* 16, 91.
Routeburn; Takitimu Mountains. Common in December, from 3,000 ft. to 3,500 ft.

D. PARTHENIATA Guen., *Ent. Mo. Mag.* 5, 93; Meyr., *Trans. N.Z. Inst.* 16, 92.
Dunedin; The Hump (3,500 ft.); Cecil Peak. December to February.

D. CALLICRENA (Meyr.), *Trans. N.Z. Inst.* 16, 87.
Humboldt Range; Lake Harris; Hunter Mountains. From 3,000 ft. to 4,000 ft. December and January.

D. HECTORI (Butl.), *Proc. Zool. Soc. Lond.* 1877, 387, pl. 42, 4; Meyr., *Trans. N.Z. Inst.* 16, 91.
Bold Peak; Advance Peak; Mount Earnslaw; Hunter Mountains. From 4,000 ft. to 5,000 ft. December and January. Mr. Meyrick records it from the summit of Ben Lomond, but it is probably extinct in that locality now, as during the past eight or nine years the peak has been frequently visited by entomologists, all of whom have failed to find *hectori*. Possibly two species are confused under this name. The smaller form is the insect referred to by Mr. Meyrick, while the larger variety has been described and figured by Mr. Hudson (*N.Z. M. & B.* 70, pl. 8, 32). Apart from size, however, there does not seem to be any satisfactory distinguishing character.

D. FULMINEA Philp., *Trans. N.Z. Inst.* 47, 195.
Bold Peak. February. The unique example is in the collection of the Dominion Museum.

NOTOREAS INSIGNIS (Butl.), *Proc. Zool. Soc. Lond.* 1877, 393, pl. 43, 1; Meyr., *Trans. N.Z. Inst.* 16, 85.
Wakatipu. January to March.

N. ORPHNAEA (Meyr.), *Trans. N.Z. Inst.* 16, 85.
Generally distributed in mountainous country, and found from 3,000 ft. to 5,500 ft. November to February.

N. ANTHRACIAS (Meyr.), *Trans. N.Z. Inst.* 16, 84.
The Hump; Takitimu Mountains; Wakatipu. From 2,500 ft. to 5,000 ft. December to February.

N. PARADELPHA (Meyr.), *Trans. N.Z. Inst.* 16, 86.
One of the most common mountain forms, ranging from 2,000 ft. to 4,000 ft. November to February. There is considerable variety in point of size, those from the Hunter Mountains reaching 27 mm.

N. PERORNATA (Walk.), *Cat.* 1672; Meyr., *Trans. N.Z. Inst.* 16, 87.
Wakatipu. November to March. From 2,500 ft. to 4,000 ft. The Wakatipu form of this species is considerably larger than the northern variety.

N. ISOLEUCA Meyr., *Trans. Ent. Soc. Lond.* 1897, 4, 386.

Ben Lomond, in March. Not common.

N. HEXALEUCA (Meyr.), *Trans. N.Z. Inst.* 46, 103.

Ben Lomond; Flagstaff Hill. November to March. Occurs rather sparingly from 1,000 ft. to 3,500 ft. Placed provisionally in *Dasyuris* by Mr. Meyrick; the discovery of the male shows it to belong to *Notoreas.*

N. MECHANITIS (Meyr.), *Trans. N.Z. Inst.* 16, 86.

Ben Lomond and Hunter Mountains, in January. From 4,000 ft. to 5,000 ft. Not common. The southern form appears to differ from the northern (Mount Arthur) in the cilia of both wings being sharply divided into a fuscous basal half and a white apical half. There are other slight but not constant differences.

N. OPIPARA Philp., *Trans. N.Z. Inst.* 47, 196.

Table Hill and Mount Rakiahua, Stewart Island. On the bare hilltops at about 2,000 ft., in December.

N. BREPHOS (Walk.), *Cat.* 1037; Meyr., *Trans. N.Z. Inst.* 16, 89.

Generally distributed in open country from sea-level to 4,000 ft. November to January. A small variety from Flagstaff Hill seems to connect the typical form with the following species.

N. ZOPYRA (Meyr.), *Trans. N.Z. Inst.* 16, 89.

Routeburn; Ben Lomond; Takitimu Mountains. December and January. I record this species with some doubt, as it appears to me to be almost impossible to separate it from the preceding form.

N. FULVA (Huds.), *Trans. N.Z. Inst.* 37, 357, pl. 22, 2.

Near Mount Ida (3,500 ft.); Alexandra. March.

N. SYNCLINALIS Huds., *Trans. N.Z. Inst.* 35, 244, pl. 30, 6.

Stewart Island; Seaward Moss; Wyndham; Longwoods; Preservation Inlet. October to March. Confined apparently to the south-western coastal region, where it is common in areas of a boggy nature and on the bare tops of some low hills. Examples from the exposed top of Table Hill are more reduced in wing-expanse than Preservation specimens (see *Trans. N.Z. Inst.* 45, 431), while those from the more sheltered summit of Longwood Range show no departure from the normal.

SAMANA FALCATELLA Walk., *Cat.* 197; Meyr., *Trans. N.Z. Inst.* 16, 93.

Queenstown. A single example taken by Mr. Curtis. "I have only seen one specimen, received by Mr. R. W. Fereday from Captain Hutton, probably taken in the neighbourhood of Dunedin."—(Meyrick.) Evidently a very rare insect.

LEPTOMERIS RUBRARIA (Dbld.), *Dieff. N.Z.* 2, 286; Meyr., *Trans. N.Z. Inst.* 16, 57.

Alexandra; Macetown. October and December. This widely spread species does not occur near Invercargill, and I have not seen examples from the neighbourhood of Dunedin; it is probable that Wakatipu and Central Otago mark the southern limits of distribution.

ADEIXIS INOSTENTATA Walk., *Cat.* 1012; *griseata* Huds., *Trans. N.Z. Inst.* 35, 244, pl. 30, 5.

Seaward Moss and other coastal swamps near Invercargill. December to March. The restricted distribution in New Zealand of this Australian insect would seem to point to a recent introduction by medium of shipping at the port of Bluff. When at rest the wings are held so as to meet below the body, and a position is generally chosen with the head pointing downwards.

DICHROMODES GYPSOTIS Meyr., *Trans. N.Z. Inst.* 20, 60; *niger* Meyr. (*nec* Butl.), *Trans. N.Z. Inst.* 16, 94.

Invercargill; Wakatipu. January. I reared the species from larvae found feeding on lichen. A description of the larva was not secured, but it was of a remarkable character, the margins of each segment being expanded into fimbriated processes, thus imitating the edges of the food-plant.

D. SPHAERIATA (Feld.), *Reis. Nov.* 131, 14; *petrina* Meyr., *Trans. N.Z. Inst.* 24, 216.

Queenstown. December to February.

D. IDA Huds., *Trans. N.Z. Inst.* 37, 356, pl. 22, 2.

Ida Valley. October.

D. SIMULANS Huds., *Trans. N.Z. Inst.* 40, 107.

Old Man Range, at about 4,000 ft., in February.

THEOXENA SCISSARIA (Guen.), *Ent. Mo. Mag.* 5, 43; Meyr., *Trans. N.Z. Inst.* 16, 56.

Ida Valley. October. Rare.

EPIRRANTHIS ALECTORARIA (Walk.). *Cat.* 259; Meyr., *Trans. N.Z. Inst.* 16, 95.

Generally distributed in forest districts to 3,000 ft. October to June. It is, I think, probable that two species are confused under this name. The large form, which does not graduate completely into the smaller, has the termen of the forewings less angulated; the pair of small ringed dots is also relatively and actually nearer the termen. The small form is much the commoner near Invercargill.

E. HEMIPTERARIA (Guen.). *Phal.* 9, 220, pl. 6, 2; Meyr., *Trans. N.Z. Inst.* 20, 60.

Distribution coextensive with the preceding species. November to March.

SELIDOSEMA ARGENTARIA Philp., *Trans. N.Z. Inst.* 45, 77.

Invercargill; Wyndham. December to May. The note under *fenerata* (*Trans. N.Z. Inst.* 36, 165) refers to this species, which may be regarded as the southern representative of *fenerata*.

S. RUDIATA (Walk.). *Cat.* 1420; *astrapia* Meyr., *Trans. N.Z. Inst.* 22, 218.

Stewart Island; Invercargill; Dunedin. November to February. Not common.

S. SUAVIS (Butl.). *Cist. Ent.* 2, 497; *lupinata* Meyr. (*nec* Feld.), *Trans. N.Z. Inst.* 16, 98.

Generally distributed in forest districts at all elevations. August to May.

S. LUPINATA (Feld.), *Reis. Nov.* 131, 19; *humillima* Huds., *N.Z. M. & B.* 83, pl. 9, 5.

Generally distributed. January to May. Attached to *Leptospermum*. The female is very rare.

S. LEUCELAEA Meyr., *Trans. N.Z. Inst.* 41, 6.

Generally distributed. September to May. Usually in forest, but frequently found in open lands.

S. PRODUCTATA (Walk.). *Cat.* 1197; Meyr., *Trans. N.Z. Inst.* 16, 98.

Generally distributed in forest at all elevations. September to March. The higher elevations produce the largest specimens, but at the same time examples occur quite as small as the lowland forms.

S. PUNGATA Feld., *Reis. Nov.* 131, 23; *fascialata* Philp., *Trans. N.Z. Inst.* 35, 247, pl. 32, 7.

Generally distributed but not common. January to March.

S. LACTIFLUA Meyr., *Trans. N.Z. Inst.* 44, 117.

Hooper's Inlet (Otago Peninsula). A single example taken by Mr. C. E. Clarke in February.

S. MELINATA (Feld.), *Reis. Nov.* 129, 9; Meyr., *Trans. N.Z. Inst.* 16, 99.

Generally distributed. December to March. Near Dunedin a variety occurs in which the whole of the space between the first and second lines is suffused with brownish black.

S. OCHREA Howes, *Trans. N.Z. Inst.* 43, 127, pl. 1, 1.

Dunedin. February to April.

S. MONACHA Huds., *Trans. N.Z. Inst.* 35, 245, pl. 30, 4; *maculosa* Howes, *Trans. N.Z. Inst.* 46, 96.

Queenstown; Humboldt Range; Routeburn. November to February.

S. LUTEA Philp., *Trans. N.Z. Inst.* 46, 119.

Bold Peak. December to February.

S. TERRENA Philp., *Trans. N.Z. Inst.* 47, 196.

Bold Peak and Mount Cleughearn, at about 3,000 ft. December to February.

S. DEJECTARIA (Walk.), *Cat.* 394; Meyr., *Trans. N.Z. Inst.* 16, 100.

Generally distributed. October to April, and occasionally during the winter.

S. PANAGRATA (Walk.), *Cat.* 1360; Meyr., *Trans. N.Z. Inst.* 16, 100.

Generally distributed. September to June.

HYBERNIA INDOCILIS (Walk.), *Cat.* 1530; Meyr., *Trans. N.Z. Inst.* 16, 97.

Queenstown, in September. Rare.

CHALASTRA PELURGATA Walk., *Cat.* 1430; *streptophora* Meyr., *Trans. N.Z. Inst.* 16, 106.

Generally distributed in bush districts. September to February.

SESTRA HUMERARIA (Walk.), *Cat.* 940; *flexata* Huds., *N.Z. M. & B.* 90, pl. 9, 37.

Invercargill; Kinloch. September to November. Most common in kamahi (*Weinmannia racemosa*) forests, such as Seaward Bush.

S. FLEXATA (Walk.), *Cat.* 1421; *humeraria* Huds., *N.Z. M. & B.* 89, pl. 10, 1 and 2.

Generally distributed in all lowland forests. November to February. Some varieties of this species closely approach *S. humeraria* in colour and markings, but the latter form is constantly less concave on the upper half of the termen of the forewing. Any previous notes of mine regarding this and the preceding species should be transposed.

AZELINA GALLARIA (Walk.), *Cat.* 185; Meyr., *Trans. N.Z. Inst.* 16, 105.

Generally distributed, but nowhere common. November to February.

A. FORTINATA (Guen.), *Ent. Mo. Mag.* 5. 41; Meyr., *Trans. N.Z. Inst.* 16. 106.

Generally distributed and fairly common. September to March. Most plentiful in localities where tree-ferns (*Dicksonia* and *Hemitelia*) are abundant; it rests on the dead hanging fronds of these ferns.

GARGAPHIA MURIFERATA Walk., *Cat.* 1635. Meyr., *Trans. N.Z. Inst.* 16. 107.

Generally distributed, and, like the preceding species, much attached to tree-ferns. September to March.

DECLANA LEPTOMERA (Walk.), *Cat.* 1662: Huds., *N.Z. M. & B.* 94, pl. 10, 29 to 31A.

Generally distributed. October to March. Near Invercargill and in the Wakatipu district the males are usually much suffused with fuscous-brown.

D. EGREGIA (Feld.), *Reis. Nov.* 131, 24: Meyr., *Trans. N.Z. Inst.* 16, 101.

Generally distributed in forest districts, but not anywhere common. Ascending to about 2,500 ft. November to February. Through the kindness of Mr. G. Howes I have had the opportunity of rearing this species from the larva. The food-plant is *Nothopanax Colensoi*. When full-grown the larva is about 35 mm. in length and is stoutly built, the body being rugose and irregular. There are two pairs of prolegs, and the anal claspers are broad and flat. The colour is pale ochreous-brown mixed with fuscous on ventral surface and thorax; head faintly greenish; second thoracaic segment much swollen dorsally, pale pink; a double transverse row of 4 black dots on median area, the first row hidden by fold except when the head is much depressed, a number of black dots and markings on anterior area; dorsal line pale, dark-margined, interrupted; subdorsal darker, black-margined; lateral indistinct; spiracles yellowish-red. Segments 9, 10, and 11 almost wholly fuscous, marked off from pale posterior segments by oblique black margin; on segments 6 and 9 a prominent pale dorsal ridge. The young stages are darker in colour. Pupation took place under fragments of dead leaves loosely bound together with a few threads of silk. Pupa elongate, 20 mm., dark red-brown. I think that the appearance of this curious larva is probably of intimidative value. Though generally twig-like in form, the swollen pink thorax is very striking and noticeable. When the larva is disturbed the head is depressed, the spotted dorsal area is brought into view, and the creature sways several times to and fro. Further careful observations and experiments on this interesting larva are much needed.

D. FLOCCOSA Walk., *Cat.* 1649; Meyr., *Trans. N.Z. Inst.* 16, 102.

Found everywhere, and occurring throughout the year. At Queenstown the majority of the specimens are uniformly brownish-cinereous, with the markings more or less obsolete.

D. JUNCTILINEA (Walk.), *Cat. Suppl.* 643; Huds., *N.Z. M. & B.* 98, pl. 10, 37 and 38.

Generally distributed but not common. September to April.

D. GRISEATA Huds., *N.Z. M. & B.* 98, pl. 10, 32.

Invercargill; Dunedin; Queenstown. September to May. Rare. In Mr. Hudson's description of the moth an error occurs, the male being said to have simple antennae. This is not so; the antennae of that sex are rather more strongly bipectinated than in *D. floccosa*.

D. SINUOSA Philp., *Trans. N.Z. Inst.* 47, 197.

Hunter Mountains; Wakatipu. From 2,000 ft. to 3,250 ft. October to February.

D. HERMIONE Huds., *N.Z. M. & B.* 98, pl. 10, 36.

Invercargill; Orepuki; Wakatipu. From 2,000 ft. to 3,000 ft. October to March.

D. NIVEATA Butl., *Cist. Ent.* 2, 500; Meyr., *Trans. N.Z. Inst.* 16, 104.

Generally distributed but not common. September to March. Larva on *Rubus australis.*

D. GLACIALIS Huds., *Trans. N.Z. Inst.* 35, 245, pl. 30, 2.

Ben Lomond; Hunter Mountains. From 2,000 ft. to 4,000 ft. November to January. Further observation confirms the opinion that this species is mimetic of *Metacrias* (see *Trans N.Z. Inst.* 45, 431). When alarmed by being struck at with the net or from any other cause the moth does not attempt to hide by dropping into the herbage, but rises higher in the air, as if to make itself more conspicuous.

VANESSA GONERILLA (Fabr.), *Syst. Ent.* 498, 237; Huds., *N.Z. M. & B.* 105, pl. 12, 5 and 6.

Generally distributed. Hibernated specimens appear in September, and a new brood is in flight about January, continuing to March, and in mild seasons through April. Exceptionally warm weather results occasionally in the appearance of this butterfly in midwinter.

V. CARDUI L., Huds., *N.Z. M. & B.* 108, pl. 12, 1 and 2.

Invercargill: Fiordland. October to March. The species appears only occasionally: seasons often pass without any being observed.

ARGYROPHENGA ANTIPODUM Dbld., *Ann. & Mag. Nat. Hist.* 16, 307; Huds., *N.Z. M. & B.* 110, pl. 11, 3 to 7.

Generally distributed in open country to about 2,000 ft. The larva is known to feed on the indigenous tussock-grasses, but there must be other food-plants too, as newly emerged butterflies, incapable of flight, have been found in situations far removed from native pasture.

EREBIA MERULA Hew., *Ent. Mo. Mag.* 1874, 12, 10; *pluto* (Frdy.) Huds., *N.Z. M. & B.* 114, pl. 11, 8 to 10.

Hewitson's name has priority; Fereday's description was not published till 1876, and his suggestion (without description) of the name *pluto* prior to the publication of Hewitson's paper can have no standing.

Occurs on all mountains from 4,000 ft. upwards. January to March.

E. BUTLERI (Frdy.). *Trans. N.Z. Inst.* 12, 264.

Bold Peak. January to March.

CHRYSOPHANUS SALUSTIUS Fabr., Huds., *N.Z. M. & B.* 116, pl. 12, 18 to 21.

Generally distributed. November to February. Frequents the edges of forest, openings therein, the sides of hedges, and similar situations.

C. BOLDENARUM (White), *Proc. Ent. Soc. Lond.*, Ser. 3, 1, 26; Huds., *N.Z. M. & B.* 118, pl. 12, 13 to 17.

Generally distributed. Attached to shingly situations, and ascending to about 4,000 ft. November to March.

NEOLUCIA OXLEYI (Feld.), *Reis. Nov.* 2, 280; Huds., *N.Z. M. & B.* 119.

Queenstown. October to March.

SPOROPHYLA OENOSPORA (Meyr.), *Trans. Ent. Soc. Lond.* 1897, 388.

Ben Lomond; Alexandra; Ida Valley. November to April.

HOMOEOSOMA VAGELLA Zell., *Isis.* 1848. 863.

Invercargill. January to March. At light only.

EPHESTIA KUEHNIELLA Zell.

This introduced pest is now established in the flour-mills throughout Otago. The moths emerge from November to March.

OROCRAMBUS MELAMPETRUS Meyr., *Trans. N.Z. Inst.* 17. 133.

Vanguard Peak. January.

O. CATACAUSTUS (Meyr.). *Trans. N.Z. Inst.* 17. 134.

The Hump; Hunter Mountains; Bold Peak. From 3,000 ft. to 4,000 ft. December and January.

O. PERVIUS Meyr., *Trans. N.Z. Inst.* 44, 118.

Lake Wakatipu and Hunter Mountains, at elevations of from 3,000 ft. to 3,600 ft. December to February.

O. SUBITUS Philp., *Trans. N.Z. Inst.* 44. 116.

The Hump; Longwoods; Hunter Mountains; Bold Peak. From 3,000 ft. to 4,000 ft. December to February.

O. THYMIASTES Meyr., *Trans. Ent. Soc. Lond.* 1901. 567.

Seaward Moss. January and February.

O. MACHAERISTES Meyr., *Trans. Ent. Soc. Lond.* 1905. 224.

Bold Peak; Mount Earnslaw; Vanguard Peak. December to February.

O. SCOPARIOIDES Philp., *Trans. N.Z. Inst.* 46, 119.

Ben Lomond; Paradise; Commissioner's Creek. December to February. In marshy spots, from 3,000 ft. to 4,000 ft.

CRAMBUS CORRUPTUS (Butl.), *Proc. Zool. Soc. Lond.* 1877. 399, pl. 43, 9; Meyr., *Trans. N.Z. Inst.* 15. 20.

Wedderburn (Central Otago).

C. HELIOTES Meyr., *Trans. N.Z. Inst.* 20, 68.

Paradise, in January.

C. AETHONELLUS Meyr., *Trans. N.Z. Inst.* 15. 19.

Longwood Range; Takitimu Mountains; Flagstaff Hill; Wedderburn. December and January. The notes under this name (*Trans. N.Z. Inst.* 36. 167) refer to *C. melitastes*.

C. SARISTES Meyr., *Trans. N.Z. Inst.* 41, 8.

Seaward Moss. December and January. It is probable that this form is only a variety of *aethonellus* Meyr. The Seaward Moss insects are always much darker than typical specimens of *aethonellus*, but in other localities all shades of ground-colour occur and the cilia vary from white to fuscous.

C. AULISTES Meyr., *Trans. N.Z. Inst.* 41, 9.

Invercargill (Meyrick). I am unacquainted with this species; it is evidently nearly allied to the preceding.

C. MELITASTES Meyr., *Trans. N.Z. Inst.* 41. 9.

Invercargill. November to January. Extremely common in open situations where the vegetation is short. The female occasionally has the forewings wholly grey-whitish.

C. APSELIAS Meyr., *Trans. N.Z. Inst.* 39, 109.

Generally distributed. November to April. Though Invercargill examples offer no difficulty in point of distinctness from the following species, some of the Dunedin varieties appear to connect the two, and it is not improbable that there is but the one wide-ranging and variable form, *ramosellus* Dbld.

C. RAMOSELLUS Dbld., *Dieff. N.Z.* 2, 288; Meyr., *Trans. N.Z. Inst.* 15, 21.

Dunedin. This locality seems to be the southern limit of the typical form. Mr. Meyrick records it from Invercargill (*Trans. N.Z. Inst.* 17, 139), but probably the extremely similar preceding species was mistaken for it.

C. CONOPIAS Meyr., *Trans. N.Z. Inst.* 39, 110.

Dunedin; Routeburn. January.

C. ANGUSTIPENNIS (Zell.), *Hor. Soc. Ent. Ross.* 13, 15, pl. 1, 3; Meyr., *Trans. N.Z. Inst.* 15, 22.

Invercargill. November and December. Not common. Attached to *Arundo conspicua*.

C. HETERAULUS Meyr., *Trans. Ent. Soc. Lond.* 1905, 225.

Routeburn; Humboldt Range. 3,600 ft. February.

C. CRENAEUS Meyr., *Trans. N.Z. Inst.* 17, 135.

Dunedin (Meyrick).

C. ENCHOPHORUS Meyr., *Trans. N.Z. Inst.* 17, 136.

Otago Peninsula. January to March.

C. HAPLOTOMUS Meyr., *Trans. N.Z. Inst.* 15, 23.

Lake Wakatipu (Meyrick).

C. DIPLORRHOUS Meyr., *Trans. N.Z. Inst.* 17, 136.

Ben Lomond; Bold Peak; Mount Earnslaw. At 4,000 ft. All the Bold Peak examples which I have seen are considerably smaller than those from other localities.

C. CALLIRRHOUS Meyr., *Trans.* N.Z. Inst., 15, 24.

Invercargill. January. On coastal sandhills.

C. SIMPLEX (Butl.), *Proc. Zool. Soc. Lond.* 1877, 400, pl. 43, 12; Meyr., *Trans. N.Z. Inst.* 15, 24.

Generally distributed. November to January.

C. SIRIELLUS Meyr., *Trans. N.Z. Inst.* 15, 24.

Invercargill; Fiordland; Paradise. December to March.

C. APICELLUS Zell., *Mon. Cramb.* 31; Meyr., *Trans. N.Z. Inst.* 15, 26.

Generally distributed. December and January.

C. PARAXENUS Meyr., *Trans. N.Z. Inst.* 17, 137.

Macetown; Ben Lomond, 3,500 ft. November and December.

C. OBSTRUCTUS Meyr., *Ent. Mo. Mag.* 1911, 82.

Generally distributed but not common. January to March.

C. VITELLUS Dbld., *Dieff. N.Z.* 2, 289; Meyr., *Trans. N.Z. Inst.* 15, 27.

Generally distributed. December to March.

C. FLEXUOSELLUS Dbld., *Dieff. N.Z.* 2, 289; Meyr., *Trans. N.Z. Inst.* 15, 28.

Generally distributed. December to February.

C. TUHUALIS Feld., *Reis Nov.* 137, 18; Meyr., *Trans. N.Z. Inst.* 15, 28.
Wyndham; Routeburn; Dunedin. Rare near Invercargill. February and March.

C. SOPHRONELLUS Meyr., *Trans. N.Z. Inst.* 17, 138.
Hinds (Central Otago). March.

C. CYCLOPICUS Meyr., *Trans. N.Z. Inst.* 15, 29.
Wedderburn; Alexandra. March and April.

C. SOPHISTES Meyr., *Trans. Ent. Soc. Lond.* 1905, 226.
Ida Valley.

C. HARPOPHORUS Meyr., *Trans. N.Z. Inst.* 15, 30.
Humboldt Range.

C. ONCOBOLUS Meyr., *Trans. N.Z. Inst.* 17, 138.
Invercargill. December. Rare.

C. XANTHOGRAMMUS Meyr., *Trans. N.Z. Inst.* 15, 32.
Tewaewae Bay; Routeburn; Macetown; Ida Valley. December to February.

C. OPPOSITUS Philp., *Trans. N.Z. Inst.* 47, 197.
The Hump; Hunter Mountains. From 3,000 ft. to 4,000 ft. December to January.

ARGYRIA PENTADACTYLA Zell., *Mon. Cramb.* 38; *strigosus* Meyr., *Trans. N.Z. Inst.* 15, 31.
Alexandra.

TAUROSCOPA TRAPEZITIS Meyr., *Trans. Ent. Soc. Lond.* 1905, 227.
Wakatipu; Takitimu Mountains. From 2,000 ft. to 5,000 ft. Not common. November to February.

T. GORGOPIS Meyr., *Trans. N.Z. Inst.* 20, 69.
Cecil Peak; Remarkables; Bold Peak; Advance Peak. From 4,000 ft. to 6,000 ft. December. The females are often very small, and are probably varying in the direction of flightlessness.

T. GLAUCOPHANES Meyr., *Trans. N.Z. Inst.* 39, 110.
Takitimu Mountains; Hunter Mountains; Ben Lomond; Advance Peak; Old Man Range. From 4,000 ft. to 5,000 ft. December to February. The male has a pencil of yellow hairs about 2½ mm. in length in a fold on the dorsum of the hindwing near base. This is not present in the other members of the genus. Well-defined races of this species occupy different portions of its distributional area. The Wakatipu and Central Otago form is bluish-grey, with the markings fairly distinct; the wings are shorter and broader than in other districts. The Takitimu race is somewhat narrower-winged, and is of a uniform fuscous-brown, the markings being almost obsolete. The Hunter Mountains variety has the greatest wing-expanse, though proportionately narrower than the Wakatipu form; there is considerable admixture of white and ochreous, especially in the female, and the markings are well defined.

DIPTYCHOPHORA PERSOPHANES Meyr., *Trans. N.Z. Inst.* 15, 11.
Generally distributed. Attached to *Leptospermum*. November to March.

D. CHRYSOCHYTA Meyr., *Trans. N.Z. Inst.* 15, 12.
Invercargill; Bluecliff. December to February. Not common.

D. INTERRUPTA Feld., *Reis. Nov.* 135, 15; *astrosema* Meyr., *Trans. N.Z. Inst.* 15, 13.
Ida Valley; Lake Wanaka; Queenstown. December.

D. LEPIDELLA (Walk.), *Cat.* 35, 1761; Meyr., *Trans. N.Z. Inst.* 15, 14.
Generally distributed and very common in all forest districts, ascending to about 2,000 ft. December to February.

D. LEUCOXANTHA Meyr., *Trans. N.Z. Inst*, 15, 15.
Stewart Island; Invercargill; Longwoods; Routeburn. December and January.

D. SELENAEA Meyr., *Trans. N.Z. Inst.* 17, 131.
Generally distributed. December to February.

D. AURISCRIPTELLA (Walk.), *Cat.* 30, 976; Meyr., *Trans. N.Z. Inst.* 15, 16.
Generally distributed in forest at low elevations. December and January.

D. HARMONICA Meyr., *Trans. N.Z. Inst.* 20, 71.
Invercargill: Orepuki. December and January.

D. HELIOCTYPA Meyr., *Trans. N.Z. Inst.* 15, 17.
Generally distributed in open damp situations. December to February. Wakatipu examples show a great range of variation, from dark chocolate-brown to variegated light-ochreous forms. Near Invercargill the dark variety only occurs.

D. EPIPHAEA Meyr., *Trans. N.Z. Inst.* 17, 132.
Longwood Range; Hunter Mountains; Glenorchy. Ascending to 3,250 ft. December and January. Rare.

D. ELAINA Meyr., *Trans. N.Z. Inst.* 15, 17.
Dunedin. March. Not common.

GADIRA ACERELLA Walk., *Cat.* 35, 1742; Meyr., *Trans. N.Z. Inst.* 15, 8.
Invercargill; Dunedin. November to February.

NYMPHULA NITENS (Butl.), *Cist. Ent.* 2, 556; Meyr., *Trans. N.Z. Inst.* 17, 130.
Invercargill; Tuatapere (Wallace); Dunedin; Wakatipu. December to March. Much attracted by light.

MUSOTIMA NITIDALIS (Walk.), *Cat.* 34, 1317.
Generally distributed wherever the food-plant (*Pteris incisa*) of the larva is found. November to February.

DIASEMIA GRAMMALIS Dbld., *Dieff. N.Z.* 2, 287.
Invercargill; Ben Lomond, on lower slopes. October to January.

NESARCHA HYBREALIS (Walk.), *Cat.* 18, 797.
Generally distributed in forest. October to February.

MECYNA MAORIALIS (Feld.), *Reis. Nov.* 134, 34.
Invarcargill (very rare); Wakatipu; Dunedin. November to January.

M. DAICLEALIS (Walk.), *Cat.* 19, 1017; Meyr., *Trans. N.Z. Inst.* 21, 155.
Dunedin (Meyrick).

M. NOTATA (Butl.), *Cist. Ent.* 2, 493.
Generally distributed. October to March.

M. flavidalis (Dbld.). *Dieff. N.Z.* 2, 287.

Generally distributed in forest and amongst rough herbage. December to February.

M. marmarina (Meyr.). *Trans. Ent. Soc. Lond.* 1884, 329.

Queenstown: Dunedin. October to February.

Proteroeca comastis Meyr., *Trans. Ent. Soc. Lond.* 1884, 335.

Generally distributed in open dry situations and on mountains to about 2,000 ft. October to January.

Heliothela atra (Butl.). *Proc. Zool. Soc. Lond.* 1877, 404; Meyr., *Trans. N.Z. Inst.* 17, 70.

Generally distributed in dry open situations, ascending to about 5,000 ft. December to February. Not common.

Scoparia thyridias Meyr., *Trans. Ent. Soc. Lond.* 1905, 228.

The Hump (3,000 ft.): Routeburn. January and February. Not common.

S. oreas Meyr., *Trans. N.Z. Inst.* 17, 81.

Lake Wakatipu (5,000 ft.), (Meyrick).

S. philerga Meyr., *Trans. N.Z. Inst.* 17, 81.

Generally distributed in forest districts. November to March.

S. chlamydota Meyr., *Trans. N.Z. Inst.* 17, 82.

Invercargill: Dunedin: Routeburn. December to March.

S. hemiplaca Meyr., *Trans. N.Z. Inst.* 21, 155.

Invercargill, in forest. January. Very rare.

S. dochmia Meyr., *Trans. Ent. Soc. Lond.* 1905, 229.

Lake Wakatipu, at 1,300 ft.

S. minusculalis Walk., *Cat.* 34, 1503; Meyr., *Trans. N.Z. Inst.* 17, 82.

Generally distributed in lowland forest. December to April.

S. minualis Walk., *Cat.* 34, 1504; Meyr., *Trans. N.Z. Inst.* 17, 83.

Invercargill: Bold Peak. December and January.

S. chimeria Meyr., *Trans. N.Z. Inst.* 17, 84.

Generally distributed but not abundant. December to March. A bush-frequenting species.

S. dinodes Meyr., *Trans. N.Z. Inst.* 17, 85.

Stewart Island: Invercargill: Takitimu Mountains: Monowai Flat: Dunedin. November to February. I have no records from Wakatipu or Central Otago, but as the species occurs in Canterbury it is in all probability generally distributed throughout Otago.

S. parmifera Meyr., *Subant. Isl. N.Z.* 72.

Longwood Range. Fairly common in upper bush at about 2,500 ft. in December.

S. animosa Meyr., *Trans. N.Z. Inst.* 46, 103.

Invercargill. November and December. Not common.

S. acharis Meyr., *Trans. N.Z. Inst.* 17, 85.

Invercargill: Queenstown: Dunedin. November to January.

S. cymatias Meyr., *Trans. N.Z. Inst.* 17, 86.

Invercargill: Lake Monowai: Queenstown. December and January.

S. MICROPHTHALMA Meyr., *Trans. N.Z. Inst.* 17, 87.
Lake Harris. January.

S. HEMICYCLA Meyr., *Trans. N.Z. Inst.* 17, 87.
Bold Peak; Routeburn. In forest at 2,500 ft. January.

S. XYSMATIAS Meyr., *Trans. N.Z. Inst.* 39, 111.
Bold Peak; Old Man Range. At about 4,500 ft. February.

S. ERGATIS Meyr., *Trans. N.Z. Inst.* 17, 88.
Invercargill; Ben Lomond; Kinloch. Abundant in open waste places. October to January.

S. AUTOCHROA Meyr., *Trans. N.Z. Inst.* 39, 111.
Invercargill. November. Common in open marshy situations.

S. ENCAPNA Meyr., *Trans. N.Z. Inst.* 20, 65.
Invercargill, in open swamps, November to February. Lake Harris, at about 2,800 ft., in January.

S. CRITICA Meyr., *Trans. N.Z. Inst.* 17, 88.
Queenstown; Routeburn. December and January. Not common.

S. CHARACTA Meyr., *Trans. N.Z. Inst.* 17, 90.
Invercargill; Wyndham; Dunedin. January to March.

S. USTIMACULA Feld., *Reis. Nov.* 135, 17; Meyr., *Trans. N.Z. Inst.* 17, 91.
Generally distributed and very common in all lowland forest districts. October to December.

S. PONGALIS Feld., *Reis. Nov.* 137, 33; Meyr., *Trans. N.Z. Inst.* 17, 91.
Invercargill; Dunedin. February. Rare.

S. MELANAEGIS Meyr., *Trans. N.Z. Inst.* 17, 92.
Invercargill; Dunedin; Paradise; Routeburn. Ascending to about 2,500 ft. November to January.

S. LOCULARIS Meyr., *Trans. N.Z. Inst.* 44, 118.
Takitimu Mountains; Wakatipu; Flagstaff Hill. From 1,000 ft. to 3,500 ft. January.

S. TRISCELIS Meyr., *Subant. Isl. N.Z.* 71.
Hunter Mountains; Longwood Range. From 2,500 ft. to 3,000 ft. December. Apparently confined to *Nothofagus* forests.

S. CHORISTES Meyr., *Trans. N.Z. Inst.* 39, 112.
Invercargill. December. Rare.

S. PERIPHANES Meyr., *Trans. N.Z. Inst.* 17, 94.
Invercargill; Wakatipu. December to February.

S. COLPOTA Meyr., *Trans. N.Z. Inst.* 20, 65.
Dunedin. January. Rare. The notes under this name (*Trans. N.Z. Inst.* 33, 181, and 36, 168) refer to the preceding species.

S. PHALERIAS Meyr., *Trans. Ent. Soc. Lond.* 1905, 230.
Bluff; Ben Lomond. November and December. Bluff examples are much smaller than the mountain form, but otherwise identical.

S. DIPHTHERALIS Walk., *Cat.* 34, 1501; Meyr., *Trans. N.Z. Inst.* 17, 94.
Kinloch; Routeburn. December.

S. SUBMARGINALIS Walk., *Cat.* 27, 48; Meyr., *Trans. N.Z. Inst.* 17, 95.
Generally distributed in forest and ascending to about 2,000 ft. November to January.

S. CATAXESTA Meyr., *Trans. N.Z. Inst.* 17, 96.
Wakatipu; Central Otago. November to March.

S. ASALEUTA Meyr.. *Trans. N.Z. Inst.* 39, 112.
Wakatipu. An occasional straggler at Invercargill.

S. GYROTOMA Meyr., *Trans. N.Z. Inst.* 41, 7.
Ida Valley; Alexandra. November.

S. INDISTINCTALIS (Walk.), *Cat.* 27, 48; Meyr., *Trans. N.Z. Inst.* 16, 97.
Invercargill; Lake Monowai; Queenstown; Dunedin. November to January.

S. ATMOGRAMMA Meyr., *Trans. N.Z. Inst.* 47, 202.
Invercargill; Ben Lomond. September to November. Not common.

S. PSAMMITIS Meyr., *Trans. N.Z. Inst.* 17, 99.
Generally distributed; ascending to about 2,500 ft. September to April.

S. CHALICODES Meyr., *Trans. N.Z. Inst.* 17, 98.
Bold Peak. February. The record of this species near Invercargill (*Trans. N.Z. Inst.* 33, 180) is extremely doubtful.

S. EPICOMIA Meyr., *Trans. N.Z. Inst.* 17, 99.
Stewart Island; Invercargill; Dunedin. Common in dense forest. October to January.

S. FEREDAYI Knaggs, *Ent. Mo. Mag.* 4, 80; Meyr.. *Trans. N.Z. Inst.* 17, 100.
Generally distributed in open country and round the outskirts of forest. November to April. The female often has short and narrow wings, and is an example of the tendency towards an apterous condition in the female not uncommon in New Zealand Lepidoptera.

S. ACOMPA Meyr., *Trans. N.Z. Inst.* 17, 100.
Hunter Mountains, Wakatipu. From 1,200 ft. to 2,500 ft. December.

S. CYPTASTIS Meyr., *Trans. N.Z. Inst.* 41, 7.
Seaward Moss; Invercargill; Wyndham; Longwood Range. October to February. The hill form (Longwoods, 2,700 ft.) is generally larger, but does not differ in any other respect.

S. CRYPSINOA Meyr., *Trans. N.Z. Inst.* 17, 102.
Ida Valley; Wakatipu; Takitimu Mountains. November to January. Common in open country from 2,000 ft. to 3,500 ft.

S. AGANA Meyr., *Trans. N.Z. Inst.* 44, 119.
Lake Wakatipu (Meyrick).

S. AXENA Meyr., *Trans. N.Z. Inst.* 17, 103.
Invercargill; Routeburn; Dunedin. November to January.

S. STEROPAEA Meyr., *Trans. N.Z. Inst.* 17, 103.
Stewart Island; Invercargill; Queenstown; Dunedin. December to February. Not common.

S. EXILIS Knaggs, *Ent. Mo. Mag.* 4, 81; Meyr., *Trans. N.Z. Inst.* 17, 104.
Generally distributed in open dry situations. November and December.

S. ELAPHRA Meyr., *Trans. N.Z. Inst.* 17, 105.
Invercargill; Dunedin. August to February. Rare.

S. PALTOMACHA Meyr., *Trans. N.Z. Inst.* 17, 105.
Ben Lomond; Routeburn. At about 3,500 ft. December and January.

S. SABULOSELLA (Walk.), *Cat.* 27, 178; Meyr., *Trans. N.Z. Inst.* 17, 106.
Generally distributed. October to January.

S. PANOPLA Meyr., *Trans. N.Z. Inst.* 17, 107.
Hunter Mountains, 4,500 ft. January.

S. CLAVATA Philp., *Trans. N.Z. Inst.* 44, 116.

The Hump; Hunter Mountains. In forest from 2,500 ft. to 3,000 ft., in December. The example from the Hunter Mountains—the second specimen met with to date—differs considerably from the type. The forewings are ochreous-brown and the terminal fascia is broadly interrupted at middle. The hindwings are also ochreous-tinged.

S. TRIVIRGATA Feld., *Reis. Nov.* 137, 29; Meyr., *Trans. N.Z. Inst.* 17, 107.

Generally distributed in open country to about 4,000 ft. November and December. The female of this species is often very small, measuring as little as 15 mm. in wing-expanse, while the male reaches 25 mm. I have observed that these small females have very poor powers of flight.

In a small open space in the Titiroa Forest (Hunter Mountains), at an elevation of about 2,700 ft., an isolated colony of this moth was found to have established itself. It is most unusual to find this species in the heart of the forest, and no individuals were noticed on the track either above or below. All the specimens obtained were slightly darker than the ordinary open-country form, the forewings having a greater admixture of brownish-ochreous and the black stripes being very pronounced. The locality is on the bank of a mountain stream, and it is suggested that isolation in this damp spot is producing a melanic variety.

S. AUGASTIS Meyr., *Trans. N.Z. Inst.* 39, 113.

Invercargill; Dunedin. Always in swampy localities. February to April.

S. PETRINA (Meyr.). *Trans. N.Z. Inst.* 17, 111.
Generally distributed, and to be met with throughout the year.

S. HALOPIS Meyr., *Subant. Isl. N.Z.* 72.
Mataura, in February. One specimen only.

S. CYAMEUTA (Meyr.), *Trans. N.Z. Inst.* 17, 112.

Generally distributed. November to January. The notes under *cyameuta* (*Trans. N.Z. Inst.* 33, 180) refer to *S. petrina*.

S. DRYPHACTIS Meyr., *Trans. N.Z. Inst.* 13, 61.
Lake Wakatipu (Meyrick).

S. ASTRAGALOTA (Meyr.). *Trans. N.Z. Inst.* 17, 113.
Lake Wakatipu (Meyrick).

S. ROTUELLA (Feld.), *Reis. Nov.* 137, 30; Meyr., *Trans. N.Z. Inst.* 17, 113.
Generally distributed. October to April.

S. EJUNCIDA Knaggs, *Ent. Mo. Mag.* 4, 81; Meyr., *Trans. N.Z. Inst.* 17, 114
Dunedin; Ben Lomond (3,000 ft. to 4,000 ft.). December to March.

S. XIPHOSPORA (Meyr.), *Trans. N.Z. Inst.* 17. 115.
Ben Lomond and Hunter Mountains at 3,500 ft. December to February. The costa is more narrowly brown in the southern form of this species.

S. ASPIDOTA (Meyr.), *Trans. N.Z. Inst.* 17, 115.
Dunedin; Wakatipu. In forest to 2,000 ft. December to February.

S. SIDERASPIS (Meyr.), *Trans. Ent. Soc. Lond.* 1905, 231.
Humboldt Range; Mount Earnslaw; Advance Peak. At 5,000 ft. and upwards. January. The species bears considerable resemblance to some forms of *Tauroscopa glaucophanes*.

S. NOMEUTIS Meyr., *Trans. N.Z. Inst.* 17. 116.
Longwood Range; The Hump; Hunter Mountains. From 3,000 ft. to 4,000 ft. November to February. The Hunter Mountain form is unusually large, a characteristic of several species inhabiting that locality. It is probably to be accounted for by the abundant vegetation, and the sheltered position of the range.

S. ORGANAEA Meyr., *Trans. Ent. Soc. Lond.* 1901, 569.
Bluff; Broad Bay (Otago Peninsula); Flagstaff Hill. November to January. Not common.

S. LUMINATRIX Meyr., *Trans. N.Z. Inst.* 41, 8.
Generally distributed in lowland forest. November to December.

S. LEGNOTA (Meyr.), *Trans. N.Z. Inst.* 17, 117.
Invercargill (very rare); Wakatipu (to 2,000 ft.). December and January.

S. FUMATA Philp., *Trans. N.Z. Inst.* 47, 198.
Flagstaff Hill; Longwood Range. From 1,000 ft. to 2,800 ft. December.

S. CHALARA Meyr., *Trans. Ent. Soc. Lond.* 1901, 570.
Kingston; Ben Lomond. November to January.

S. OCTOPHORA (Meyr.), *Trans. N.Z. Inst.* 17, 118.
Invercargill; Dunedin; Ben Lomond; Routeburn. In rough herbage to 2,000 ft. November to January.

S. ASTERISCA (Meyr.), *Trans. N.Z. Inst.* 17, 118.
Invercargill; Wakatipu. Rare. January and February.

S. LEUCOGRAMMA (Meyr.), *Trans. N.Z. Inst.* 17, 119.
Invercargill; Sunnyside (Waiau); Wakatipu. Rare. December and January.

DIPLOPSEUSTIS PERIERALIS (Walk.), *Cat.* 19, 958; *minima* Meyr., *Trans. N.Z. Inst.* 20, 63.
Invercargill; Wyndham; Dunedin. September to April.

PYRALIS FARINALIS L., *Syst. Nat.* 226; Meyr., *Trans. N.Z. Inst.* 18, 122.
Dunedin (Howes).

MOROVA SUBFASCIATA Walk., *Cat.* 32, 523; Meyr., *Trans. N.Z. Inst.* 16, 108.
Invercargill. January. Very rare.

PLATYPTILIA HELIASTIS Meyr., *Trans. N.Z. Inst.* 17, 129.
Mount Earnslaw, 2,500 ft., in January.

P. FALCATALIS Walk., *Cat.* 30, 931; Meyr., *Trans. N.Z. Inst.* 17, 128.
Generally distributed in forest districts. December and January.

P. AEOLODES Meyr., *Trans. Ent. Soc. Lond.* 1902, 278.

Invercargill; Bluecliff (Waiau). September to March. This is the species referred to as *haasti* (*Trans. N.Z. Inst.* 36, 168).

P. DEPRIVATALIS Walk., *Cat.* 30, 946; *haasti* Meyr., *Trans. N.Z. Inst.* 17, 128.

Invercargill; Ben Lomond, at 2,500 ft. October to May.

P. CAMPSIPTERA Meyr., *Trans. N.Z. Inst.* 39, 113.

Ben Lomond (2,500 ft.); Humboldt Range (3,600 ft.). October to January.

P. EPOTIS Meyr., *Trans. Ent. Soc. Lond.* 1905, 231.

Humboldt Range, at 3,600 ft.

ALUCITA MONOSPILALIS (Walk.), *Cat.* 30, 930; Meyr., *Trans. N.Z. Inst.* 17, 124.

Generally distributed in lowland forest. December to March.

A. LYCOSEMA (Meyr.). *Trans. N.Z. Inst.* 17, 124.

Invercargill, rare; Dunedin. December.

A. INNOTATALIS (Walk.), *Cat.* 30, 945; Meyr., *Trans. N.Z. Inst.* 17, 124.

Generally distributed in open country. October to February.

STENOPTILIA CELIDOTA (Meyr.). *Trans. N.Z. Inst.*, 17, 125.

Lake Wakatipu (Meyrick).

S. CHARADRIAS (Meyr.). *Trans. N.Z. Inst.* 17, 126.

Lake Harris. Amongst *Cassinia*, at 2,800 ft., in January.

S. VIGENS (Feld.), *Reis. Nov.* 140, 49; Meyr., *Trans. N.Z. Inst.* 44, 119.

Lake Wakatipu (Meyrick).

S. ORITES (Meyr.). *Trans. N.Z. Inst.* 17, 126.

Ben Lomond, at 2,500 ft. November and January.

OECETICUS OMNIVORUS (Frdy.), *Trans. N.Z. Inst.* 10, 260, pl. 9.

Generally distributed, but not so common as formerly.

CARPOSINA CONTACTELLA (Walk.), *Cat.* 35, 1813.

Bluff; Invercargill; Queenstown. Attached to *Leptospermum*. November to January.

C. THALAMOTA (Meyr.). *Trans. N.Z. Inst.* 41, 12.

Invercargill; Wyndham. December to February. Rare.

C. ADREPTELLA (Walk.). *Cat.* 29, 654; Meyr., *Trans. N.Z. Inst.* 15, 66.

Generally distributed. September to December. A variety with two diverging black streaks from base of forewing to about $\frac{3}{4}$ is not uncommon.

C. IOPHAEA (Meyr.). *Trans. N.Z. Inst.* 39, 118.

Invercargill; Wyndham. October to February.

C. CRYODANA (Meyr.), *Trans. N.Z. Inst.* 17, 148.

Invercargill; Dunedin. November.

C. EXOCHANA (Meyr.). *Trans. N.Z. Inst.* 20, 76.

Generally distributed. September to December.

C. GONOSEMANA (Meyr.). *Proc. Linn. Soc. N.S.W.* 1882, 179; Meyr., *Trans. N.Z. Inst.* 15, 67.

Generally distributed in lowland bush. November to February.

C. MORBIDA Meyr., *Trans. N.Z. Inst.* 44, 120.
Lake Wakatipu, in February.

PROSELENA NIPHOSTROTA (Meyr.), *Trans. N.Z. Inst.* 39. 117.
Invercargill; Clifden (Wallace); Dunedin. January.

P. ANTIQUANA (Walk.), *Cat.* 28. 307; *nephelotana* Meyr., *Trans. N.Z. Inst.* 15, 57.
Dunedin. Not uncommon from September to March.

PYRGOTIS PYRAMIDIAS Meyr., *Trans. Ent. Soc. Lond.* 1901. 571.
Generally distributed. October to February.

CATAMACTA GAVISANA (Walk.), *Cat.* 28, 312; *conditana* Meyr. (*nec* Walk.), *Trans. N.Z. Inst.* 15, 40.
Generally distributed. October to March.

C. LOTINANA (Meyr.), *Trans. N.Z. Inst.* 15, 40.
Dunedin. January.

CAPUA CYCLOBATHRA (Meyr.). *Trans. N.Z. Inst.* 39. 114.
Invercargill; Dunedin. November to March.

C. PLAGIATANA (Walk.), *Cat.* 28. 370; Meyr., *Trans. N.Z. Inst.* 15, 38.
Generally distributed in all bush districts to 3,000 ft. September to June.

C. PLINTHOGLYPTA (Meyr.), *Trans. N.Z. Inst.* 24. 218.
Invercargill. November to February. Attached to the rimu (*Dacrydium cupressinum*).

C. ARCUATA Philp., *Trans. N.Z. Inst.* 47. 198.
Invercargill. Rare. January.

C. SEMIFERANA (Walk.), *Cat.* 28. 306; Meyr., *Trans. N.Z. Inst.* 15, 37.
Generally distributed in both open and forest country. October to March.

EURYTHECTA ROBUSTA (Butl.), *Proc. Zool. Soc. Lond.* 1877. 403; Meyr., *Trans. N.Z. Inst.* 15. 56.
Ben Lomond; Alexandra. October to December.

E. ZELAEA Meyr., *Trans. Ent. Soc. Lond.* 1905. 233.
Ida Valley.

E. POTAMIAS Meyr., *Trans. N.Z. Inst.* 41, 11.
Invercargill. On grassy spots among sandhills near the coast. March.

E. PARALOXA Meyr., *Trans. N.Z. Inst.* 39. 117.
Invercargill. On coastal sandhills. November to February.

E. EREMANA (Meyr.). *Trans. N.Z. Inst.* 17. 144.
Generally distributed in open country. December.

E. TRIMACULATA Philp., *Trans. N.Z. Inst.* 47, 198.
Ben Lomond and Queenstown Hill. From 1,000 ft. to 2,500 ft. Common in November and December.

EPICHORISTA HEMIONANA (Meyr.), *Trans. N.Z. Inst.* 15, 43.
Dunedin; Paradise. January to April.

E. PERSECTA Meyr., *Trans. N.Z. Inst.* 46. 104.
Invercargill; Queenstown; Dunedin. November to April. The notes under *Tortrix leucaniana* (*Trans. N.Z. Inst.* 33, 181) refer to this species.

Ascerodes prochlora Meyr., *Trans. Ent. Soc. Lond.* 1905, 234.

Mount Rakiahua (Stewart Island); The Hump; Hunter Mountains; Humboldt Range. From 2,000 ft. to 4,000 ft. December to February. The specimens from the exposed summit of Rakiahua are much smaller and narrower-winged than those from other localities.

Tortrix pictoriana (Feld.), *Reis. Nov.* 137, 55; Meyr., *Trans. N.Z. Inst.* 15, 51.

Wakatipu; Hunter Mountains. January to March. Common. An occasional straggler near Invercargill.

T. leucaniana (Walk.), *Cat.* 28, 370; Meyr., *Trans. N.Z. Inst.* 15, 53.
Invercargill; Dunedin; Alexandra. October and March.

T. charactana (Meyr.), *Proc. Linn. Soc. N.S.W.* 1881, 492; *Trans. N.Z. Inst.* 15, 50.
Invercargill. September to January. Fairly common in coastal bush.

T. orthropis (Meyr.). *Trans. Ent. Soc. Lond.* 1901, 573.
Invercargill; Wyndham; Dunedin. December to February.

T. conditana (Walk.). *Cat.* 28. 306; *enoplana* Meyr., *Trans. N.Z. Inst.* 15, 49.
Invercargill; Dunedin. November to January.

T. tigris Philp., *Trans. N.Z. Inst.* 46, 120.
Invercargill. January. Very rare.

T. excessana (Walk.), *Cat.* 28, 303; Meyr., *Trans. N.Z. Inst.* 15, 48.
Generally distributed. September to June.

T. acrocausta (Meyr.), *Trans. N.Z. Inst.* 39, 116.
Generally distributed in forest to 3,000 ft. September to February.

T. molybditis Meyr., *Trans. N.Z. Inst.* 39, 116.
Invercargill; Stewart Island. December to February.

T. crypsidora (Meyr.). *Trans. N.Z. Inst.* 41, 11.
Invercargill. January. Rare.

Ctenopseustis obliquana (Walk.), *Cat.* 28, 302; Meyr., *Trans. N.Z. Inst.* 15, 60.
Generally distributed. September to June.

Harmologa amplexana (Zell.), *Zool. Bot. Ver.* 1875, 222; Meyr., *Trans. N.Z. Inst.* 15, 47.
Generally distributed. November to January.

H. siraea Meyr., *Trans. N.Z. Inst.* 17, 145.

Hunter Mountains. From 3,000 ft. to 4,000 ft. Abundant in December. The southern examples are smaller and less brightly coloured than those from the north.

H. tributaria Philp., *Trans. N.Z. Inst.* 45, 77.
Old Man Range. February.

H. palliata Philp., *Trans. N.Z. Inst.* 46, 120.

Old Man Range; Takitimu Mountains. At 3,500 ft. December to February.

H. tritochlora Meyr., *Trans. N.Z. Inst.* 44, 120.
Lake Wakatipu, 4,000 ft., in February (Meyrick).

H. ACHROSTA Meyr., *Trans. Ent. Soc. Lond.* 1901, 572.
Routeburn. February.

H. SCOLIASTIS (Meyr.), *Trans. N.Z. Inst.* 39. 114.
Generally distributed but not common. January and February.

H. OBLONGANA (Walk.), *Cat.* 28. 303; Meyr., *Trans. N.Z. Inst.* 15. 45.
Queenstown, at 2,000 ft., amongst *Leptospermum*. December. Not common.

H. SISYRANA Meyr., *Trans. N.Z. Inst.* 15. 44.
Wedderburn; Dunedin. January to April.

H. PETRIAS Meyr., *Trans. Ent. Soc. Lond.* 1901. 572.
Bluff: Longwood Range; Hunter Mountains. Attached to *Cassinia*. November to January.

H. RETICULARIS Philp., *Trans. N.Z. Inst.* 47. 199.
Longwood Range, at 2,800 ft., in December. Rare.

H. SANGUINEA Philp., *Trans. N.Z. Inst.* 47, 199.
Hunter Mountains. January. Common at 3,000 ft. amongst *Veronica buxifolia*.

H. FESTIVA Philp., *Trans. N.Z. Inst.* 47. 199.
Hunter Mountains, 3,000 ft., in January.

CNEPHASIA JACTATANA (Walk.), *Cat.* 28. 317; Meyr., *Trans. N.Z. Inst.* 15, 54.
Generally distributed in forest. January to March.

C. SPHENIAS (Meyr.), *Trans. N.Z. Inst.* 41, 11.
Invercargill; Longwood Range. November to January. Rare.

C. LATOMANA (Meyr.), *Trans. N.Z. Inst.* 17, 145.
Bold Peak. February.

C. IMBRIFERANA (Meyr.), *Proc. Linn. Soc. N.S.W.* 1881, 527; *Trans. N.Z. Inst.* 15. 55.
Dunedin. December.

C. MICROBATHRA Meyr., *Trans. N.Z. Inst.* 43, 62.
Invercargill; Orepuki. September to February. Usually found in damp forest or near watercourses.

SPILONOTA ZOPHERANA (Meyr.), *Proc. Linn. Soc. N.S.W.* 1881, 688; *Trans. N.Z. Inst.* 15, 64.
Generally distributed wherever *Leptospermum* grows. September to February.

S. EMPLASTA (Meyr.), *Trans. Ent. Soc. Lond.* 1901, 571.
Invercargill. I have some doubt as to the specific value of this form, and am inclined to regard it as a variety of the preceding species.

S. EJECTANA (Walk.), *Cat.* 28. 350; Meyr., *Trans. N.Z. Inst.* 15. 63.
Generally distributed. Attached to *Leptospermum*. December and January.

EUCOSMA MOCHLOPHORANA (Meyr.), *Trans. N.Z. Inst.* 15. 65.
Lumsden (Meyrick).

E. APHRIAS (Meyr.), *Trans. Ent. Soc. Lond.* 1901, 578.
Invercargill. December. (Meyrick.)

BACTRA XYSTROTA Meyr., *Trans. N.Z. Inst.* 43, 62.
Invercargill. On sandhills near coast in January. Rare.

B. NOTERAULA Wals., *Faun. Haw.* 1, 689; *straminea* Meyr. (*nec* Butl.), *Trans. N.Z. Inst.* 17, 142.
Dunedin. January.

LASPEYRESIA POMONELLA (L.), *Syst. Nat.* 538; Meyr., *Trans. N.Z. Inst.* 15, 61.
Wakatipu. This well-known orchard pest does not occur much farther south than the lower end of Lake Wakatipu.

PHYCOMORPHA METACHRYSA Meyr., *Trans. N.Z. Inst.* 46, 106.
Dunedin. November to March.

MEGACRASPEDUS CALAMOGONA Meyr., *Trans. N.Z. Inst.* 18, 163.
Invercargill. September to May. Larva on flower-heads of the toetoe (*Arundo conspicua*).

ARISTOTELIA PARADESMA (Meyr.), *Trans. N.Z. Inst.* 18, 163.
Invercargill. December to February. Rare.

THIOTRICHA TETRAPHALA Meyr., *Trans. N.Z. Inst.* 18, 164.
Invercargill; Dunedin. January to March. Larva in case on *Leptospermum scoparium*

PHTHORIMAEA OPERCULELLA (Zell.), *Zool. Bot. Ver.* 1873, 262; *solanella* Meyr., *Trans. N.Z. Inst.* 18, 166.
Invercargill, rare; a single example in May. Dunedin, fairly common.

P. THYRAULA (Meyr.), *Trans. N.Z. Inst.* 18, 167.
Mataura. November.

P. BRONTOPHORA (Meyr.). *Trans. N.Z. Inst.* 18, 168.
Mataura. November and December.

P. CHERADIAS (Meyr.), *Trans. N.Z. Inst.* 41, 12.
Invercargill. On sandhills near coast. November and December.

P. GLAUCOTERMA (Meyr.), *Trans. N.Z. Inst.* 43, 63.
Invercargill. On sandhills near coast. November to January.

GELECHIA SCHEMATICA Meyr., *Trans. N.Z. Inst.* 18, 168.
Queenstown. From 1,000 ft. to 2,000 ft. December and January.

G. PARAPLEURA Meyr., *Trans. N.Z. Inst.* 18, 168.
Invercargill. December and January.

G. MONOPHRAGMA Meyr., *Trans. N.Z. Inst.* 18, 169.
Generally distributed in open dry situations. November to January.

G. LITHODES Meyr., *Trans. N.Z. Inst.* 18, 170.
Dunedin; Lake Wakatipu. January.

ANISOPLACA ACRODACTYLA (Meyr.), *Trans. N.Z. Inst.* 39, 118.
Invercargill; Wyndham. November and December.

A. ACHYROTA (Meyr.). *Trans. N.Z. Inst.* 18, 170.
Dunedin; Lake Wakatipu. Rather common amongst forest in December and January (Meyrick).

ZAPYRASTRA CALLIPHANA Meyr., *Trans. N.Z. Inst.* 21. 172.
Generally distributed in open country. October to January.

SYNTOMACTIS DEAMATELLA (Walk.), *Cat.* 654; Meyr., *Trans. N.Z. Inst.* 21, 173.
Invercargill; Bold Peak. December to February. Rare.

ELACHISTA ARCHAEONOMA Meyr., *Trans. N.Z. Inst.* 21, 179.
Dunedin. December and January. (Meyrick.)

E. OMBRODOCA Meyr., *Trans. N.Z. Inst.* 21, 179.
Invercargill; Dunedin. October to March.

E. GERASMIA Meyr., *Trans. N.Z. Inst.* 21, 177.
Invercargill. December and January. Rare.

SCYTHRIS EPISTROTA (Meyr.), *Trans. N.Z. Inst.* 21, 161.
Queenstown. December.

ENDROSIS LACTEELLA Schiff., *Syst. Verz.* 139; Meyr., *Trans. N.Z. Inst.* 21, 160.
Generally distributed. Common throughout the year.

SCHIFFERMUELLERIA ORTHOPHANES (Meyr.), *Trans. Ent. Soc. Lond.* 1905, 243.
Invercargill. November and December. Not common.

BORKHAUSENIA CHRYSOGRAMMA (Meyr.), *Trans. N.Z. Inst.* 16, 44.
Invercargill; Lake Wakatipu; Sunnyside (Waiau). In forest and open waste places. November to January. I am very doubtful as to this obscure southern form being conspecific with the brilliant northern insect.

B. PARATRIMMA Meyr., *Trans. N.Z. Inst.* 43, 63.
Invercargill. November and December.

B. SIDERODETA (Meyr.), *Trans. N.Z. Inst.* 16, 43.
Generally distributed in forest districts. November to January. Very variable; I think it probable that more than one species is included under the name. Stewart Island specimens are larger than those from any other locality.

B. MELANAMMA Meyr., *Trans. Ent. Soc. Lond.* 1905, 240.
Ida Valley; Ben Lomond (2,000 ft.). December and January.

B. HOPLODESMA (Meyr.), *Trans. N.Z. Inst.* 16, 44.
Ben Lomond (Meyrick).

B. MARANTA (Meyr.), *Proc. Linn. Soc. N.S.W.* 1885, 791.
Generally distributed in open dry situations. October to January.

B. ANAEMA (Meyr.), *Trans. N.Z. Inst.* 16, 42.
Invercargill; Stewart Island; Lake Wakatipu. December.

B. ARMIGERELLA (Walk.), *Cat.* 698; Meyr., *Trans. N.Z. Inst.* 16, 41.
Generally distributed. November to February.

B. APERTELLA (Walk.), *Cat.* 29, 698; *oporaea* Meyr., *Trans. N.Z. Inst.* 16, 40.
Generally distributed. November to January.

B. ERIPHAEA Meyr., *Trans. N.Z. Inst.* 46, 107.
Ben Lomond. Beaten from *Nothofagus* at 2,500 ft. in November.

B. PHEGOPHYLLA (Meyr.), *Trans. N.Z. Inst.* 16, 39.
At the head of Lake Wakatipu and at Lake Harris, in December. On *Nothofagus Solanderi.*

B. PERICHLORA Meyr., *Trans. N.Z. Inst.* 39, 119.
Invercargill; Hunter Mountains. In forest, ascending to about 3,250 ft. October to January.

B. BASELLA (Walk.), *Cat.* 492; Meyr., *Trans. N.Z. Inst.* 39, 119.
Invercargill; Bluecliff. December. Rare.

B. POLITIS (Meyr.), *Trans. N.Z. Inst.* 20, 81.
Dunedin. October.

B. PRONEPHELA Meyr., *Trans. N.Z. Inst.* 39, 120.
Invercargill; Bluecliff. On the outskirts of forest. October to February.

B. CHLORADELPHA Meyr., *Trans. Ent. Soc. Lond.* 1905, 239.
Dunedin. October.

B. OXYINA (Meyr.). *Trans. N.Z. Inst.* 16, 45.
Lake Wakatipu, in December. On *Nothofagus Solanderi*, from 1,000 ft. to 3,000 ft.

B. MONODONTA (Meyr.). *Trans. N.Z. Inst.* 43, 75.
Hunter Mountains; Ben Lomond; Paradise. From 2,000 ft. to 3,000 ft., on *Nothofagus Solanderi*. November to January.

B. NYCTERIS (Meyr.). *Trans. N.Z. Inst.* 22, 219.
Invercargill; Wyndham; Riverton. October to December.

B. HOMODOXA (Meyr.). *Trans. N.Z. Inst.* 16, 43.
Ben Lomond. On *Nothofagus Solanderi*, at 2,500 ft. November and December.

B. INNOTELLA (Walk.), *Cat.* 29, 652; *griseata* Meyr., *Trans. N.Z. Inst.* 16, 39.
Invercargill; Dunedin. December to March.

B. BRACHYACMA Meyr., *Trans. N.Z. Inst.* 41, 13.
Invercargill; Dunedin. In forests and open swamps. October and November.

B. CENCHRIAS Meyr., *Trans. N.Z. Inst.* 41, 13.
Invercargill. In low-lying forest. December to February. Not common.

B. AMNOPIS Meyr., *Trans. N.Z. Inst.* 43, 65.
Invercargill; Mataura. October to December.

B. CROTALA Meyr., *Trans. N.Z. Inst.* 47, 213.
Generally distributed in forest districts. Also much attached to hedges and plantations of *Cupressus macrocarpa*. November and December.

B. EPIMYLIA (Meyr.), *Trans. N.Z. Inst.* 16, 36.
Kingston and Queenstown. November and December. The note on this species (*Trans. N.Z. Inst.* 36, 169) may be struck out, the identification being incorrect.

B. CHLORITIS (Meyr.). *Trans. N.Z. Inst.* 16, 36.
Lake Wakatipu (1,000 ft.), in December (Meyrick).

B. LETHARGA (Meyr.), *Trans. N.Z. Inst.* 16, 35.
Invercargill; Dunedin. December and January. Rare.

B. SCHOLAEA (Meyr.). *Trans. N.Z. Inst.* 16, 35.
Generally distributed. November to February.

B. PSEUDOSPRETELLA Stt., *Cat. Brit. Tin.* 14; Meyr., *Trans. N.Z. Inst.* 16, 34.
Generally distributed. December to March.

B. ROBIGINOSA (Philp.), *Trans. N.Z. Inst.* 47, 200.
Longwood Range; Hunter Mountains. Amongst *Cassinia* and *Veronica* scrub, from 2,500 ft. to 3,500 ft. December and January.

GYMNOBATHRA HABROPIS Meyr., *Trans. N.Z. Inst.* 20, 80.
Dunedin. November to March.

G. COARCTATELLA (Walk.). *Cat.* 768; Meyr., *Trans. N.Z. Inst.* 16, 28.
Generally distributed. October to February.

G. SARCOXANTHA Meyr., *Trans. N.Z. Inst.* 16, 29.
Dunedin. January and March. (Meyrick.)

G. PARCA (Butl.), *Proc. Zool. Soc. Lond.* 1877, 405; Meyr., *Trans. N.Z. Inst.* 16, 29.
Generally distributed in forest to 3,000 ft. November to February.

G. CALLIPLOCA Meyr., *Trans. N.Z. Inst.* 16, 30.
Generally distributed in forest, ascending to about 2,500 ft. November to March.

G. THOLODELLA Meyr., *Trans. N.Z. Inst.* 16, 30.
Generally distributed in lowland forest. January to April.

G. OMPHALOTA Meyr., *Trans. N.Z. Inst.*, 20, 81.
Generally distributed in forest at low elevations. November and December.

G. SQUAMEA Philp., *Trans. N.Z. Inst.* 47, 200.
Hunter Mountains, 3,500 ft., in January.

IZATHA PERONEANELLA (Walk.), *Cat.* 658; Meyr., *Trans. N.Z. Inst.* 16, 22.
Generally distributed. November to January.

I. PICARELLA (Walk.), *Cat.* 699; Meyr., *Trans. N.Z. Inst.* 16, 23.
Generally distributed. November to February.

I. BALANOPHORA (Meyr.), *Trans. Ent. Soc. Lond.* 1897, 389.
Bold Peak; Flagstaff Hill. February.

I. MIRA Philp., *Trans. N.Z. Inst.* 45, 78.
Longwood Range; The Hump; Dunedin. October to December.

I. CONVULSELLA (Walk.). *Cat.* 29, 656; *paraneura* Meyr., *Trans. N.Z. Inst.* 24, 219.
Invercargill; Queenstown. October to December.

I. AMORBAS (Meyr.), *Trans. N.Z. Inst.* 43, 66.
Invercargill; Lake Wakatipu. Rare. November.

TRACHYPEPLA CONSPICUELLA (Walk.), *Cat.* 651; Meyr., *Trans. N.Z. Inst* 16, 15.
Queenstown. December.

T. EURYLEUCOTA Meyr., *Trans. N.Z. Inst.* 16, 14.
Generally distributed. December and January. This and the four following species are forest-frequenting forms.

T. GALAXIAS Meyr., *Trans. N.Z. Inst.* 16, 17.
Invercargill; Wyndham. November to March.

T. CONTRITELLA (Walk.). *Cat.* 29. 657 ; *nyctopis* Meyr., *Trans. N.Z. Inst.* 16, 16.

Invercargill ; Lake Wakatipu ; Dunedin. November to February.

T. PROTOCHLORA Meyr., *Trans. N.Z. Inst.* 16, 18.

Invercargill ; Wyndham. November to January.

T. ASPIDEPHORA Meyr., *Trans. N.Z. Inst.* 16, 19.

Invercargill ; Dunedin. December and January. Somewhat rare.

T. ANASTRELLA Meyr., *Trans. N.Z. Inst.* 16, 19.

Invercargill ; Dunedin. December to March. Frequents gardens and hedges, and often enters houses.

ATOMOTRICHA SORDIDA (Butl.), *Proc. Zool. Soc. Lond.* 1877, 405 ; Meyr., *Trans. N.Z. Inst.* 16, 11.

Invercargill. September. Rare.

A. CHLORONOTA Meyr., *Trans. N.Z. Inst.* 46, 110.

Invercargill. August to May. The notes under *ommatias* (*Trans. N.Z. Inst.* 33, 182, and 36, 169) refer to this form. It is doubtful if *ommatias* occurs in Otago, but the species of *Atomotricha* are exceedingly difficult to differentiate.

BAREA CONFUSELLA (Walk.), *Cat.* 29, 682.

Bold Peak ; Dunedin. January and February. Not uncommon.

OXYTHECTA AUSTRINA (Meyr.), *Trans. N.Z. Inst.* 46, 107.

Ben Lomond, at ?,000 ft., on open slopes. December.

NYMPHOSTOLA GALACTINA (Feld.), *Reis. Nov.* 140, 34 ; Meyr., *Trans. N.Z. Inst.* 16, 6.

Generally distributed but not common. December to February.

PROTEODES CARNIFEX (Butl.), *Proc. Zool. Soc. Lond.* 1877, 406 ; Meyr., *Trans. N.Z. Inst.* 16, 7.

Ben Lomond, Lake Monowai. December and January.

P. PROFUNDA Meyr., *Proc. Zool. Soc. Lond.* 1905, 236.

Invercargill ; Longwood Range ; The Hump. In forest to 3,000 ft. November to February. The mountain specimens are considerably larger than the lowland forms.

LATHICROSSA LEUCOCENTRA Meyr., *Trans. N.Z. Inst.* 16, 26.

Invercargill ; Dunedin. December to February. Rare.

CRYPTOLECHIA APOCRYPTA (Meyr.), *Trans. N.Z. Inst.* 18, 172.

Generally distributed in all forest districts except at high elevations. November to January.

C. LIOCHROA (Meyr.), *Trans. N.Z. Inst.* 23, 98.

Invercargill ; Ben Lomond. December and January.

C. COMPSOTYPA (Meyr.), *Trans. N.Z. Inst.* 18, 172.

Invercargill. November to February. Rare.

EUTORNA CARYOCHROA Meyr., *Trans. N.Z. Inst.* 21, 158.

Generally distributed in open dry situations to about 3,000 ft. January and February.

E. SYMMORPHA Meyr., *Trans. N.Z. Inst.* 21, 158.

Generally distributed at low elevations. November to April.

AGRIOPHARA CORICOPA (Meyr.), *Trans. Ent. Soc. Lond.* 1897, 389.
Dunedin. October.

STATHMOPODA CAMINORA Meyr., *Trans. N.Z. Inst.* 22, 219.
Generally distributed in forest at low elevations. November to January. Some of the varieties of this species can hardly be separated from the following form, and it is possible that there is only the one species.

S. SKELLONI (Butl.). *Cist. Ent.* 2, 562; Meyr., *Trans. N.Z. Inst.* 21, 169.
Generally distributed. November to January.

S. PLUMBIFLUA Meyr., *Trans. N.Z. Inst.* 43, 75.
Invercargill; Alexandra. November to April. Rare.

S. CAMPYLOCHA Meyr., *Trans. N.Z. Inst.* 21, 168.
Dunedin. January and February. (Meyrick.)

S. APOSEMA Meyr., *Trans. Ent. Soc. Lond.* 1901, 575.
Woodhaugh (Dunedin). Common in forest during October and November.

THYLACOSCELES ACRIDOMIMA Meyr., *Trans. N.Z. Inst.* 21, 171.
Generally distributed in forest districts. Attached to *Aspidium vestitum.* November to January.

TROCHILIUM TIPULIFORME (Clerck.). *Icon.* pl. 9, 1; Meyr., *Trans. N.Z. Inst.* 22, 214.
Generally distributed. December and January.

HELIOSTIBES ELECTRICA Meyr., *Trans. N.Z. Inst.* 21, 157.
Invercargill. January and February.

H. ATYCHIOIDES (Butl.). *Proc. Zool. Soc. Lond.* 1877, 405, pl. 43, 14; Meyr., *Trans. N.Z. Inst.* 20, 83.
Generally distributed. December and January. Larvae in colonies on *Leptospermum* and the introduced juniper.

H. ILLITA (Feld.), *Reis. Nov.* 140, 32; Meyr., *Trans. N.Z. Inst.* 20, 83.
Invercargill; Dunedin. January. Rare.

SIMAETHIS EXOCHA Meyr., *Trans. N.Z. Inst.* 39, 121.
Humboldt Range, 3,600 ft., in December.

S. COLPOTA Meyr., *Trans. N.Z. Inst.* 43, 67.
Invercargill. December to March. The notes (*Trans. N.Z. Inst.* 33, 182) on *S. combinatana* refer to this insect.

S. MARMAREA Meyr., *Trans. N.Z. Inst.* 20, 85.
Lake Wakatipu (2,200 ft.), in December (Meyrick).

S. BARBIGERA Meyr., *Trans. N.Z. Inst.* 47, 203.
The Hump; Hunter Mountains; Bold Peak. Abundant at 3,000 ft. to 4,000 ft. December and January.

CHOREUTIS BJERKANDRELLA Thunb., *Diss. Ent.* 1, 36, pl. 3, 23, 24.
Generally distributed in open situations and ascending to 3,000 ft. October to January.

GLYPHIPTERYX RUGATA Meyr., *Trans. N.Z. Inst.* 47, 203.
Invercargill; Alexandra. In forest and also on hedges of *Cupressus macrocarpa.* January to April.

G. ACHLYOESSA (Meyr.), *Proc. Linn. Soc. N.S.W.* 1880, 252.
Invercargill. In open grassy places. November and December.

G. BACTRIAS Meyr., *Trans. N.Z. Inst.* 43, 67.
Invercargill. In marshy localities near the seashore. November to January.

G. METASTICA Meyr., *Trans. N.Z. Inst.* 39, 120.
Invercargill. In marshy localities on the sandhills near the coast. October to February.

G. AULOGRAMMA Meyr., *Trans. N.Z. Inst.* 39, 121.
Invercargill. Amongst rough herbage near the coast. October and November.

G. CODONIAS Meyr., *Trans. N.Z. Inst.* 41, 15.
Invercargill. Most plentiful in waste places near the coast. November to January.

G. OXYMACHAERA Meyr., *Proc. Linn. Soc. N.S.W.* 1880, 251.
Generally distributed in open dry situations. January to March.

G. IOCHEAERA Meyr., *Proc. Linn. Soc. N.S.W.* 1880, 243.
Generally distributed wherever the food-plant (*Juncus*) of the larva is found. November to January.

G. LEPTOSEMA Meyr., *Trans. N.Z. Inst.* 43, 75.
Bluff. November.

G. NEPHOPTERA Meyr., *Trans. N.Z. Inst.* 20, 87.
Bluff. In forest near the seashore. March.

G. TRISELENA Meyr., *Proc. Linn. Soc. N.S.W.* 1880, 234.
Generally distributed in open grassy places. December to January.

G. CIONOPHORA (Meyr.), *Trans. N.Z. Inst.* 20, 88.
Dunedin (Meyrick).

G. ASTRAPAEA Meyr., *Proc. Linn. Soc. N.S.W.* 1880, 245.
Invercargill (Meyrick).

G. ERASTIS Meyr., *Trans. N.Z. Inst.* 43, 76.
Lake Wakatipu (Meyrick).

ZELLERIA COPIDOTA (Meyr.), *Trans. N.Z. Inst.* 21, 163.
Lake Wakatipu, in December and January (Meyrick).

HYPONOMEUTA CUPREA Meyr., *Trans. Ent. Soc. Lond.* 1901, 575.
Lake Wakatipu (Meyrick).

PARECTOPA AETHALOTA (Meyr.), *Proc. Linn. Soc. N.S.W.* 1880, 143; Meyr., *Trans. N.Z. Inst.* 21, 185.
Dunedin, in January (Meyrick).

P. AELLOMACHA (Meyr.), *Proc. Linn. Soc. N.S.W.* 1880, 158; *Trans. N.Z. Inst.* 21, 184.
Longwood Range. In forest at 2,500 ft. December.

GRACILARIA LINEARIS Butl., *Proc. Zool. Soc. Lond.* 1877, 406; Meyr., *Trans. N.Z. Inst.* 43, 67.
Generally distributed at low altitudes. September to February.

G. ELAEAS Meyr., *Trans. N.Z. Inst.* 43, 66.
Hunter Mountains; Ben Lomond. From 2,000 ft. to 3,500 ft. November and December.

G. SELENITIS Meyr., *Trans. N.Z. Inst.* 41, 15.

Generally distributed in *Nothofagus* forests from 2.500 ft. upwards. December to February. The species is extremely common, and when a number of them are disturbed from the beech-foliage a clicking sound, like the pattering of raindrops, may be heard. I am unable to offer any explanation as to how this sound is produced.

G. CHRYSITIS Feld., *Reis. Nov.* 140, 43; Meyr., *Trans. N.Z. Inst.* 21. 183.
Invercargill. May and November. Rare.

BATRACHEDRA PSITHYRA Meyr., *Trans. N.Z. Inst.* 21, 181.
Queenstown, at 2,000 ft., in December.

B. ARENOSELLA (Walk.). *Cat.* 857; Meyr., *Trans. N.Z. Inst.* 21, 181.
Invercargill, in swampy situations. February.

B. AGAURA Meyr., *Trans. Ent. Soc. Lond.* 1901, 579.
Invercargill. December and January.

DOLICHERNIS CHLOROLEUCA Meyr., *Trans. N.Z. Inst.* 23. 99.
Invercargill. In swampy situations. December. Rare.

PROTOSYNAEMA STEROPUCHA Meyr., *Trans. N.Z. Inst.* 18. 174.
Generally distributed. September to April.

PHYLACODES CAUTA Meyr., *Trans. Ent. Soc. Lond.* 1905, 242.
Ida Valley.

ORTHENCHES PORPHYRITIS Meyr., *Trans. N.Z. Inst.* 18, 176.

Generally distributed in lowland forest. September to March. A variety frequently occurs which is almost wholly suffused with white.

O. SEMIFASCIATA Philp., *Trans. N.Z. Inst.* 47. 200.
Queenstown; Patupo River (Fiordland). January to March.

PLUTELLA MEGALYNTA Meyr., *Trans. N.Z. Inst.* 47, 203.

Invercargill (a single specimen); Table Hill, Stewart Island, at 2,000 ft.; Hunter Mountains, from 3.000 ft. to 4,000 ft. December. The Invercargill specimen is the only one I have met with under natural conditions; at Table Hill and on the Hunter Mountains the species was commonly found drowned in the tarns on the hillsides. There is an unusual variation in point of size, some of the Hunter Mountain examples having a wing-expanse of 39 mm.*

P. ANTIPHONA Meyr., *Trans. Ent. Soc. Lond.* 1901, 576.
Invercargill; Hunter Mountains; Alexandra. December to April.

P. MACULIPENNIS Curt., *Brit. Ent.* pl. 420; *cruciferarum* Meyr., *Trans. N.Z. Inst.* 18, 177.
Generally distributed. October to March.

P. PSAMMOCHROA Meyr., *Trans. N.Z. Inst.* 18, 179.
Ben Lomond, at 2,000 ft. November.

NEPTICULA OGYGIA Meyr., *Trans. N.Z. Inst.* 21, 187.
Dunedin, in January (Meyrick).

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* The type specimen of this form was given to me by Mr. W. G. Howes. It was amongst some Wellington Lepidoptera, but as there is a little uncertainty as to the locality it is advisable, for the present, to record it as a southern form only.

BEDELLIA SOMNULENTELLA (Zell.), *Isis*, 1847, 894; Meyr., *Trans. N.Z. Inst.* 21, 164.

Dunedin. September to November. (Meyrick.)

B. PSAMMINELLA Meyr., *Trans. N.Z. Inst.* 21, 165.

Dunedin. September, and from December to February. Common. (Meyrick.)

ERECHTHIAS ACRODINA (Meyr.), *Trans. N.Z. Inst.* 44, 122.

Bluff; Dunedin. November and December. Common on dead *Leptospermum* scrub.

E. CHARADROTA Meyr., *Proc. Linn. Soc. N.S.W.* 1880, 268.

Invercargill. Very common in forest. October and November.

E. HEMICLISTRA (Meyr.), *Trans. N.Z. Inst.* 43, 77.

Seaward Moss. A single specimen.

E. FULGURITELLA (Walk.). *Cat.* 28, 548.

Invercargill; Wyndham: Lake Wakatipu; Dunedin. November to February.

DRYADAULA MYRRHINA Meyr., *Trans. Ent. Soc. Lond.* 1905, 243.

Invercargill; Dunedin. September to November.

D. CASTANEA Philp.. *Trans. N.Z. Inst.* 47, 201.

Invercargill. November and December. Rare.

ESCHATOTYPA MELICHRYSA Meyr., *Proc. Linn. Soc. N.S.W.* 1880. 257: *Trans. N.Z. Inst.* 41, 16.

Invercargill; Stewart Island. November to March. Plentiful in most forests.

E. DEROGATELLA (Walk.), *Cat.* 28, 485; Meyr., *Trans. N.Z. Inst.* 41, 16.

Invercargill. November and December. Much more rare than the preceding species.

CRYPSITRICHA MESOTYPA (Meyr.), *Trans. N.Z. Inst.* 20, 94.

Invercargill, in mixed forest; Lake Wakatipu. September to December.

C. ROSEATA (Meyr.), *Trans. N.Z. Inst.* 45, 28.

Invercargill. December and January. Rare.

ARCHYALA PARAGLYPTA Meyr., *Trans. N.Z. Inst.* 21, 159.

Invercargill. January and February. Rare.

A. TERRANEA (Butl.). *Cist. Ent.* 2, 510; Meyr., *Trans. N.Z. Inst.* 20. 100.

Generally distributed. November and December.

SAGEPHORA PHORTEGELLA Meyr., *Trans. N.Z. Inst.* 20, 96.

Common in all forests at low elevations. September to February.

TRICOPHAGA TAPETIELLA (Linn.), *Syst. Nat.* 536; Meyr., *Trans. N.Z. Inst.* 20, 98.

Invercargill. December to March.

MONOPIS ORNITHIAS (Meyr.), *Trans. N.Z. Inst.* 20, 97.

Invercargill; Dunedin; Queenstown. October to January.

M. ETHELELLA (Newm.), *Trans. Ent. Soc. Lond.* 3 (n.s.), 288; Meyr., *Trans. N.Z. Inst.* 20, 97.

Generally distributed, and occurring throughout the year.

M. CROCICAPITELLA Clem., *Proc. Acad. Nat. Sci. Philad.* 1859. 257; *ferruginella* Meyr., *N.Z. Inst.*, 20. 97 (*nec* Hb.).

Invercargill. November to March.

TINEOLA BISELLIELLA Hüm., *Ess. Ent.* 3. 13; Meyr., *Trans. N.Z. Inst.* 20. 101.

Lake Wakatipu. December to February. (Meyrick.)

TINEA MARGARITIS Meyr., *Trans. N.Z. Inst.* 46. 116.

Invercargill. December and January. This and the two following species appear to be mimetic of *Glyphipteryx*. All three forms are, however, rare, and it is consequently difficult to get observational evidence on the matter.

T. ARGODELTA Meyr., *Trans. N.Z. Inst.* 47. 204.

Invercargill. December to February. Rare.

T. ASTRAEA Meyr., *Trans. N.Z. Inst.* 43. 68.

Invercargill. December.

T. FUSCIPUNCTELLA Hw., *Lep. Brit.* 562; Meyr., *Trans. N.Z. Inst.* 20. 100.

Invercargill; Paradise; Dunedin. October to April.

T. MOCHLOTA Meyr., *Trans. N.Z. Inst.* 20. 100.

Invercargill; Queenstown; Dunedin. December and January.

T. MYSTICOPA Meyr., *Trans. N.Z. Inst.* 46, 115.

Invercargill; Dunedin. September to December.

PROTERODESMA BYRSOPOLA Meyr., *Subant. Isl. N.Z.* 74.

Invercargill; Orepuki. October to January.

LYSIPHRAGMA EPIXYLA Meyr., *Trans. N.Z. Inst.* 20, 105.

Generally distributed in forest districts. November to January. Larva under dead bark of *Griselinea littoralis*.

L. HOWESI Quail, *Trans. N.Z. Inst.* 33, 154.

Invercargill. November and December. Not common. I formerly treated this as a synonym of *mixochlora* Meyr., but I now regard it as a distinct species.

TITANOMIS SISYROTA Meyr., *Trans. N.Z. Inst.* 20, 104.

Haldane. A dead specimen of this gigantic Tineid was found by Mr. Robert Gibb on a road near the coast in the summer of 1900.

TALEPORIA SCORIOTA (Meyr.), *Trans. N.Z. Inst.* 41. 16.

Invercargill, in bush. September to November.

T. APHROSTICHA Meyr., *Trans. N.Z. Inst.* 44. 123.

The Hump (3,500 ft.). December.

MALLOBATHRA ARANEOSA Meyr., *Trans. N.Z. Inst.* 46. 117.

Longwood Range; The Hump; Ben Lomond; Dunedin. Most common from 2,000 ft. to 3,000 ft. September to February.

M. GLOBULOSA Meyr., *Trans. N.Z. Inst.* 46, 117.

Invercargill. September (Meyrick). I do not know this form; it is evidently very near, possibly identical with, *scoriota* Meyr.

M. CRATAEA Meyr., *Trans. N.Z. Inst.* 20. 102.

Invercargill. Round the edges of the forest or in openings within it. September and November.

M. HOMALOPA Meyr., *Trans. N.Z. Inst.* 23, 100.

Invercargill; The Hump (3,000 ft.). In open country near forest. October to December.

M. MICROPHANES Meyr., *Trans. N.Z. Inst.* 20, 103.

Dunedin (Meyrick).

PORINA UMBRACULATA (Guen.), *Ent. Mo. Mag.* 5, 1; Meyr., *Trans. N.Z. Inst.* 22, 209.

Generally distributed. October to February.

P. DESPECTA (Walk.), *Cat.* 594; Meyr., *Trans. N.Z. Inst.* 22, 209.

Dunedin. November to February.

P. CERVINATA (Walk.), *Cat.* 595; Meyr., *Trans. N.Z. Inst.* 22, 208.

Alexandra. November. The notes on this and the preceding species (*Trans. N.Z. Inst.* 33, 179, and 36, 170) are valueless, having been founded on mistaken identifications.

P. JOCOSA Meyr., *Trans. N.Z. Inst.* 44, 124.

Invercargill. October to December.

P. COPULARIS Meyr., *Trans. N.Z. Inst.* 44, 123.

Invercargill. December to February.

P. MINOS Huds., *Trans. N.Z. Inst.* 37, 357.

Ophir (Central Otago); Paradise. May.

P. FUSCA Philp., *Trans. N.Z. Inst.* 46, 121.

Bold Peak; Ben Lomond. At about 4,500 ft., in December.

P. SENEX Huds., *Trans. N.Z. Inst.* 40, 107; *annulata* Hmltn., *Trans. N.Z. Inst.* 41, 48.

Mount Aurum, above 4,000 ft.; Old Man Range, about 4,000 ft. February.

P. DINODES Meyr., *Trans. N.Z. Inst.* 22, 206.

Stewart Island; Invercargill; Dunedin. January to March.

MNESARCHAEA PARACOSMA Meyr., *Trans. N.Z. Inst.* 18, 180.

Ben Lomond; Dunedin. On short herbage in open situations to 2,000 ft. December and January.

SABATINCA QUADRIJUGA Meyr., *Trans. N.Z. Inst.* 44, 126.

Invercargill. October. On the bare ground under *Podocarpus dacrydioides* and other trees. The note on *chalcophanes* (*incongruella*) (*Trans. N.Z. Inst.* 33, 185) refers to this species.

S. CAUSTICA Meyr., *Trans. N.Z. Inst.* 44, 124.

Seaward Moss; Bluff; Longwood Range (2,500 ft.). Amongst rough herbage in open situations. October to December.

S. CHRYSARGYRA (Meyr.), *Trans. N.Z. Inst.* 18, 182.

Ben Lomond, 2,000 ft., in December. On mossy patches in the *Nothofagus* forest.

S. CALLIARCHA Meyr., *Trans. N.Z. Inst.* 44, 121.

Invercargill; Bluecliff. December and January. Rare.

## ART. XIII.—*Descriptions of New Species of Lepidoptera.*

By ALFRED PHILPOTT.

Communicated by Dr. W. B. Benham, F.R.S.

[*Read before the Otago Institute, 5th September, 1916; received by Editors, 30th December, 1916; issued separately, 16th July, 1917.*]

### CARADRINIDAE.

**Aletia munda** n. sp.

♂. 33–34 mm. Head and thorax dark grey. Palpi grey, stout, and rather short. Antennae in ♂ moderately serrate, fasciculate-ciliated to apex. Abdomen pale fuscous-grey. Forewings rather short, costa almost straight, apex rounded, termen evenly rounded, oblique; *grey, rather bluish-tinted;* an irregular double interrupted black line at $\frac{1}{3}$; orbicular moderate, rounded, open above and beneath, *ringed with ochreous-white margined with black;* claviform irregularly rounded, touching first line, black; reniform broad, *ringed with ochreous-white, black-margined;* an obscure dentate median dark line passing between orbicular and reniform; second line indicated by a chain of black lunules; subterminal line parallel to termen, ochreous-white, anteriorly black-margined, serrate; a series of black dots on termen; cilia fuscous with paler basal line. Hindwings dark shining fuscous; a black line round termen: cilia pale fuscous with a darker median line.

Nearest to *A. moderata* (Walk.), but the stigmata, especially the prominent reniform, are quite different.

Taken at Waiouru in March by Mr. H. W. Simmonds. I am indebted to Dr. J. A. Thomson, of the Dominion Museum, for the opportunity of describing this form, two good examples having been forwarded by him for that purpose. Type (♂) in coll. Dominion Museum.

**Aletia accurata** n. sp.

♂. 34 mm. Head, palpi, and thorax grey slightly tinged with brown: terminal joint of palpi rather elongate. Antennae in ♂ very shortly ciliated. Abdomen ochreous-brown. Forewings, costa almost straight, apex rectangularly rounded, termen bowed, slightly oblique; *olive-grey; veins marked with white interrupted by black dots;* lines almost obsolete, faintly indicated by white scales; *orbicular well defined, ovate, filled with white, finely margined with black;* reniform rather narrow, bluntly projecting at lower anterior corner, white-ringed, finely margined with black; termen serrately margined with white: cilia brown. Hindwings fuscous-grey-brown: cilia grey with darker median line.

The form of the stigmata differentiates this species from its allies. It has a peculiarly neat and smooth appearance.

Titahi Bay (Wellington), December. The type (coll. M. O. Pascoe) is the only example at present known.

### HYDRIOMENIDAE.

**Chloroclystis furva** n. sp.

♂. 17–20 mm. Head, palpi, thorax, and abdomen dark reddish-brown sprinkled sparsely with grey and black. Antennae black, annulated with whitish, in ♂ ciliate-fasciculate, ciliations 4. Forewings triangular, costa slightly sinuate, apex obtuse, termen angulated at middle, subsinuate beneath; *dark dull-reddish-brown; numerous obscure bluish-green and black transverse lines;* upper half of second line frequently more prominently greenish and followed by a rather broad reddish band; a thin waved bluish-green subterminal line usually present: cilia fuscous-grey, suffusedly barred and mixed with darker. Hindwings in ♂ slightly but broadly projecting on middle of termen; dark greyish-fuscous; veins dotted with whitish scales; dorsal fasciae hardly indicated: cilia as in forewings.

Near *C. rivalis* Philp., but much darker in appearance; the details of wing-shape also show considerable differences.

Mount Cleughearn, Hunter Mountains, in January. The male was found commonly in a restricted spot at about 3,250 ft. No females were obtained.

### Chloroclystis humilis n. sp.

♂♀. 22–25 mm. Head, palpi, thorax, and abdomen grey sprinkled with black. Palpi in ♀ 3½, in ♂ slightly less. Antennae in ♂ evenly ciliated, ¾. Forewings rather narrow, costa hardly arched, termen bowed, strongly oblique; *fuscous-grey, irrorated with black*, sometimes with faint pink suffusion; numerous waved white lines, more prominent on apical half of wing; *margin of the slightly darker basal portion of wing sharply and triangularly indented opposite discal spot;* a black line along termen: cilia whitish-grey with fuscous median line. Hindwings, termen unevenly rounded, in ♂ deeply sinuate above middle; greyish-white with numerous incomplete waved bluish lines: cilia grey, obscurely barred with fuscous.

Nearest to *C. sphragitis* (Meyr.), but showing no greenish coloration.

Queenstown and Ben Lomond. Discovered by Mr. M. O. Pascoe, who secured several examples of each sex in November and December. Types: ♂ in coll. M. O. Pascoe, ♀ in coll. A. Philpott.

### Hydriomena expolita n. sp.

♂. 30 mm. Head, palpi, and antennae purplish-grey. Thorax fuscous-brown mixed with grey. Abdomen fuscous-grey with some reddish scales laterally. Forewings moderate, triangular, costa moderately arched, apex subacute, termen sinuate, oblique; *whitish-grey with faint purplish tinge;* markings dark purplish-fuscous; basal line thick, evenly curved, projecting angularly at middle; anterior margin of median band inwardly oblique beneath costa at ⅓, thence broadly excurved to dorsum at ¼; *posterior margin from ⅔ costa to ¾ dorsum, with strong broad apically-indented projection at middle;* traces of a thin waved white subterminal line; an oblique suffused purplish-fuscous fascia from apex: cilia grey, obscurely barred with fuscous, tips whitish. Hindwings elongate, termen angularly projecting at middle; purplish-grey; basal half darker, being marked off by a median fascia parallel to termen: cilia as in forewings. Undersides: Forewings ochreous-reddish with the upper markings faintly reproduced; hindwings ochreous-reddish, terminal half suffused with whitish.

Nearest to *H. triphragma* (Meyr.), from which it differs chiefly in the shape of the posterior margin of the median band.

Discovered by Mr. J. H. Lewis at Broken River, Canterbury. Seven or eight examples were taken, but I have not been able to ascertain the dates of capture.

### Xanthorhoe umbrosa n. sp.

♂♀. 33–40 mm. Head, palpi, and thorax dull-greenish, tinged with ochreous and sprinkled with blackish. Antennae moderately bipectinated, brownish-ochreous. Abdomen ochreous-grey with paired black dorsal dots on each segment. Forewings triangular, costa almost straight, termen waved, bowed, oblique; *dull green, ochreous-tinged;* veins interruptedly outlined in black; *numerous obscure irregularly-dentate fuscous transverse fasciae;* five of these fasciae, having the interspaces suffused with fuscous, form the median band, anterior margin of which is irregularly curved from $\frac{1}{3}$ costa to $\frac{1}{3}$ dorsum, the posterior margin, from $\frac{2}{3}$ costa to $\frac{2}{3}$ dorsum, has a moderate blunt double projection at middle: a black discal dot; an obscure waved pale subterminal line, suffusedly margined with fuscous anteriorly; a waved black terminal line: cilia greenish-grey, mixed and suffusedly barred with fuscous, and with a pale median line. Hindwings with termen rounded, crenate; greenish-grey: *the markings of the forewings faintly reproduced but less curved and dentate;* a prominent black crenate terminal line: cilia as in forewings. Undersides grey, with fuscous markings of upper sides clearly shown.

In form of wing and markings this species approaches *X. cedrinodes* Meyr. From the greenish forms of the genus it is at once distinguished by its much larger size.

Mount Cleughearn, Hunter Mountains, at about 3,250 ft. Common in January at flowers of *Dracophyllum longifolium.* The female appears to be rare; out of nineteen specimens taken only one belonged to that sex.

### Xanthorhoe nebulosa n. sp.

♂♀. 34 mm. Head, thorax, and abdomen whitish-ochreous finely sprinkled with fuscous. Antennae in ♂ with rather short pectinations. Forewings triangular, costa strongly arched, sinuate at middle, apex moderately sharp, termen subsinuate, oblique; *ochreous-grey-whitish; termen broadly margined with greyish-fuscous:* costal edge very narrowly fuscous; a thin curved brown line near base; first line (anterior edge of median band) irregularly subdentate, curved, brown, from $\frac{1}{3}$ costa to $\frac{1}{3}$ dorsum; second line (posterior edge of median band) irregular, slight triple projection at middle, excurved beneath, from $\frac{2}{3}$ costa to $\frac{3}{4}$ dorsum, brown; an obscure waved pale subterminal line: cilia greyish-ochreous. Hindwings ochreous-grey-whitish; a median fascia and a broad terminal band greyish-fuscous: cilia greyish-ochreous.

Near *X. subobscurata* (Walk.), but smaller and differently marked.

One of each sex taken at Clarence River and Coverham (Marlborough) in February and March by Dr. J. A. Thomson and Mr. H. Hamilton. Types (♂ and ♀) in coll. Dominion Museum.

### Notoreas villosa n. sp.

♂. 35–38 mm. Head, palpi, and thorax ochreous-brown. Antennae, stalk whitish, annulated with black, pectinations 2 mm. Abdomen black, densely strewn with yellowish-white scales, anal tuft ochreous. Forewings moderate, costa hardly arched, almost straight, termen bowed, oblique; *light ochreous-brown,* often densely strewn with white scales; *markings white; first line bent outwardly beneath costa, thence inwardly oblique to dorsum,* posteriorly dark-margined, often obsolete on upper portion; a suffused median shade sometimes present; *second line broad, inwardly* *oblique, twice sinuate*, anteriorly dark-margined; a thin dark line parallel to second line, sometimes obsolete; subterminal broad, waved, parallel to termen: cilia yellowish-white, barred with fuscous, and with a fuscous basal line. Hindwings rather narrow; brownish-fuscous, densely sprinkled with grey-whitish on basal $\frac{2}{3}$; two parallel curved white fasciae beyond middle, second sometimes obsolete: cilia as in forewings. Undersides ochreous-brown; second and subterminal lines of forewings and post-median lines of hindwings usually indicated; a dark discal spot on both wings.

♀. 16 mm. Semiapterous. Forewings oblong, apex subacute, termen hardly rounded, oblique. Hindwings oblong, slightly narrower than forewings, termen and dorsum slightly concave. Legs and antennae normally developed. Palpi small and not densely haired. Legs fuscous, tarsal joints annulated with white. The rest of the insect is white minutely speckled with dark fuscous, and with a slight ochreous tint on head and anterior portion of thorax.

In this species the antennal pectinations reach their highest development, and it is significant that this is coincident with the semiapterous condition of the female. It is probable that *N. villosa* is an offshoot from *N. orphnaea* (Meyr.), that species being attached to rocky and shingly ground, while the former has become adapted to areas covered with more ample vegetation.

Common from December to February in well-grassed situations at from 3,000 ft. to 4,000 ft. The male was first met with on The Hump (Waiau) in 1910, and was subsequently found on the Hunter Mountains. The female was not discovered till December, 1915, when three specimens were taken by Mr. C. C. Fenwick on The Hump. So far, the two localities mentioned are the only ones in which the species has been observed, but in all probability it also occurs on the intervening Princess Range.

## Crambidae.

### Orocrambus cultus n. sp.

♂♀. 24–26 mm. Head, palpi, and thorax dark ochreous-brown, in ♀ lighter. Abdomen ochreous-grey-brown. Forewings elongate, costa slightly arched at base, thence almost straight, apex rectangular, termen bowed, not oblique; brownish-ochreous, finely sprinkled with black and, in ♀, with grey; a rather broad central ochreous-white streak from base to $\frac{2}{5}$, margined with blackish beneath and round apex; a suffused and interrupted whitish transverse fascia at $\frac{2}{3}$; *second line prominent, white, shortly oblique towards termen, thence straight to before tornus*, margined anteriorly with a series of black dashes: cilia fuscous-grey, tips and a series of obscure basal dots white. Hindwings fuscous-grey, in ♀ slightly ochreous-tinged: cilia grey-whitish with a fuscous median line.

Not far removed from *O. machaeristis* Meyr., but differing in the presence of the well-defined second line; the basal streak is also much shorter.

Discovered by Mr. M. O. Pascoe on Cecil Peak, Wakatipu, at an altitude of about 6,000 ft. The examples (two of each sex) were secured early in January and on the 25th February. Types in coll. M. O. Pascoe.

### Crambus scutatus n. sp.

♂. 29–32 mm. Head and palpi ochreous-brown. Thorax brown with broad suffused ochreous-whitish central stripe. Abdomen greyish-ochreous. Forewings moderate, *somewhat oblong*, costa rather strongly and evenly arched, apex subacute, termen subsinuate, oblique; greyish-ochreous-brown; *a narrow whitish-ochreous stripe beneath costa from base to apex;* extreme costal edge brown, dilated on apical half; *a rather broad straight white central stripe, narrowly margined above and beneath with brown;* an obscure whitish-ochreous streak along dorsum: cilia grey-whitish, darker round tornus. Hindwings dark brownish-fuscous: cilia whitish-ochreous with fuscous basal line.

Nearest to *C. oppositus* Philp., but the forewings are not dilated posteriorly and there are several minor distinctions in the character of the pale stripes.

Longwood Range. Five males amongst rough herbage on the open tops at about 2,700 ft. in December.

## PYRAUSTIDÆ.

### Scoparia fimbriata n. sp.

♂. 20 mm. Head and thorax ochreous-brown. Palpi elongate, whitish beneath. *Antennae in ♂ moderately bipectinate;* brown. Abdomen greyish-ochreous. Forewings elongate-triangular, costa gently arched, apex obtuse, termen almost straight, slightly oblique: pale ochreous-brown, darker basally; first line whitish, slightly sinuate and inwardly oblique, broadly margined posteriorly with blackish-brown: reniform 8-shaped, upper half filled with blackish-brown, lower half brown-ringed, pale; some dark suffusion beneath costa between first and second lines: second line thin, indistinct, pale, clearly margined anteriorly with blackish-brown, broadly indented below costa and irregularly dentate on lower half: cilia ochreous with interrupted blackish-brown basal line. Hindwings and cilia ochreous-grey; lunule and subterminal line fuscous.

Extremely similar to *S. acompa* Meyr., but somewhat broader-winged. The antennal structure of the male at once distinguishes it.

Mount Cleughearn, Hunter Mountains, in an open spot in the forest at about 2,750 ft. Three specimens in December and January.

### Mecyna adversa n. sp.

♂♀. 20–21 mm. Head, palpi, and thorax ferruginous, palpi white beneath. Abdomen ochreous. Forewings triangular, costa slightly sinuate in middle, moderately arched on posterior half, apex subacute, termen sinuate, oblique: ferruginous, narrowly brighter along costa; *an irregular transverse outwardly-oblique white discal dot at middle;* a dark second line obscurely indicated: cilia dark brown with pale median line. Hindwings yellow, with discal dot and broad terminal band fuscous: cilia fuscous.

Distinguished from *M. notata* (Butl.), its nearest ally, by the *outwardly-oblique* discal spot of forewings.

Discovered by Mr. G. W. Howes at Queenstown in the last week of February, 1912. Mr. C. E. Clarke has since secured the species in the same locality about the middle of February.

## TORTRICIDAE.

### Epichorista tenebrosa n. sp.

♂ 25–28 mm.; ♀ 22 mm. Head and palpi ochreous-grey mixed with brown, palpi 3. Antennal ciliations of ♂ 1½. Thorax purplish-brown sprinkled with brown. Abdomen ochreous-grey. Forewings elongate-triangular in ♂, suboblong in ♀, costa almost straight, without fold, apex obtuse, termen subsinuate, hardly oblique; *dull grey-brown with purplish gloss and numerous obscure strigulations of reddish or fuscous;* margin of basal patch usually indicated by a more pronounced irregular strigula; median fascia from ⅓ costa, irregular, outwardly oblique, inner margin only marked: cilia grey mixed with brown. Hindwings fuscous-grey, obscurely mottled with darker: cilia grey with darker basal line.

In point of size comparable only with *E. elephantina* (Meyr.), but that species appears to be widely dissimilar in colour and markings. In some specimens of *E. tenebrosa* the markings are almost entirely obsolete.

Ben Lomond, in February. Discovered by Mr. C. E. Clarke, who has kindly placed at my service for description a series of six males and one female. Types (♂ and ♀) in coll. C. E. Clarke.

## Heliodinidae.

### Stathmopoda seminuda n. sp.

♂. 14 mm. Head, palpi, and thorax white. Antennae whitish, darker towards apex. Abdomen fuscous-grey. Forewings narrow, slightly dilated basally: *leaden-fuscous, beneath fold shining white;* median portion of fold margined with black: an obscure ochreous subcostal stripe from ¼ to ¾: some ochreous scales round tornus: cilia fuscous. Hindwings and cilia fuscous.

An obscure form, nearest *S. caminora* Meyr., but the head in that species is yellowish.

Rare. A single specimen taken at Invercargill in November, 1906. Mr. C. E. Clarke has recently secured a second example at Broad Bay, Dunedin, also in November. This latter specimen, being in excellent condition, has been made the type.

## Glyphipterygidae.

### Glyphipteryx aenea n. sp.

♂. 11 mm. Head dark shining brown, with prismatic reflections. Palpi loosely scaled, fuscous-brown, mixed with shining grey-whitish internally except at apex. Antennae dark fuscous. Thorax dark brass-coloured. Abdomen dark fuscous, anal tuft grey. Forewings lanceolate: shining brass-coloured: *a snow-white stripe on costa from before middle to apex, attenuated anteriorly:* cilia white on costa, grey on termen. Hindwings and cilia fuscous-grey.

Nearest *G. cionophora* (Meyr.) in wing-shape; in ground-colour resembling *G. codonias* Meyr. and *G. transversella* Walk., but somewhat paler than either of these species.

The Hump (Waiau), and Mount Burns, Hunter Mountains. From December to February at elevations of from 3,000 ft. to 3,500 ft.

## Plutellidae.

### Orthenches vinitincta n. sp.

♂. 15 mm. Head white, sprinkled with fuscous. Antennae white, basal joints greenish. Palpi whitish, second joint outwardly brownish-fuscous except at apex, terminal joint outwardly narrowly brownish-fuscous at base and apex. Thorax greyish-green, with a pair of black posterior median dots. Abdomen grey-whitish. Legs, anterior pair fuscous annulated with whitish; posterior pair grey; tarsi annulated with fuscous.

Forewings, costa subsinuate, apex broadly rounded, termen oblique beneath; *dorsal half irregularly suffused with pink;* costal half irrorated with fuscous and black; a rather prominent black dot on costa at ½ and a number of blackish strigulae on apical third; a distinct black discal dot; cilia brownish-pink; a broad black bar on tornus preceded by a narrow fuscous bar and followed by two small black patches. Hindwings elongate-ovate, with a ridge of long hairs on basal portion of vein 1*c* directed towards lower median; shining greyish-white; cilia white, round apex brownish-pink; an obscure dark basal line.

Near *O. prasinodes* Meyr., but that species is not described as having any pink suffusion in forewings, and there are other differences.

Rowallan (Waiau), in coastal forest. A single specimen taken by Mr. C. C. Fenwick in December. Type in coll. C. C. Fenwick.

## TINEIDAE.

### Mallobathra illustris n. sp.

♂. 15 mm. Head fuscous, the loose hair-scales tipped with greyish. Palpi comparatively elongate, second joint rough beneath, terminal joint rather pointed; fuscous tipped with greyish. Antennal ciliations ½. Thorax and abdomen purplish-fuscous. Forewings, costa subsinuate, apex round-pointed, termen bowed, oblique; dull purplish-fuscous; *markings creamy white; a large triangular patch on dorsum reaching from ¼ to ½*, its apex about middle of disc; an obscure dot on costa above this, sometimes obsolete; *an inwardly-oblique short fascia on costa beyond middle; a similar but smaller one before apex and an outwardly-oblique one between these two;* a small triangular patch before tornus; three or four minute dots in apical half of wing; cilia purplish-fuscous with a white bar beneath apex and at tornus, and a broad white patch at middle. Hindwings and cilia light fuscous.

Very distinct from any other species of the genus.

The Hump, at about 3,000 ft. I have met with it rarely in December and February; Mr. C. C. Fenwick has also a specimen taken in December at the same locality.

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# ART. XIV.—*Descriptions of New Zealand Lepidoptera.*

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

Communicated by G. V. Hudson, F.E.S.

[*Received by Editors, 30th December, 1916; issued separately, 16th July, 1917.*]

## PLUSIADAE.

### Catada Walk.

ANTENNAE in ♂ ciliated. Palpi very long, curved, ascending, second joint thickened with rough projecting scales, terminal joint long, with loosely appressed scales, pointed. Thorax and abdomen without crests. Tibiae smooth-scaled. Neuration normal (5 of hindwings parallel).

An Indo-Malayan genus of some extent, belonging to the subfamily Hypenides.

**Catada impropria** Walk., *Cat.* xxxiii, 1064 (*Thermesia*).

♂. 34 mm. Forewings somewhat elongate-triangular, termen crenate; brown, mixed with whitish-ochreous and sprinkled with dark fuscous; first and second lines whitish-ochreous partially edged with dark fuscous, curved, irregularly dentate; median irregularly sinuate, indistinct dark fuscous; subterminal indicated by posterior margin of dark-fuscous suffusion, dentate, connected with second line in middle by a blotch of dark-fuscous suffusion; a praemarginal series of cloudy blackish dots. Hindwings with termen crenate; colour and markings much as in forewings, but dark posterior blotch submedian and less defined.

Thames (Hudson): one specimen. A Queensland species. I am not acquainted with its habits, but have no reason to think it likely to be artificially introduced; it is more probably a wind-borne immigrant, and may prove to be widely distributed in the Pacific islands.

## TORTRICIDAE.

### **Olindia** Guen.

Palpi subascending. Thorax with posterior crest. Forewings with 7 to termen, separate. Hindwings without basal pecten, 3 and 4 connate, 5 rather approximated, 6 and 7 closely approximated at base.

Hitherto represented by one European species only.

**Olindia miraculosa** n. sp.

♀. 23 mm. Head and thorax purplish-fuscous, thoracic crest blackish-fuscous. Palpi fuscous. Abdomen dark grey. Forewings elongate, posteriorly dilated, costa moderately arched, apex obtuse, termen hardly rounded, nearly vertical; pale-brownish, transversely strigulated with purplish-grey, extreme costal edge whitish-ochreous; some purplish suffusion towards base of costa; an evenly broad whitish-edged blackish-fuscous fascia rising from dorsum about $\frac{1}{4}$, proceeding in a regular curve to near costa before middle and returning to dorsum at $\frac{2}{3}$; a triangular apical patch of purplish suffusion, deepest along costa; cilia purplish-fuscous. Hindwings dark grey; cilia ochreous-whitish, with dark-grey basal shade.

Wainuiomata, in December (Miss Stella Hudson): one specimen. This is a most surprising species, its strikingly conspicuous markings being unlike anything else, whilst its generic affinity is equally unexpected. I think, however, that it may possibly prove identical with the species figured by Felder (without description) as *Paedisca mahiana* (*Reis. Nov.* pl. cxxxvii, 40) from New Zealand, and not otherwise known to me, which has a somewhat similar scheme of marking, but totally different and in fact reversed colouring, the dark fascia being represented by a pale area and the enclosed semicircular dorsal blotch dark instead of light. Such an excessive range of variation cannot be assumed without evidence, and therefore I have been constrained to treat the species as new. Felder's generic attribution is of no scientific authority, and the colouring of his figure recalls some South American insects, whilst his localities are sometimes erroneous. Special effort should be made to find further examples of this curious insect, which may be very local.

**Epichorista siriana** Meyr.

Amongst examples of this species from Karori sent by Mr. Hudson is a female, which is quite similar in colouring to the male. When, however, I originally described the species, from a series taken by myself at Hamilton. I treated a widely different female specimen with reddish-ochreous forewings and whitish hindwings as being the other sex of the species; after reconsideration of the specimens, all taken together in the same locality, this still seems to me to be probably correct. I desire to direct the attention of collectors to this peculiar case; it ought not to be difficult to determine whether the species has a dimorphic female (which would be unprecedented in this group), or whether there is some error.

## EUCOSMIDAE.

**Spilonota dolopaea** Meyr.

Additional specimens sent by Mr. Hudson show that the male has a long expansible blackish hair pencil from base lying in a dorsal fold of hindwings; in the original example this was completely concealed and therefore unfortunately overlooked, but in those now sent it is exposed and conspicuous, constituting a very distinctive character.

## COSMOPTERYGIDAE.

Recent study has led me to conclude that *Batrachedra* should properly be included in this family instead of the Coleophoridae, which latter group is therefore unrepresented in New Zealand.

**Batrachedra filicicola** n. sp.

♂. 8 mm. Head and thorax bronzy-whitish. Palpi with appressed scales, whitish, with faint greyish marks at apex of second joint, and base and apex of terminal joint. Abdomen grey. Forewings narrow-lanceolate, apex narrowly produced; violet-grey, becoming darker posteriorly, produced apex blackish: cilia grey, base round apical third of wing paler and sprinkled with blackish, sometimes forming indistinct dots, at apex with a short black subbasal bar. Hindwings violet-grey; cilia grey.

Karori, on tree-ferns, in November (Hudson); five specimens. Probably the larva would feed on vegetable refuse accumulated on the stems.

## NEPTICULIDAE.

**Nepticula oriastra** n. sp.

♀. 6 mm. Head, antennae, thorax, and abdomen ochreous-white. Forewings lanceolate; ochreous-white; a small black dot on fold before $\frac{1}{3}$ of wing; apical third of wing blackish: cilia ochreous-white, base dark grey. Hindwings and cilia whitish.

Otira River, on scree east side of gorge at 3,000 ft., on underside of leaves of *Celmisia*, in January (Miss Stella Hudson); two specimens. A very remarkable and interesting species: the minute insects of this genus are difficult of observation, and the circumstances of discovery reflect great credit on the entomological acumen of the fair captor. The larva probably mines in the leaves of the *Celmisia*.

## Art. XV.—*Revision of New Zealand Notodontina.*

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

Communicated by G. V. Hudson, F.E.S.

[*Received by Editors, 30th December, 1916; issued separately, 16th July, 1917.*]

I now complete my revision of the New Zealand Lepidoptera by dealing with the Notodontina. This group is relatively more prominent in New Zealand than elsewhere, being only surpassed in numbers by the Tineina. It should be realized, however, that they are comparatively easy to collect, calling in general for little skill or acumen; so that the group is probably better known than any other, and would, indeed, have been pretty well exhausted before now if it were not that many species are strictly alpine and very local, requiring to be visited in their special haunts.

This group exhibits the same inequality of representation of families that has been noticed in the others; three-fourths of the whole number of species belong to the family Hydriomenidae, which is very adequately represented, whilst the Selidosemidae and Monocteniadae are very imperfectly exhibited, and the other families either wholly absent or indicated only by one or two casually introduced immigrants. Nearly all the local affinities are with the South American region, in accordance with the principles laid down in earlier papers of this series; but the few Monocteniadae are mainly related to Australian forms.

I take the opportunity of explaining here why I am unable to accept the proposal made by Mr. Prout, and communicated through Mr. Howes (*Proc. N.Z. Inst.* vol. 44, p. 54), to establish a genus *Larentia* Treitschke (whose name is disguised as Frietschke in the above communication) to include those species of *Xanthorhoe* in which the hindwings have "vein 5 from below centre of discocellular, which is angled," since it may afford a useful lesson in the principles of classification, a subject on which I hope to be able to issue a more extended treatise some day. I will begin by explaining the nature of the structure referred to, using my own terminology.

The posterior wall of the cell of the hindwings (between veins 4 and 6) I call the "transverse vein." From about the centre of this, or rather above it, a weak internal fold runs towards the base, representing an original internal vein, and the junction of these usually coincides nearly with the lower end of the dark discal spot; the transverse vein is commonly more or less slightly angled inwards at the point of junction, but may also be practically straight. Now, in some species of *Xanthorhoe* vein 5 rises from the point of junction mentioned above; in others it rises from a more or less pronounced outward angulation between this point and vein 4. Mr. Prout would keep the species of the first category as *Xanthorhoe*, and separate from them those of the second as *Larentia*, and the proposal sounds plausible.

When I formulated my classification of the European species of this group in 1892, on lines which have since met with general acceptance, I did not overlook this variation in structure, but rejected it after examination as unsuitable for use. Since that time, however, my available material has been greatly increased, and therefore, in view of Mr. Prout's proposal, I made a new examination of all the species which I have included under *Xanthorhoe* from all regions, and noted the following points:—

(1.) Every intermediate stage is found between these two types of structure, distinct as they may appear in extreme forms. The outward angulation of the lower part of the transverse vein depends solely on the postion of 5 as a concomitant variation: if 5 rises much below the point of junction the angulation is pronounced: if from near below, the angle is difficult of perception; and in some species 5 so closely approaches the point of junction that they can be classed in either category.

(2.) Insistence on this character would in repeated instances involve the separation of species which in all other respects appear to be closely and truly related together. For example, *cinerearia* would be a *Larentia* and *semisignata* a *Xanthorhoe*, as correctly noted by Mr. Prout. Now, these, though so similar as to have been long thought identical, are perhaps not so very closely related, having some difference also in antennal pectinations and shape of wing; but *plumbea* is so similar in all respects to *cinerearia* as to be nearly indistinguishable, agreeing with it exactly in all those characters of size, antennal pectinations, and shape of wing in which *semisignata* differs; and yet *plumbea* would be an undoubted *Xanthorhoe*. Again, *beata*, *benedicta*, and *adonis* must be admitted by every New Zealand entomologist to be exceedingly closely allied. Now, *beata* is an obvious *Larentia*, with 5 rather widely remote from the point of junction; in *benedicta* it is less remote, but still well separated in general (though I have an example in which one wing would pass for *Xanthorhoe*); whilst in *adonis* 5 is sometimes barely separate, but in general practically indistinguishable from normal *Xanthorhoe*, the transverse vein being straight, without either inward or outward angulation, and 5 rising from just by the lower end of the discal spot; similarly *chorica*, which is certainly more nearly related to these three than to any other, is quite as *adonis*. Again, consider the group of nearly related species 113–123: *frivola* and *helias* would be *Xanthorhoe*, *recta* would be *Larentia*, *dionysias* would be *Xanthorhoe*, *aegrota* to *sericodes* would be *Larentia*, *nephelias* would be *Xanthorhoe*. If *nephelias* is not closely related to *sericodes*, what is it related to?

(3.) Having grouped, as well as might be, all the species under the two heads of *Xanthorhoe* and *Larentia*, I considered the groups thus formed, to see if they had any characters of homogeneity as wholes, and it appeared that they had not: there was no other structural or superficial character which distinguished or belonged to one genus as compared with the other: nor was there any geographical support to the distinction, for both genera occurred indiscriminately in all regions.

(4.) Precisely the same variation of structure occurs in other allied genera, such as *Hydriomena* and *Notoreas*, and even in small genera such as *Asaphodes*. It must, therefore, either be a basic and primitive distinction, in which case all these genera must be thrown together and redistributed on this as a primary base (which is apparently not proposed by any one, and would confuse affinities to a degree far exceeding that shown above), or the particular modification of structure must be liable to arise independently in a number of instances: there is no other alternative. If the second of these alternatives is (as it appears) not disputed, there can be no reason why the modification should not arise independently in different parts of the same genus, as well as in different genera; and if that can take place the character is a bad one, and cannot be used for systematic purposes except where confirmed by other characters. When several genera of a family have been established on normal considerations, and it is found that a common variation tends to run through them, the employment of which as a distinguishing character would split up the whole into pairs of closely allied genera (the stalking or separation of veins 7 and 8 of the forewings in the Glyphipterygidae is a case in point, though the same character is of high importance in other families), it should not be so employed.

The proposed alteration appears, then, from (1) to be undefinable, from (2) to be unnatural, from (3) to be useless, and from (4) to be illogical. These would seem to be all the possible lines of argument, and they all point to the same conclusion, the rejection of the proposal. I find the fourth sufficient by itself; but with the support of the other three (which could be extended in detail if necessary) it ought to carry conviction.

One other case in which Mr. Prout's views as to genera differ from mine may be worthy of a short discussion. The two New Zealand and one European species which I unite in the genus *Epirrhanthis* he treats as forming three different genera. The purpose of genera is to unite species into groups based on a natural community of origin, so as to provide an abridged notation for their discussion as units in problems of phylogeny and geography. Monotypic genera are useless for this purpose (being simply species), and, though sometimes necessary, should be avoided when possible. Now, Mr. Prout has published his considered views on the Monocteniadae (to which *Epirrthanthis* belongs) in the *Genera Insectorum* (under the title of "Oenochrominae"). He admits these three genera to be nearly allied, for he places them together, and produces nothing else as being nearly allied to them, the genera on each side of them being remote; the distinctions alleged between them are in minor characters, which can be regarded as specific merely (it is often not understood that not only all species, but all individuals, differ in structure); it is true he treats one of the species (with doubt) as two, but there is small justification for that course (he was perhaps misled by the difference in the sexes); the aggregate of the three species can be defined as a whole (I so define it in this paper): what, then, is gained by keeping them separate? It can serve no object but a fancied equalization of generic standard, which Mr. Prout has himself elsewhere admitted to be unrealizable: no two genera are equivalent in value. Whereas by uniting them the interesting geographical relation is clearly brought out and summarized under the single head: we are substituting a genus which signifies something for three which signify nothing.

As to some other opinions expressed by my friend Mr. Prout in the former paper quoted, it will be charitable to assume that they were not intended for publication. When, for example, he states that *Selidosema* "is a European genus, and probably does not occur in New Zealand" (p. 53), the argument seems defective, in view of the fact that all the largest New Zealand genera of Lepidoptera without exception are European. I add as a further generalization that they are always common European genera, and that they are never equally well developed in Australia. A more correct inference would have been that as the group of New Zealand species in question is a considerable one, therefore it is most probably European.

Again, when Mr. Prout recommends distinguishing *euclidiata* from *catapyrrha* by the absence of red on the underside, "until it can be proved that they are conspecific," he seems to be wholly unaware that *euclidiata* is an Australian species, with double areole, and ciliated antennae of male, whilst *catapyrrha* has single areole and pectinated antennae (fully explained by me twenty-six years ago in *Proc. Linn. Soc. N.S.W.* 1890, p. 876). If we are ever able to regard these as conspecific, our notions of species will have undergone remarkable change.

As in previous papers of this series, I have only given synonymy and references sufficient for local use.

## 1. HYDRIOMENIDAE.

Forewings: 10 rising separate, anastomosing with 11 and 9 (forming double areole), or rising out of 11 and anastomosing with 9 (forming simple areole). Hindwings: 5 fully developed, parallel to 4, 6 and 7 almost always stalked or connate, 8 anastomosing with upper margin of cell from near base to beyond middle, or seldom approximated only and connected by bar beyond middle.

A very large family of universal distribution, equally plentiful in New Zealand.

### 1. Tatosoma Butl.

*Tatosoma* Butl., *Cat. Lep. N.Z.* 17 (1874); type, *agrionata* Walk.

Face smooth. Antennae gradually dilated from base to near apex, apex attenuated in ♂ simple. Abdomen in ♂ extremely long. Forewings: areole double. Hindwings small, in ♂ with dorsal lobe folded into a pocket, 8 free, connected with cell by bar before angle, in ♀ neuration normal.

Endemic; it is, however, a closely related development of the characteristically South American genus *Rhopalodes*, from which it differs only by the unusual elongation of the male abdomen. The habits of these curious insects should be an interesting study.

1. *T. lesterata* Walk., *Cat.* xxv, 1416; Meyr., *Trans. N.Z. Inst.* xvi, 67; Huds., *N.Z. Moths*, 39, pl. vi, 25; *ranata* Feld., *Reis. Nor.* pl. cxxxi, 11.
   Wellington, Nelson, Christchurch.
2. *T. tipulata* Walk., *Cat.* xxv, 1417; Meyr., *Trans. N.Z. Inst.* xliii, 71; *collectaria* Walk., *Cat.* xxv, 1419; *agrionata* Huds., *N.Z. Moths*, 40, pl. vi, 26, 27.
   Wellington, Nelson, Otira River, Dunedin, Wallacetown.
3. *T. agrionata* Walk., *Cat.* xxv, 1417; Meyr., *Trans. N.Z. Inst.* xliii, 71; *inclinataria* Walk., *Cat.* xxv, 1418; *mistata* Feld., *Reis. Nor.* pl. cxxxi, 12.
   Christchurch, Wallacetown.
4. *T. alta* Philp., *Trans. N.Z. Inst.* xlv, 76; *apicipallida* Prout, *Trans. N.Z. Inst.* xlvi, 122.
   Otira River, Humboldt Range (1,200–4,500 ft.).
5. *T. transitaria* Walk., *Cat.* xxv, 1419; Meyr., *Trans. N.Z. Inst.* xliii, 71.
   Locality unrecorded; perhaps North Island.
6. *T. fasciata* Philp., *Trans. N.Z. Inst.* xlvi, 118.
   Lake McKenzie.
7. *T. timora* Meyr., *Trans. N.Z. Inst.* xvii, 64; Huds., *N.Z. Moths*, 40, pl. vi, 28, 29; *agrionata* Meyr., *Trans. N.Z. Inst.* xvi, 68.
   Ohakune, Palmerston North, Wellington, Christchurch.
8. *T. topia* Philp., *Trans. N.Z. Inst.* xxxv, 247, pl. xxxii, 3, 4.
   Otira River, Lake Wakatipu, Invercargill.

### 2. Elvia Walk.

*Elvia* Walk., *Cat.* xxv, 1430 (1862); type, *glaucata* Walk.

Face with cone of scales. Antennae in ♂ flattened, bipectinated. Palpi rather long, rough-scaled. Forewings: areole simple, 11 running into 12. Hindwings normal. Wings longitudinally folded in repose.

Endemic.

9. *E. glaucata* Walk., *Cat.* xxv. 1431; Feld., *Reis. Nov.* pl. cxxxii, 25; Meyr., *Trans. N.Z. Inst.* xvi. 65; Huds., *N.Z. Moths.* 46, pl. vi, 23. 24: *donovani* Feld., *Reis. Nov.* pl. cxxxii. 5.
North and South Islands.

### 3. Microdes Guen.

*Microdes* Guen., *Lep.* x, 296 (1857); type, *villosata* Guen.

Face with cone of scales. Antennae in ♂ simple or ciliated. Palpi long or very long, rough-scaled. Forewings: areole simple, 11 running into 12. Hindwings in ♂ reduced, narrowed or distorted.

A genus of very few species, confined to Australia and New Zealand.

10. *M. epicryptis* Meyr., *Trans. Ent. Soc. Lond.* 1897. 384.
Wellington.

11. *M. villosata* Guen., *Lep.* x. 297, pl. xv. 8; Meyr., *Proc. Linn. Soc. N.S.W.*, 1890. 802: *quadristrigata* Walk., *Cat.* xxiv. 1200: Meyr., *Trans. N.Z. Inst.* xvii. 67: *interclusa* Walk., *Cat.* xxiv. 1202: *mixtaria* Walk., *Cat.* xxvi. 1663: *toriata* Feld., *Reis. Nov.* pl. cxxxi, 34: *rectilineata* Huds., *N.Z. Moths.* 45, pl. vi. 22 (*bis*).
Wellington, Stewart Island; common and widely distributed in Australia and Tasmania.

### 4. Phrissogonus Butl.

*Phrissogonus* Butl., *Ann. Mag. Nat. Hist.* (5) ix. 94 (1882); type, *laticostatus* Walk.

Face with small cone of scales. Antennae in ♂ simple or ciliated. Palpi moderate, rough-scaled. Abdomen slightly crested. Forewings in ♂ with glandular swelling or projecting tuft on costa; areole simple, 11 running into 12. Hindwings normal.

A small Australian genus, of which two species are found also in New Zealand.

12. *P. laticostatus* Walk., *Cat.* xxiv. 1196; Meyr., *Proc. Linn. Soc. N.S.W.* 1890, 801; id. *Trans. N.Z. Inst.* xlv, 22: *canata* Walk., *Cat.* xxv, 1357; Butl., *Ann. Mag. Nat. Hist.* (5) ix. 94.
Nelson; Kermadec Islands; very common and generally distributed in Australia and Tasmania.

13. *P. denotatus* Walk., *Cat.* xxv. 1361; Meyr., *Trans. N.Z. Inst.* xx. 53; id. *Proc. Linn. Soc. N.S.W.* 1890. 798: Huds., *N.Z. Moths.* 45, pl. vi. 19: *parvulata* Walk., *Cat.* xxvi. 1721.
North and South Islands; Kermadec Islands; common and widely distributed in Australia and Tasmania. Larva on flowers of *Brachyglottis repanda*.

### 5. Chloroclystis Hübn.

*Chloroclystis* Hübn., *Verz.* 323 (1816); type, *rectangulata* Linn.
*Pasiphila* Meyr., *Trans. N.Z. Inst.* xvi, 66 (1884); type, *bilineolata* Walk.

Face with small cone of scales. Antennae in ♂ ciliated or simple. Palpi moderate or long, rough-scaled. Abdomen slightly crested. Forewings: areole simple, 11 running into 12. Hindwings normal.

A rather extensive genus, well represented in India: occurring also in Africa, Europe, and Australia, but nowhere so prominent as in New Zealand. Owing to their variability and similarity the species have been much misunderstood, and require close study.

14. *C. inductata* Walk., *Cat.* xxv. 1322; Meyr., *Trans. N.Z. Inst.* xx. 53: *subitata* Walk., *Cat.* xxv. 1362.
Locality unrecorded: this and other species collected by Colonel Bolton appear to indicate an interesting locality containing forms unfamiliar to modern collectors, but possibly destroyed.

15. *C. semialbata* Walk., *Cat.* xxvi, 1708; Meyr., *Trans. N.Z. Inst.* xlv, 23: *indicataria* Walk., *Cat.* xxvi, 1708; Meyr., *Trans. N.Z. Inst.* xx. 52; Huds., *Subantarct. Isl. N.Z.* pl. ii, 20–22.
Napier, Wellington, Nelson, Christchurch: Auckland Island; Kermadec Islands.

16. *C. sandycias* Meyr., *Trans. Ent. Soc. Lond.* 1905, 219; *plinthina* Huds., *N.Z. Moths,* 41, pl. vi, 8.
Wellington, Otira River, Invercargill.

17. *C. plinthina* Meyr., *Trans. N.Z. Inst.* xxi. 49.
Invercargill.

18. *C. melochlora* Meyr., *Trans. N.Z. Inst.* xliii, 58.
Otira River.

19. *C. muscosata* Walk., *Cat.* xxv, 1246; Meyr., *Trans. N.Z. Inst.* xx, 50: *cidariaria* Guen., *Ent. M. Mag.* v. 62: *aquosata* Feld., *Reis. Nov.* pl. cxxxii, 38: *bilineolata* Huds., *N.Z. Moths*, pl. vi, 9, 10.
Auckland, Napier, Wellington, Nelson, Christchurch.

20. *C. paralodes* Meyr., *Trans. N.Z. Inst.* xlv, 23.
Wellington, Lake Wakatipu.

21. *C. zatricha* Meyr., *Trans. N.Z. Inst.* xlv. 24.
Wellington.

22. *C. lacustris* Meyr., *Trans. N.Z. Inst.* xlv, 24.
Arthur's Pass, Lake Wakatipu.

23. *C. bilineolata* Walk., *Cat.* xxv, 1246; Meyr., *Trans. N.Z. Inst.* xx, 50: *antarctica* Huds., *N.Z. Moths,* 42, pl. vi, 20.
Wellington, Christchurch, Arthur's Pass, Dunedin, Lake Wakatipu, Invercargill. Larva on *Veronica.*

24. *C. lunata* Philp., *Trans. N.Z. Inst.* xliv, 115.
Wellington, Wallacetown. Larva on *Veronica.*

25. *C. cotinaea* Meyr., *Trans. N.Z. Inst.* xlv. 24.
Masterton.

26. *C. charybdis* Butl., *Cist. Ent.* 2, 503; *calida* ib. 504.
Wellington, Dunedin.

27. *C. dryas* Meyr., *Trans. N.Z. Inst.* xxiv. 97; Huds., *N.Z. Moths,* 43, pl. vi, 12.
Wellington.

28. *C. aristias* Meyr., *Trans. Ent. Soc. Lond.* 1897, 385; Huds., *N.Z. Moths.* 42, pl. vi, 21, 22.
Mount Arthur: 4,000 ft.
29. *C. furva* Philp., this volume, p. 239.
Hunter Mountains.
30. *C. rubella* Philp., *Trans. N.Z. Inst.* xlvii, 193.
Humboldt Range.
31. *C. erratica* Philp. MS.
Hunter Mountains.
32. *C. modesta* Philp., *Trans. N.Z. Inst.* xlvii, 193.
Humboldt Range; 3,000–4,000 ft.
33. *C. halianthes* Meyr., *Trans. N.Z. Inst.* xxxix, 107; *rufulitincta* Prout, *Trans. N.Z. Inst.* xlvi, 123.
Lake Wakatipu.
34. *C. magnimaculata* Philp., *Trans. N.Z. Inst.* xlvii, 193.
Mount Cook, Lake Wakatipu.
35. *C. malachita* Meyr., *Trans. N.Z. Inst.* xlv, 25; *luminosa* Philp., *Trans. N.Z. Inst.* xlvii, 192.
Wellington, Lake Harris, Lake Wakatipu.
36. *C. lichenodes* Purd., *Trans. N.Z. Inst.* xx, 70; Huds., *N.Z. Moths.* 44, pl. vi, 15, 16.
Wellington, Otira River, Dunedin, Stewart Island.
37. *C. maculata* Huds., *N.Z. Moths.* 44, pl. vi, 18.
Wellington, Otira River.
38. *C. sphragitis* Meyr., *Trans. N.Z. Inst.* xxi, 51; Huds., *N.Z. Moths.* 43, pl. vi, 13, 14.
Kaitoke, Wellington, Christchurch, Otira River.
39. *C. minima* Huds., *Trans. N.Z. Inst.* xxxvii, 356.
Ida Valley. I have not seen this species.
40. *C. nereis* Meyr., *Trans. N.Z. Inst.* xxi, 51; Huds., *N.Z. Moths.* 43, pl. vi, 11.
Ruapehu, Mount Arthur, Mount Hutt, Lake Harris, Mount Earnslaw, Humboldt Range; 2,500–5,000 ft.

### 6. Eucymatoge Hübn.

*Eucymatoge* Hübn., *Verz.* 325 (1816): type, *togata* Hübn.

Face with cone of scales. Antennae in ♂ ciliated. Palpi moderate, rough-scaled. Abdomen with slight crests throughout. Forewings: areole double. Hindwings normal.

A genus of moderate extent and general distribution, with the interesting feature of special development in the Hawaiian Islands.

41. *E. arenosa* Howes, *Trans. N.Z. Inst.* xliii, 127, pl. i, 2.
Wellington, Moeraki.
42. *E. gobiata* Feld., *Reis. Nov.* pl. cxxxi, 2; Meyr., *Trans. N.Z. Inst.* xvi, 70; Huds., *N.Z. Moths.* pl. vi, 44; *simulans* Butl., *Cist. Ent.* 2, 506; *unduligera* ib. 506; *rivularis* ib. 507.
North and South Islands. Larva on *Corposma.*
43. *E. anguligera* Butl., *Cist. Ent.* 2, 506; Meyr., *Trans. N.Z. Inst.* xli, 5; *gobiata* Huds., *N.Z. Moths.* pl. vi, 43.
Wellington, Invercargill.

### 7. Hydriomena Hübn.

*Hydriomena* Hübn., *Verz.* 322 (1816); type, *elutata* Hübn. *Cephalissa* Meyr., *Trans. N.Z. Inst.* xvi, 93 (1884); type, *siria* Meyr. *Anachloris* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type, *subochraria* Doubl.

Face with cone of scales. Antennae in ♂ ciliated. Palpi moderate, rough-scaled. Abdomen sometimes crested on two basal segments. Forewings: areole double. Hindwings normal.

A very large genus, dominant in almost all regions, and extensively developed in Australia, but comparatively much less important in New Zealand.

44. *H. siria* Meyr., *Trans. N.Z. Inst.* xvi, 93; Huds., *N.Z. Moths*, 51, pl. vi, 48.
Dunedin, Invercargill. Isolated in New Zealand, but I have seen a Chilian species apparently closely related to it.

45. *H. triphragma* Meyr., *Trans. N.Z. Inst.* xvi, 74; Huds., *N.Z. Moths*, 49; *siris* Hawth., *Trans. N.Z. Inst.* xxix, 283; Huds., *N.Z. Moths*, 55, pl. vii, 16.
Wellington, Blenheim, Dunedin.

46. *H. purpurifera* Fer., *N.Z. Journ. Sci.* 1, 531; Meyr., *Trans. N.Z. Inst.* xvi, 75; Huds., *N.Z. Moths*, 49, pl. vii, 12.
Ohakune, Mount Arthur, Mount Hutt, Castle Hill, Dunedin, Lake Wakatipu.

47. *H. rixata* Feld., *Reis. Nov.* pl. cxxxii, 1; Meyr., *Trans. N.Z. Inst.* xvi, 75; Huds., *N.Z. Moths*, 49, pl. vii, 11; *squalida* Butl., *Cist. Ent.* 2, 505.
North and South Islands.

48. *H. similata* Walk., *Cat.* xxv, 1413; Meyr., *Trans. N.Z. Inst.* xvi, 76; Huds., *N.Z. Moths*, 50, pl. vii, 14; *timarata* Feld., *Reis. Nov.* pl. cxxxii, 19.
Napier, Wellington, Christchurch, Dunedin, Lake Wakatipu, Invercargill. Larva on *Coprosma*.

49. *H. callichlora* Butl., *Cist. Ent.* 2, 509; Meyr., *Trans. N.Z. Inst.* xvi, 76; Huds., *N.Z. Moths*, 50, pl. vii, 13.
Wellington, Otira River, Christchurch, Invercargill.

50. *H. arida* Butl., *Cist. Ent.* 2, 509; Meyr., *Trans. N.Z. Inst.* xvii, 64; Huds., *N.Z. Moths*, 50 pl. vii, 15; *chaotica* Meyr., *Trans. N.Z. Inst.* xvi, 76.
Picton, Mount Arthur, Akaroa, Mount Hutt, Arthur's Pass, Dunedin, Stewart Island.

51. *H. hemizona* Meyr., *Trans. Ent. Soc. Lond.* 1897, 385; Huds., *N.Z. Moths*, 48, pl. vii, 10.
Wellington, Mount Arthur, Lake Wakatipu.

52. *H. officiosa* Meyr., *Trans. N.Z. Inst.* xlii, 69.
Kermadec Islands.

53. *H. subrectaria* Guen., *Lep.* x, 411; Meyr., *Proc. Linn. Soc. N.S.W.* 1890, 829; *responsata* Walk., *Cat.* xxv, 1409; *casta* Butl., *Cist. Ent.* 2, 553.
Queenstown; also widely distributed in south-east Australia doubtless its home.

54. *H. deltoidata* Walk., *Cat.* xxv. 1321; Meyr., *Trans. N.Z. Inst.* xvi, 70; Huds., *N.Z. Moths*, 47, pl. vii, 1–9: *inclarata* Walk., *Cat.* xxv, 1411: *perductata* ib. 1412: *congressata* ib. 1412: *conversata* ib. 1413: *descriptata* ib. 1414: *bisignata* ib. 1415: *aggregata* ib. 1415: *congregata* ib. 1415: *plagifuscata* ib. 1416: *pastinaria* Guen., *Ent. M. Mag.* v, 64: *inopiata* Feld., *Reis. Nov.* pl. cxxxii, 3: *monoliata* ib. 8: *perversata* ib. 14, 24.

North and South Islands. Larva on *Plantago*.

55. *H. prionota* Meyr., *Trans. N.Z. Inst.* xvi, 73; Huds., *N.Z. Moths*. 47, pl. vi. 47.

Mount Arthur, Castle Hill, Dunedin.

56. *H. subochraria* Doubl., *Dieff. N.Z.* 2, 285; Butl. *Cat. Lep. N.Z.*, pl. iii, 16; Meyr., *Trans. N.Z. Inst.* xvi, 73; Meyr., *Proc. Linn. Soc. N.S.W.* 1890, 851; Huds., *N.Z. Moths*, 48, pl. vi, 45, 46: *euboliaria* Walk., *Cat.* xxvi, 1684: *strangulata* Guen., *Lep.* x, 423: *fuscinata* Guen., *Ent. M. Mag.* v, 92.

North, South, and Stewart Islands. Also widely distributed in Australia and Tasmania.

57. *H. lithurga* Meyr., *Trans. N.Z. Inst.* xliv, 71.

Makara. I think this may prove to occur in Australia.

### 8. **Asthena** Hübn.

*Asthena* Hübn., *Verz.* 310 (1816); type, *candidata* Schiff.

Face smooth, flat. Antennae in ♂ ciliated. Palpi short, slender, loosely scaled. Forewings: areole double. Hindwings normal.

A small genus of wide distribution; the New Zealand species are of Australian type

58. *A. schistaria* Walk., *Cat.* xxiii, 782; Meyr., *Trans. N.Z. Inst.* xvi, 69; Huds., *N.Z. Moths*, 52, pl. vi, 39–42: *subpurpureata* Walk., *Cat.* xxvi, 1588: *tuhuata* Feld., *Reis. Nov.* pl. cxxviii, 5.

North, South, and Stewart Islands. Larva on *Leptospermum*.

59. *A. pulchraria* Doubl., *Dieff. N.Z.* 2, 286; Meyr., *Trans. N.Z. Inst.* xx, 69; Meyr., *Proc. Linn. Soc. N.S.W.* 1890, 813: Huds., *N.Z. Moths*, 52, pl. vi, 37, 38: *plurilineata* Walk., *Cat.* xxii, 563, 676: *ondinata* Guen., *Lep.* ix, 438, pl. xix, 4; Butl., *Cat. N.Z. Lep.*, pl. iii, 20; Feld., *Reis. Nov.* pl. cxxviii, 17.

North and South Islands. Common and widely distributed in Australia and Tasmania.

### 9. **Euchoeca** Hübn.

*Euchoeca* Hübn., *Verz.* 298 (1816); type, *obliterata* Hufn. *Epicyme* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886).

Face smooth, flat. Antennae in ♂ ciliated. Palpi short, slender, loosely scaled. Forewings: areole simple. Hindwings normal.

Also small and widely distributed.

60. *E. rubropunctaria* Doubl., *Dieff. N.Z.* 2, 287; Meyr., *Trans. N.Z. Inst*, xvi, 60; Meyr., *Proc. Linn. Soc. N.S.W.* 1890, 811; Huds., *N.Z. Moths*, 51, pl. vi, 35: *pulchraria* Walk., *Cat.* xxiii, 780; Butl., *Cat. N.Z. Lep.* pl. iii, 18: *risata* Guen., *Lep.* ix, 438: *nullata* Guen., *Ent. M. Mag.* v, 42.

North, South, and Stewart Islands; Kermadec Islands. Widely distributed in Australia and Tasmania. Larva on *Halorrhagis alata*.

### 10. Venusia Curt.

*Venusia* Curt., *Brit. Ent.* 759 (1839); type, *cambrica* Curt. *Epiphryne* Meyr., *Trans. N.Z. Inst.* xvi, 60 (1884); type, *undosata* Feld. *Pancyma* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type, *verriculata* Feld. *Aulopola* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type, *xanthaspis* Meyr.

Face smooth. Antennae in ♂ bipectinated, apex simple. Palpi loosely scaled. Forewings: areole simple. Hindwings normal.

The typical species occurs throughout northern temperate regions, and I have also one from South America.

61. *V. dissimilis* Philp., *Trans. N.Z. Inst.* xlvi, 118.
Ben Lomond.

62. *V. verriculata* Feld., *Reis. Nov.* pl. cxxxi, 20; Meyr., *Trans. N.Z. Inst.* xvi, 62; Huds., *N.Z. Moths*, 53, pl. vi, 30, 31.
Wellington, Christchurch, Ashburton, Dunedin, Invercargill. Lava on *Cordyline.*

63. *V. charidema* Meyr., *Subantarct. Isl. N.Z.* 1, 70.
Wellington, Ben Lomond, Auckland and Campbell Islands.

64. *V. undosata* Feld., *Reis. Nov.* pl. cxxviii, 2; Meyr., *Trans. N.Z. Inst.* xvi, 60; Huds., *N.Z. Moths*, 54, pl. vi, 33, 34: *citrinata* Warr., *Nov. Zool.* x, 265.
Napier, Palmerston North, Wellington, Nelson, Mount Arthur, Mount Hutt, Christchurch, Dunedin, Lake Wakatipu. Larva on *Plagianthus betulinus.*

65. *V. xanthaspis* Meyr., *Trans. N.Z. Inst.* xvi, 61; Huds., *N.Z. Moths*, 54, pl. vi, 32.
Tararua Ranges, Lake Guyon, Mount Arthur, Otira River, Lake Wakatipu.

### 11. Asaphodes Meyr.

*Asaphodes* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type, *abrogata* Walk. *Probolaea* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type, *megaspilata* Walk. *Homodotis* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type, *rufescens* Butl.

Face with cone of projecting scales. Palpi moderate, rough-scaled. Antennae in ♂ bipectinated, apex simple. Forewings: areole simple. Hindwings normal.

Endemic.

66. *A. stephanitis* Meyr., *Trans. N.Z. Inst.* xxxix, 108.
Invercargill.

67. *A. abrogata* Walk., *Cat.* xxiv, 1075; Meyr., *Trans. N.Z. Inst.* xvi, 61; Huds., *N.Z. Moths*, 55, pl. vii, 21: *servularia* Guen., *Ent. M. Mag.* v, 43.
Murimutu, Kekerangu, Christchurch, Castle Hill, Dunedin, Invercargill.

68. *A. megaspilata* Walk., *Cat.* xxiv, 1198; Meyr., *Trans. N.Z. Inst.* xvi, 63; Huds., *N.Z. Moths*, 55, pl. vii, 17–20: *assata* Feld., *Reis. Nov.* pl. cxxxi, 4: *nehata* ib. 6.
North and South Islands.

69. *A. parora* Meyr., *Trans. N.Z. Inst.* xvii, 63; Huds., *N.Z. Moths*, 56; *humeraria* Meyr., *Trans. N.Z. Inst.* xvi, 64.
Wellington, Christchurch, Mount Hutt, Dunedin.

70. *A. rufescens* Butl., *Cist. Ent.* 2, 502; Meyr., *Trans. N.Z. Inst.* xvii, 63; Huds., *N.Z. Moths,* 56: *cymosema* Meyr., *Trans. N.Z. Inst.* xvi, 63.
Dunedin, Stewart Island.

### 12. Paradetis Meyr.

*Paradetis* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type, *porphyrias* Meyr.

Face smooth. Antennae in both sexes bipectinated, apex simple. Palpi short, slender, loosely scaled. Forewings: areole simple. Hindwings in both sexes with 8 connected with cell by oblique bar before angle; in ♂ 2 absent.

Endemic. If related to any New Zealand genus it must probably be to *Asaphodes,* but the modification of hindwing is very remarkable; it resembles that found in *Tatosoma* and its allies, but there does not seem to be any other relationship with them, nor is there any apparent lobe or gland in the male which would account for the absorption of vein 2. This absorption, with reduction of the dorsal area, has been compensated by extension in the costal area, and conversion of the normal anastomosis of 8 into a connection by bar only, and this structure has been ultimately transferred to the female also, notwithstanding that in this sex there was no need for it, 2 being present as usual.

71. *P. porphyrias* Meyr., *Trans. N.Z. Inst.* xvi, 58; ib. xviii, 184; Huds., *N.Z. Moths,* 41, pl. vi, 36.
Wainuiomata, Mount Arthur, Otira River, Castle Hill, Lake Wakatipu.

### 13. Xanthorhoe Hübn.

*Xanthorhoe* Hübn., *Verz.* 327 (1816); type, *montanata* Borkh. *Helastia* Guen., *Ent. M. Mag.* v, 94 (1868); type, *cinerearia* Doubl. *Epyaxa* Meyr., *Trans. N.Z. Inst.* xvi, 71 (1884); type, *rosearia* Doubl.

Face with cone of projecting scales. Antennae in ♂ bipectinated, apex usually simple. Palpi moderate, rough-scaled. Forewings: areole double. Hindwings normal.

A cosmopolitan genus of considerable extent, but relatively far more prominent in New Zealand than anywhere else; the species are numerous and varied, and evidently by no means yet exhausted.

72. *X. chlamydota* Meyr., *Trans. N.Z. Inst.* xvi, 72; Huds., *N.Z. Moths,* 59, pl. vii, 28.
Waiouru, Wellington, Christchurch, Akaroa.

73. *X. lophogramma* Meyr., *Trans. Ent. Soc. Lond.* 1897, 386; Huds., *N.Z. Moths.,* 59, pl. vii, 47, 48.
Castle Hill.

74. *X. orophyloides* Huds., *Subantarct. Isl. N.Z.* 68, pl. ii, 12 (*orophylloides*).
Auckland and Campbell Islands.

75. *X. orophyla* Meyr., *Trans. N.Z. Inst.* xvi, 71; Huds., *N.Z. Moths,* 58, pl. vii, 24, 25.
Nelson, Castle Hill, Mount Hutt, Dunedin, Lake Wakatipu; 2,500–4,000 ft

76. *X. semifissata* Walk., *Cat.* xxv, 1320 ; Meyr., *Trans. N.Z. Inst.* xvi, 72 ; Huds., *N.Z. Moths,* 59, pl. vi, 26, 27 : *ypsilonaria* Guen., *Ent. M. Mag.* v, 64 : *delicatulata* ib. 94.
North and South Islands ; sea-level to 4,500 ft.

77. *X. rosearia* Doubl., *Dieff. N.Z.* 2. 285 ; Butl., *Cat. N.Z. Lep.* pl. iii, 13 ; Meyr., *Trans. N.Z. Inst.* xvi, 71 ; Huds., *N.Z. Moths,* 57, pl. vii, 22, 23 : *ardularia* Guen., *Ent. M. Mag.* v, 63 : *inamoenaria* ib. 63.
Wellington, Nelson, Christchurch, Akaroa, Otira River, Dunedin ; Chatham Islands. Larva on *Nasturtium.*

78. *X. cinnabaris* Howes, *Trans. N.Z. Inst.* xliv, 203 (*cinnabari*).
Garvie Mountains.

79. *X. bulbulata* Guen., *Ent. M. Mag.* v, 94 ; Meyr., *Trans. N.Z. Inst.* xvi, 84 ; Huds., *N.Z. Moths,* 68, pl. viii, 1.
Wellington, Kekerangu, Castle Hill, Christchurch, Dunedin.

80. *X. practica* Meyr., *Trans. N.Z. Inst.* xliii, 72.
Porirua. Motueka.

81. *X. lucidata* Walk., *Cat.* xxiv, 1200 ; Prout, *Proc. N.Z. Inst.* xliv, 53 : *plurimata* Walk., *Cat.* xxv, 1321.
Locality unrecorded.

82. *X. venipunctata* Walk., *Cat.* xxvi, 1666 ; *psamathodes* Meyr., *Trans. N.Z. Inst.* xvi, 81 ; *lucidata* Huds., *N.Z. Moths,* 64, pl. vii, 38.
Taranaki, Napier, Palmerston North, Wellington, Dunedin, Stewart Island ; Chatham Islands.

83. *X. homalocyma* Meyr., *Trans. Ent. Soc. Lond.* 1902, 274.
Chatham Islands.

84. *X. subductata* Walk., *Cat.* xxiv, 1198 ; Meyr., *Trans. N.Z. Inst.* xx, 55 ; Huds., *N.Z. Moths,* 57.
Auckland.

85. *X. suppressaria* Walk., *Cat.* xxvi, 1721 : Meyr., *Trans. N.Z. Inst.* xvii, 67.
Auckland.

86. *X. cinerearia* Doubl., *Dieff. N.Z.* 2, 286 ; Huds., *N.Z. Moths,* pl. viii, 2 ; Prout, *Proc. N.Z. Inst.* xliv, 52 : *invexata* Walk., *Cat.* xxiv, 1199 ; Butl., *Cat. N.Z. Lep.* pl. iii, 11 : *inoperata* Walk., *Cat.* xxiv, 1201 : *diffusaria* ib. 1201 : ? *infusata* ib. 1199 : *infantaria* Guen., *Ent. M. Mag.* v. 62 : *eupitheciaria* ib. 95 : *adonata* Feld., *Reis. Nov.* pl. cxxxi, 31.
North and South Islands ; sea-level to 4,000 ft. Larva on lichens.

87. *X. farinata* Warr., *Nov. Zool.* 3, 388 ; Prout, *Proc. N.Z. Inst.* xliv, 52.
Wellington.

88. *X. plumbea* Philp., *Trans. N.Z. Inst.* xlvii, 194.
Lake Wakatipu ; to 3,500 ft.

89. *X. semisignata* Walk., *Cat.* xxiv, 1200 ; Prout, *Proc. N.Z. Inst.* xliv, 52 : *punctilineata* Walk., *Cat.* xxiv, 1202 ; Butl., *Cat. N.Z. Lep.* pl. iii, 12 : *dissociata* Walk., *Cat.* xxvi, 1734 : *similisata* ib. 1735 : *corcularia* Guen., *Ent. M. Mag.* v, 61 : *cinerearia* Huds., *N.Z. Moths,* pl. viii, 2A.
North and South Islands ; sea-level to 3,000 ft.

90. *X. periphaea* Meyr., *Trans. Ent. Soc. Lond.* 1905, 220.
Lake Wakatipu ; 4,000 ft.

91. *X. falcata* Butl., *Cist. Ent.* 2, 501 ; Meyr., *Trans. N.Z. Inst.* xx, 58 ; Huds., *N.Z. Moths,* 66.
Dunedin.

92. *X. camelias* Meyr., *Trans. N.Z. Inst.* xx, 58; Huds., *N.Z. Moths,* 65.
Whangarei, Otira River.

93. *X. chionogramma* Meyr., *Trans. N.Z. Inst.* xvi, 82; Huds., *N.Z. Moths,* 65, pl. vii, 42, 43.
Mount Hutt, Mount Arthur; 2,000–4,000 ft.

94. *X. cedrinodes* Meyr., *Trans. N.Z. Inst.* xliii, 72; *undulata* Philp., *Trans. N.Z. Inst.* xlv, 76.
Mount Arthur (4,200 ft.), Dunedin, Invercargill.

95. *X. umbrosa* Philp., this volume, p. 241.
Hunter Mountains.

96. *X. subobscurata* Walk., *Cat.* xxv, 1358; Huds., *N.Z. Moths,* 66: *petropola* Meyr., *Trans. N.Z. Inst.* xvi, 82.
Otira River.

97. *X. cosmodora* Meyr., *Trans. N.Z. Inst.* xx, 57; Huds., *N.Z. Moths,* 62.
Mount Arthur; 4,500 ft. I am now rather inclined to believe that this is the female of *bryopis.*

98. *X. bryopis* Meyr., *Trans. N.Z. Inst.* xx, 57; Huds., *N.Z. Moths,* 62.
Mount Arthur; 4,500 ft.

99. *X. prasinias* Meyr., *Trans. N.Z. Inst.* xvi, 81; Huds., *N.Z. Moths,* 65, pl. vii, 41.
Mount Arthur, Castle Hill, Arthur's Pass, Invercargill.

100. *X. limonodes* Meyr., *Trans. N.Z. Inst.* xx, 54; Huds., *N.Z. Moths,* 57, pl. vii, 46.
Ohakune, Wellington, Cape Terawhiti, Otira River.

101. *X. benedicta* Meyr., *Trans. N.Z. Inst.* xlvi, 102.
Wellington, Christchurch, Dunedin, Invercargill.

102. *X. beata* Butl., *Proc. Zool. Soc. Lond.* 1877, 397, pl. xliii, 6; Meyr., *Trans. N.Z. Inst.* xvi, 79; Huds., *N.Z. Moths,* 63, pl. vii, 35, 36.
Wellington, Mount Earnslaw, Lake Wakatipu, Invercargill, Stewart Island.

103. *X. adonis* Huds., *N.Z. Moths,* 63, pl. vii, 49.
Castle Hill, Lake Wakatipu, Invercargill.

104. *X. chorica* Meyr., *Trans. N.Z. Inst.* xx, 58; Huds., *N.Z. Moths,* 66, pl. vii, 44.
Ohakune, Akaroa, Otira River, Invercargill.

105. *X. cymozeucta* Meyr., *Trans. N.Z. Inst.* xlv, 25.
Ohakune.

106. *X. obarata* Feld., *Reis. Nov.* pl. cxxxii, 33; Meyr., *Trans. N.Z. Inst.* xvi, 82; Huds., *N.Z. Moths,* 66, pl. vii, 45.
Wellington, Christchurch, Mount Hutt.

107. *X. prymnaea* Meyr., *Trans. N.Z. Inst.* xliii, 73.
Mount Arthur; 3,600–4,200 ft.

108. *X. clarata* Walk., *Cat.* xxiv, 1197; Butl., *Cat. N.Z. Lep.* pl. iii, 14; Meyr., *Trans. N.Z. Inst.* xvi, 79; Huds., *N.Z. Moths,* 61, pl. vii, 31, 32: *pyramaria* Guen., *Ent. M. Mag.* v, 93.
Waiouru, Tararua Ranges, Lake Rotoiti, Mount Arthur, Castle Hill, Mount Hutt, Dunedin, Lake Wakatipu; up to 4,700 ft.

109. *X. declarata* Prout, *Trans. N.Z. Inst.* xlvi, 122.
Lake Wakatipu.

110. *X. cataphracta* Meyr., *Trans. N.Z. Inst.* xvi, 79; Huds., *N.Z. Moths,* 61, pl. vii, 33, 34.
Mount Arthur, Arthur's Pass, Lake Guyon, Lake Wakatipu; 3,000–4,500 ft.

111. *X. stricta* Philp., *Trans. N.Z. Inst.* xlvii, 195.
Humboldt Range.
112. *X. chlorias* Meyr., *Trans. N.Z. Inst.* xvi, 80; Huds., *N.Z. Moths*, 63: *princeps* Huds., *Trans. N.Z. Inst.* xxxv, 244, pl. xxx, 1.
Dun Mountain (Nelson), Castle Hill (3,100 ft.).
113. *X. frivola* Meyr., *Trans. N.Z. Inst.* xlv, 26.
Invercargill.
114. *X. helias* Meyr., *Trans. N.Z. Inst.* xvi, 81; Huds., *N.Z. Moths*, 64, pl. vii, 40.
Dunedin.
115. *X. recta* Philp., *Trans. N.Z. Inst.*, xxxvii, 330, pl. xx, 3.
Dunedin, Invercargill.
116. *X. dionysias* Meyr., *Trans. N.Z. Inst.* xxxix, 109.
Dunedin.
117. *X. aegrota* Butl., *Cist. Ent.* 2, 499; Meyr., *Trans. N.Z. Inst.* xvi, 80; Huds., *N.Z. Moths*, 64, pl. vii. 37.
Palmerston North, Kaitoke, Christchurch, Otira River, Dunedin, Lake Wakatipu, Stewart Island.
118. *X. albilineata* Philp., *Trans. N.Z. Inst.* xlvii, 194 (*albalineata*).
Stewart Island.
119. *X. exoriens* Prout, *Proc. N.Z. Inst.* xliv, 54.
Lake Wakatipu.
120. *X. imperfecta* Philp., *Trans. N.Z. Inst.* xxxvii, 330, pl. xx, 6.
Invercargill.
121. *X. oraria* Philp., *Trans. N.Z. Inst.* xxxv, 248, pl. xxxii, 6.
Invercargill.
122. *X. sericodes* Meyr., *Trans. N.Z. Inst.* xlvii, 202.
Mount Earnslaw; 4,000 ft.
123. *X. nephelias* Meyr., *Trans. N.Z. Inst.* xvi, 78; Huds., *N.Z. Moths*, 61.
Mount Arthur, Arthur's Pass (4,600 ft.).
124. *X. oxyptera* Huds., *Subantarct. Isl. N.Z.* 1, 67, pl. ii, 23.
Auckland Island.
125. *X. praefectata* Walk., *Cat.* xxiii, 781; Meyr., *Trans. N.Z. Inst* xvi, 78; Huds., *N.Z. Moths*, 60, pl. vii, 30: *subtentaria* Walk., *Cat.* xxvi, 1610: *absconditaria* ib. 1611; Butl., *Cat. N.Z. Lep.* pl. iii, 21.
Palmerston North, Nelson, Mount Arthur, Christchurch, Otira River, Dunedin: sea-level to 4,500 ft.
126. *X. mnesichola* Meyr., *Trans. N.Z. Inst.* xx, 56; Huds., *N.Z. Moths*, 60, pl. vii, 39.
Mount Arthur; 4,000–4,800 ft.
127. *X. occulta* Philp., *Trans. N.Z. Inst.* xxxv, 248, pl. xxxii, 5.
Tararua Ranges, Otira River, Invercargill.
128. *X. stinaria* Guen., *Ent. M. Mag.* v, 92; Meyr., *Trans. N.Z. Inst.* xvi, 78; Huds., *N.Z. Moths*, 60, pl. vii, 29.
Christchurch, Mount Hutt, Dunedin.

### 14. Notoreas Meyr.

*Notoreas* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type *perornata* Walk.

Face and palpi roughly hairy. Antennae in ♂ bipectinated. Thorax and femora rough-haired beneath. Forewings: areole double. Hindwings normal.

Endemic.

129. *N. synclinalis* Huds., *Trans. N.Z. Inst.* xxxv, 244, pl. xxx, 6; Meyr., *Trans. Ent. Soc. Lond.* 1905, 220.
Seaward Moss, Preservation Inlet, Stewart Island.

130. *N. insignis* Butl., *Proc. Zool. Soc. Lond.* 1877, 393, pl. xliii, 1; Meyr., *Trans. N.Z. Inst.* xvi, 85; Huds., *N.Z. Moths*, 71, pl. viii, 3.
Castle Hill; 4,000 ft.

131. *N. orphnaea* Meyr., *Trans. N.Z. Inst.* xvi, 85; Huds., *N.Z. Moths*, 71.
Lake Wakatipu (5,600 ft.), Hunter Mountains.

132. *N. opipara* Philp., *Trans. N.Z. Inst.* xlvii, 196.
Stewart Island.

133. *N. anthracias* Meyr., *Trans. N.Z. Inst.* xvi, 84; Huds., *N.Z. Moths*, 67.
Mount Hutt, Lake Wakatipu; 2,000–5,400 ft.

134. *N. atmogramma* Meyr., *Trans. N.Z. Inst.* xliii, 59.
Mount Holdsworth; 4,000 ft.

135. *N. mechanitis* Meyr., *Trans. N.Z. Inst.* xvi, 86; Huds., *N.Z. Moths*, 72, pl. viii, 9–11.
Arthur's Pass; 3,100 ft.

136. *N. isoleuca* Meyr., *Trans. Ent. Soc. Lond.* 1897, 386; Meyr., *Trans. N.Z. Inst.* xliii, 59.
Mount Arthur, Mount Peel, Arthur's Pass, Castle Hill; 4,400–4,600 ft.

137. *N. paradelpha* Meyr., *Trans. N.Z. Inst.* xvi, 86; Huds., *N.Z. Moths*, 72, pl. viii, 12–14.
Mount Arthur, Mount Peel, Lake Wakatipu; 4,000–5,000 ft.

138. *N. ischnocyma* Meyr., *Trans. Ent. Soc. Lond.* 1905, 221; *isoleuca* Huds., *N.Z. Moths*, 72, pl. viii, 27.
Castle Hill; 5,600 ft.

139. *N. perornata* Walk., *Cat.* xxvi, 1672; Meyr., *Trans. N.Z. Inst.* xvi, 87; Huds., *N.Z. Moths*, 72, pl. viii, 4–8.
Palmerston North, Wellington, Kekerangu, Mount Arthur, Lake Coleridge, Mount Hutt, Lake Wakatipu; up to 4,300 ft.

140. *N. niphocrena* Meyr., *Trans. N.Z. Inst.* xvi, 88; Huds., *N.Z. Moths*, 74.
Arthur's Pass; 4,500 ft.

141. *N. simplex* Huds., *N.Z. Moths*, 74, pl. viii, 26.
Mount Arthur; 4,000 ft.

142. *N. ferox* Butl., *Proc. Zool. Soc. Lond.* 1877, 392, pl. xlii, 8; Meyr., *Trans. N.Z. Inst.* xvi, 88; Huds., *N.Z. Moths*, 71, pl. viii, 17.
Castle Hill.

143. *N. brephos* Walk., *Cat.* xxiv, 1037 (*brephosata*); Butl., *Cat. N.Z. Lep.* pl. iii, 14; Feld., *Reis. Nov.* pl. cxxix, 5; Meyr., *Trans. N.Z. Inst.* xvi, 89; Huds., *N.Z. Moths*, 75, pl. viii, 20–23; *catocalaria* Guen., *Ent. M. Mag.* v, 62; *zopyra* Meyr., *Trans. N.Z. Inst.* xvi, 89; Huds., *N.Z. Moths*, 74, pl. viii, 18, 19.
Mount Arthur, Castle Hill, Arthur's Pass, Mount Hutt, Mount Earnslaw, Invercargill.

144. *N. vulcanica* Meyr., *Trans. N.Z. Inst.* xvi, 89; Huds., *N.Z. Moths*, 75, pl. viii, 24.
Waiouru, Makatoku, Kaweka Range.

145. *N. omichlias* Meyr., *Trans. N.Z. Inst.* xvi, 90; Huds., *N.Z. Moths*, 76, pl. viii, 25.
Mount Holdsworth, Castle Hill, Humboldt Range; 4,000–5,000 ft.

## 15. Dasyuris Guen.

*Dasyuris* Guen., *Ent. M. Mag.* v. 92 (1868): type, *partheniata* Guen. *Stathmonyma* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886): type, *hectori* Butl.

Face and palpi roughly hairy. Antennae in ♂ ciliated. Thorax and femora rough-haired beneath. Forewings: areole double. Hindwings normal.

Besides the following, I have three Australian species and one from Labrador.

146. *D. hectori* Butl., *Proc. Zool. Soc. Lond.* 1877, 397, pl. xliii. 4; Meyr., *Trans. N.Z. Inst.* xvi. 91; Huds., *N.Z. Moths*, 70, pl. viii. 32.
Mount Arthur, Arthur's Pass, Mount Hutt, Mount Earnslaw, Lake Wakatipu; 4,700–5,700 ft.

147. *D. anceps* Butl., *Proc. Zool. Soc. Lond.* 1877, 392, pl. xliii. 3; Meyr., *Trans. N.Z. Inst.* xvi. 91; Huds., *N.Z. Moths*, 69, pl. viii. 29.
Mount Arthur, Castle Hill, Arthur's Pass, Lake Wakatipu; 4,000–5,000 ft.

148. *D. enysii* Butl., *Proc. Zool. Soc. Lond.* 1877, 391, pl. xliii. 2; Huds., *N.Z. Moths*, 69, pl. viii. 28; *homoeophila* Meyr., *Trans. N.Z. Inst.* xvi. 91.
Nelson, Mount Hutt; 2,500–4,000 ft.

149. *D. partheniata* Guen., *Ent. M. Mag.* v. 93; Meyr., *Trans. N.Z. Inst.* xvi. 92; Huds., *N.Z. Moths*, 70, pl. viii. 30, 31.
Waiouru, Tararua Range, Wellington, Mount Arthur, Mount Hutt; up to 4,000 ft.

150. *D. [illegible]* Philp., *Trans. N.Z. Inst.* xlvii. 195.
Humboldt Range.

151. *D. strategica* Meyr., *Trans. N.Z. Inst.* xvi. 87; Huds., *N.Z. Moths*, 73, pl. viii. 15.
Lake Guyon.

152. *D. callicrena* Meyr., *Trans. N.Z. Inst.* xvi. 87; Huds., *N.Z. Moths*, 73, pl. viii. 16.
Mount Cook, Arthur's Pass, Mount Earnslaw, Humboldt Range; 3,000–4,000 ft.

153. *D. hexalocha* Meyr., *Trans. N.Z. Inst.* xlvi. 103.
Ben Lomond.

154. *D. transaurea* Howes, *Trans. N.Z. Inst.* xliv. 203.
Garvie Mountains.

155. *D. leucobathra* Meyr., *Trans. N.Z. Inst.* xliii. 59.
Arthur's Pass, Otira River.

156. *D. fulva* Huds., *Trans. N.Z. Inst.* xxxvii, 357, pl. xxii. 3.
Mount Ida; 3,500 ft.

## 16. Lythria Hübn.

*Lythria* Hübn., *Verz.* 300 (1816): type, *purpuraria* Linn. *Arctesthes* Meyr., *Trans. N.Z. Inst.* xviii. 184 (1886): type, *catapyrrha* Butl.

Face and palpi roughly hairy. Antennae in ♂ bipectinated. Thorax and femora rough-haired beneath. Forewings: areole simple. Hindwings normal.

There are also three European species.

157. *L. catapyrrha* Butl., *Proc. Zool. Soc. Lond.* 1877, 392, pl. xliii, 2; Meyr., *Trans. N.Z. Inst.* xvi. 64: *euclidiata* Huds., *N.Z. Moths,* 68, pl. viii, 35.
Lake Rotoiti, Lake Guyon, Otira Gorge, Dunedin, Lake Wakatipu, Invercargill.

158. *L. siris* Huds., *Trans. N.Z. Inst.* xl, 106, pl. xv, 1.
Old Man Range; 4,000 ft.

159. *L. chrysopeda* Meyr., *Trans. N.Z. Inst.* xx, 48: Huds., *N.Z. Moths,* 68. pl. viii, 33, 34.
Mount Arthur; 3,000-4,000 ft.

## 2. STERRHIDAE.

Forewings: 10 rising out of 9, 11 anastomosing or connected with 9. Hindwings: 5 fully developed, rising from middle of transverse vein, parallel to 4, 8 very shortly anastomosing with upper margin of cell near base, thence rapidly diverging.

A very considerable family, well represented in all regions except New Zealand, where the single species is an immigrant from Australia.

### 17. Leptomeris Hübn.

*Leptomeris* Hübn., *Verz.* 310 (1816); type, *umbellaria* Hübn.

Antennae in ♂ fasciculate-ciliated. Posterior tibiae in ♂ dilated, without spurs, in ♀ with all spurs present.

A large genus of almost universal distribution.

160. *L. rubraria* Doubl., *Dieff. N.Z.* 2, 286; Meyr., *Trans. N.Z. Inst.* xvi, 57; Meyr., *Proc. Linn. Soc. N.S.W.* 1887, 852; Huds., *N.Z. Moths,* 77, pl. viii, 37, 38: *repletaria* Walk., *Cat.* xxiii, 778: *attributa* ib. 779: *acidaliaria* ib. xxiv, 1037: *figlinaria* Guen., *Lep.* ix, 454, pl. xii, 8.
North and South Islands; Kermadec Islands; abundant and generally distributed in Australia and Tasmania.

## 3. MONOCTENIADAE.

Hindwings: 5 fully developed, parallel to 4, 8 approximated to upper margin of cell to middle or beyond, sometimes with connection near base.

A family of moderate extent and early type, better represented in Australia than elsewhere. The first four genera are of Australian type, the fifth American and European.

### 18. Samana Walk.

*Samana* Walk., *Cat.* xxvii, 197 (1863); type, *falcatella* Walk.

Face with cone of scales. Palpi very long, rough-scaled. Antennae in ♂ shortly ciliated. Forewings: 10 anastomosing with 9, 11 anastomosing with 10. Hindwings 6 or 7 connate or stalked, 8 approximated to beyond middle of cell.

Endemic.

161. *S. acutata* Butl., *Proc. Zool. Soc. Lond.* 1877, 401; Meyr., *Trans. N.Z. Inst.* xvii, 67; Huds., *N.Z. Moths,* 76.
"Sea-level, South Island."

162. *S. falcatella* Walk., *Cat.* xxvii, 197; Meyr., *Trans. N.Z. Inst.* xvi, 93; Huds., *N.Z. Moths,* 76, pl. viii, 36.
Nelson, Dunedin.

### 19. Theoxena Meyr.

*Theoxena* Meyr., *Trans. N.Z. Inst.* xvi, 56 (1884); type, *scissaria* Guen.

Face smooth. Palpi moderate, rough-scaled. Antennae in ♂ fasciculate-ciliated. Forewings: 10 anastomosing with 9, 11 anastomosing with 10, sometimes also very shortly with 12. Hindwings: 6 and 7 connate or stalked, 8 approximated to beyond middle of cell.

Endemic.

163. *T. scissaria* Guen., *Ent. M. Mag.* v, 43; Meyr., *Trans. N.Z. Inst.* xvi, 56; Huds., *N.Z. Moths*, 79, pl. viii, 41.
Christchurch.

### 20. Adeixis Warr.

*Adeixis* Warr., *Nov. Zool.* iv, 27 (1897); type, *inostentata* Walk. *Paragyrtis* Meyr., *Trans. Ent. Soc. Lond.* 1905, 222; type, *inostentata* Walk.

Face obliquely prominent, with small cone of scales. Palpi moderately long, rough-scaled. Antennae in ♂ bipectinated. Forewings: 10 anastomosing with 9 above 7. Hindwings: 6 and 7 approximated, 8 approximated to beyond middle of cell.

The single species is Australian, and has made its way to New Zealand.

164. *A. inostentata* Walk., *Cat.* xxiii, 1012; Meyr., *Trans. Ent. Soc. Lond.* 1905, 222: *insignata* Warr., *Nov. Zool.* iv, 27: *griseata* Huds., *Trans. N.Z. Inst.* xxxv, 244.
Ohakune, Kaitoke, Invercargill. Also common and widely distributed in Australia.

### 21. Dichromodes Guen.

*Dichromodes* Guen., *Lep.* ix, 320 (1858); type, *ainaria* Guen. *Cacopsodos* Butl., *Proc. Zool. Soc. Lond.* 1877, 395; type, *nigra* Butl.

Face with cone of scales. Palpi moderate to very long, rough-scaled. Antennae in ♂ unipectinated. Forewings: 10 usually anastomosing with 9, but sometimes separate. Hindwings: 6 and 7 approximated, 8 approximated to beyond middle of cell.

A characteristic Australian genus of considerable extent, which has established a small colony of species in New Zealand, forming a homogeneous endemic group.

165. *D. ida* Huds., *Trans. N.Z. Inst.* xxxvii, 356, pl. xxii, 2; *simulans* Huds., *Trans. N.Z. Inst.* xl, 107.
Mount Ida, Old Man Range; 4,000 ft. Larva probably on lichens.

165. *D. petrina* Meyr., *Trans. N.Z. Inst.* xxiv, 216; Huds., *N.Z. Moths*, 78, pl. viii, 39: ? *sphaeriata* Feld., *Reis. Nov.* pl. cxxxi, 14.
Paekakariki, Wellington, Kekerangu, Dunedin.

167. *D. cynica* Meyr., *Trans. N.Z. Inst.* xliii, 60.
Lyttelton.

168. *D. nigra* Butl., *Proc. Zool. Soc. Lond.* 1877, 395, pl. xliii, 4; Meyr., *Trans. N.Z. Inst.* xx, 60; Huds., *N.Z. Moths*, 78, pl. viii, 40.
Nelson, Otira Gorge; 1,500–2,000 ft.

169. *D. gypsotis* Meyr., *Trans. N.Z. Inst.* xx, 60; Huds., *N.Z. Moths*, 78: *niger* Meyr., *Trans. N.Z. Inst.* xvi, 94.
Lake Wakatipu; 1,500 ft.

### 22. Epirrhanthis Hübn.

*Epirrhanthis* Hübn., *Verz.* 296 (1816); type, *pulverata* Thunb. *Lyrcea* Walk., *Cat.* xx, 259 (1860); type, *alectoraria* Walk. *Xyridacma* Meyr., *Trans. N.Z. Inst.* xx, 60 (1888); type, *hemipteraria* Guen. *Xynonia* Prout, *Gen. Ins.* civ, 65 (1910); type, *alectoraria* Walk.

Face with tolerably appressed scales. Palpi rather short. Antennae in ♂ slightly ciliated. Forewings: 10 anastomosing with 9, 11 anastomosing with 12 and then with 10. Hindwings: 6 and 7 approximated, 8 approximated to cell to about middle, with rudimentary or incomplete connection near base.

The typical species is European. The South American genus *Phellinodes* is allied to this.

170. *E. hemipteraria* Guen., *Lep.* ix, 220, pl. vi, 2; Meyr., *Trans. N.Z. Inst.* xx, 60; Huds., *N.Z. Moths*, 80, pl. viii, 48, 49.
Auckland, Wellington, Arthur's Pass. Larva on *Veronica.*

171. *E. alectoraria* Walk., *Cat.* xx, 259; Meyr., *Trans. N.Z. Inst.* xvi, 95; Huds., *N.Z. Moths*, 80, pl. viii, 42–47: *ustaria* Walk., *Cat.* xxvi, 1519: *achroiaria* Feld., *Reis. Nov.* pl. cxxiii, 9: *varians* Butl., *Cist. Ent.* 2, 496.
North and South Islands. Larva on *Pittosporum eugenioides* and *P. tenuifolium*

## 4. SELIDOSEMIDAE.

Hindwings: 5 imperfect (not tubular) or obsolete, 6 and 7 usually separate, 8 usually obsoletely connected with upper margin of cell near base, approximated to near middle.

A very large family in all regions, but quite inadequately represented in New Zealand. It is noticeable that the larvae of many of the New Zealand species feed on ferns

### 23. Selidosema Hübn.

*Selidosema* Hübn., *Verz.* 299 (1816); type, *ericetaria* Vill. *Chalastra* Walk., *Cat.* xxv, 1429 (1862); type, *pelurgata* Walk. *Pseudocoremia* Butl., *Proc. Zool. Soc. Lond.* 1877, 394; type, *productata* Walk. *Zylobara* Butl., *Cist. Ent.* 2, 498 (1879); type, *fenerata* Feld. *Gelonia* Meyr., *N.Z. Journ. Sci.* ii, 234 (1884); type, *dejectaria* Walk. *Meyrickia* Butl., *Ent. M. Mag.* xxi, 133 (1884); type, *panagrata* Walk.

Face with appressed or shortly projecting scales. Antennae in ♂ bipectinated, towards apex simple. Palpi rough-scaled. Thorax sometimes crested posteriorly, hairy beneath. Femora nearly glabrous, posterior tibia in ♂ dilated. Forewings in ♂ with fovea; 10 sometimes connected with 9, 11 sometimes out of 10 near base only, or sometimes anastomosing with 12.

A large genus of universal distribution.

172. *S. pelurgata* Walk., *Cat.* xxv, 1430; Huds., *N.Z. Moths*, 88, pl. ix, 33–36: *cinerascens* Feld., *Reis. Nov.* pl. cxxxi, 1: *streptophora* Meyr., *Trans. N.Z. Inst.* xvi, 106.
North and South Islands. Larva on *Todea hymenophylloides.*

173. *S. aristarcha* Meyr., *Trans. N.Z. Inst.* xxiv, 216; Huds., *N.Z. Moths,* 85, pl. ix, 17, 18.
Auckland, Thames, Ohakune, Wellington. Larva on *Cyathea dealbata.*

174. *S. scariphota* Meyr., *Trans. N.Z. Inst.* xlvii, 202.
Wellington, Otira. Larva on *Carmichaelia.*

175. *S. monacha* Huds., *Trans. N.Z. Inst.* xxxv, 245, pl. xxx, 4.
Mount Ruapehu; Lake Harris, 3,000–4,500 ft.

176. *S. cremnopa* Meyr., *Trans. Ent. Soc. Lond.* 1897, 387.
Auckland.

177. *S. pungata* Feld., *Reis. Nov.* pl. cxxxi, 23; Meyr., *Trans. Ent. Soc. Lond.* 1905, 223: *fascialata* Philp., *Trans. N.Z. Inst.* xxxv, 248, pl. xxxii, 7.
Invercargill.

178. *S. productata* Walk., *Cat.* xxiv, 1197; Meyr., *Trans. N.Z. Inst.* xvi, 98; Huds., *N.Z. Moths,* 84, pl. ix, 6–9, 11–13: *fragosata* Feld., *Reis. Nov.* pl. cxxxi, 29.
North, South, and Stewart Islands. Larva on *Metrosideros scandens.*

179. *S. lactiflua* Meyr., *Trans. N.Z. Inst.* xliv, 117.
Lake Wakatipu.

180. *S. terrena* Philp., *Trans. N.Z. Inst.* xlvii, 196.
Humboldt Range.

181. *S. maculosa* Howes, *Trans. N.Z. Inst.* xlvi, 96.
Queenstown.

182. *S. leucelaea* Meyr., *Trans. N.Z. Inst.* xli, 6; *productata* Huds., *N.Z. Moths,* pl. ix, 10, 14.
Ohakune, Tararua Range, Christchurch, Otira River, Dunedin, Invercargill. Larva on *Podocarpus totara.*

183. *S. albifasciata* Philp., *Trans. N.Z. Inst.* xlvii, 196 (*albafasciata*).
Taihape, Feilding.

184. *S. melinata* Feld., *Reis. Nov.* pl. cxxix, 9; Meyr., *Trans. N.Z. Inst.* xvi, 99; Huds., *N.Z. Moths,* 85, pl. ix, 15, 16: *indistincta* Butl., *Proc. Zool. Soc. Lond.* 1877, 394, pl. xliii, 8.
North and South Islands; up to 4,000 ft.

185. *S. ochrea* Howes, *Trans. N.Z. Inst.* xliii, 127, pl. i, 1.
Dunedin.

186. *S. suavis* Butl., *Cist. Ent.* 2, 497; Meyr., *Trans. N.Z. Inst.* xxiii, 101; Huds., *N.Z. Moths,* 83, pl. ix, 3, 4: *usitata* Butl., *Cist. Ent.* 2, 501: *lupinata* Meyr., *Trans. N.Z. Inst.* xvi, 98.
North, South, and Stewart Islands. Larva on *Metrosideros scandens* and *Beilschmiedia tawa.*

187. *S. lutea* Philp., *Trans. N.Z. Inst.* xlvi, 119.
Humboldt Range.

188. *S. lupinata* Feld., *Reis. Nov.* pl. cxxxi, 19; Butl., *Cist. Ent.* 2, 496; Meyr., *Trans. N.Z. Inst.* xxiii, 101: *humillima* Huds., *N.Z. Moths,* 83, pl. ix, 5.
Wellington, Dunedin, Invercargill.

189. *S. rudiata* Walk., *Cat.* xxv, 1420 (*rudisata*); Huds., *N.Z. Moths,* 82, pl. ix, 1, 2: *astrapia* Meyr., *Trans. N.Z. Inst.*, xxii, 218.
Wellington, Dunedin, Invercargill, Stewart Island. Larva on *Olearia Traversii* and *Brachyglottis repanda.*

190. *S. argentaria* Philp., *Trans. N.Z. Inst.* xlv, 77.
Invercargill, Wallacetown, Tuturau.

191. *S. fenerata* Feld., *Reis. Nov.* pl. cxxxi, 7 ; Butl., *Cist. Ent.* 2, 498 ; Meyr., *Trans. N.Z. Inst.* xvi, 97 ; Huds., *N.Z. Moths,* 82, pl. viii, 50, 51.
North Island, Christchurch.

192. *S. ombrodes* Meyr., *Trans. Ent. Soc. Lond.* 1902, 275.
Chatham Islands.

193. *S. panagrata* Walk., *Cat.* xxv, 1360 ; Meyr., *Trans. N.Z. Inst.* xvi, 100 ; Huds., *N.Z. Moths,* 87, pl. ix, 25–30 : *menanaria* Walk., *Cat.* xxvi, 1500 : *antipodaria* Feld., *Reis. Nov.* pl. cxxvi, 3 : *desiccata* Butl., *Cist. Ent.* 2, 495 : *arenacea* ib. 495.
North, South, and Stewart Islands. Larva on *Piper excelsum, Aristotelia racemosa, Myrtus ballata.*

194. *S. dejectaria* Walk., *Cat.* xxi, 394 ; Meyr., *Trans. N.Z. Inst.* xvi, 100 ; Huds., *N.Z. Moths,* 86, pl. ix, 19–24 : *attracta* Walk., *Cat.* xxi, 394 : *exprompta* ib. 395 : *patularia* ib. 422 ; Butl., *Cat. N.Z. Lep.* pl. iii, 8 : *scriptaria* Walk., *Cat.* xxi, 422 : *erebinata* ib. xxv, 1358 : *stigmaticata* ib. 1359 : *lignosata* ib. 1361 : *pannularia* Guen., *Ent. M. Mag.* v, 42 : *maoriata* Feld., *Reis. Nov.* pl. cxxvi, 4 : *sulpitiata* ib. 7 : *caprimulgata* ib. 12.
North and South Islands. Larva on *Metrosideros, Melicytus, Solanum, Fuchsia,* &c.

### 24. Sestra Walk.

*Sestra* Walk., *Cat.* xxvi, 1750 (1862) ; type, *flexata* Walk.

Face smooth. Antennae in ♂ minutely ciliated. Palpi short, rough-scaled. Thorax hairy beneath. Femora glabrous. Forewings : 10 out of 9, sometimes anastomosing shortly with 9, 11 anastomosing with 10, 12 sometimes anastomosing shortly with 11.

Endemic ; probably allied to the preceding genus.

195. *S. flexata* Walk., *Cat.* xxv, 1421 ; *fusiplagiata* ib. xxvi, 1751 ; *encausta* Meyr., *Trans. N.Z. Inst.* xvi, 105 ; *humeraria* Huds., *N.Z. Moths,* 89, pl. x, 1, 2.
North, South, and Stewart Islands. Larva on *Pteris incisa.*

196. *S. humeraria* Walk., *Cat.* xxiii, 940 ; *obtusaria* ib. 985 ; *obtruncata* ib. xxv, 1421 ; *flexata* Huds., *N.Z. Moths,* 90, pl. ix, 37.
Auckland, Wellington, Lake Wakatipu. Probably also a fern-feeder.

### 25. Hybernia Latr.

*Hybernia* Latr., *Fam. Nat.* 477 (1825) ; type, *defoliaria* Clerck.
*Zermizinga* Walk., *Cat.* xxvi, 1530 (1862) ; type, *indocilis* Walk.

Face with appressed scales. Antennae in ♂ bipectinated, apex simple. Palpi shortly rough-scaled. Thorax with small triangular anterior crest, hairy beneath. Femora glabrous. Forewings : 10 absent (in New Zealand species), 11 separate. Wings of ♀ rudimentary.

A genus of few species, chiefly northern-temperate ; the single New Zealand species is probably an immigrant from Australia.

197. *H. indocilis* Walk., *Cat.* xxvi, 1530 (*indocilisaria*), Meyr., *Trans. N.Z. Inst.* xvi, 97; Meyr., *Proc. Linn. Soc. N.S.W.* 1891, 623; Huds., *N.Z. Moths,* 88, pl. ix, 31, 32: *boreophilaria* Guen., *Ent. M. Mag.* v. 61.

Christchurch. Common and widely distributed in Australia. Larva probably on *Leptospermum.*

### 26. Gargaphia Walk.

*Gargaphia* Walk., *Cat.* xxvi, 1634 (1862); type, *muriferata* Walk.

Face with cone of scales. Antennae in ♂ simple. Palpi rough-scaled. Forewings with hyaline scar on transverse vein; 10 out of 11, sometimes anastomosing shortly with 9.

Having now plenty of material of *Drepanodes* Guen. (which I consider synonymous with *Oxydia* Guen.), I consider the present genus distinct from it by the hyaline scar and neuration of forewings; but I have a species from Venezuela which I should include with the present genus.

198. *G. muriferata* Walk., *Cat.* xxvi, 1635; Meyr., *Trans. N.Z. Inst.* xvi, 107; Huds., *N.Z. Moths,* 91, pl. x, 7–12: *ephyraria* Walk., *Cat.* xxvi, 1761: *cookaria* Feld., *Reis. Nov.* pl. cxxiii, 26: *haastiaria* ib. 32.

North, South, and Stewart Islands.

199. *G. neoselena* Meyr., *Subantarct. Isl. N.Z.* 1, 70, pl. ii, 13.

Auckland Island. Apparently attached to *Polypodium Billardieri.*

### 27. Azelina Guen.

*Azelina* Guen., *Lep.* ix, 156 (1857); type, *lustraria* Guen. *Polygonia* Guen., *Ent. M. Mag.* v, 41 (1868) (praeocc.); type, *fortinata* Guen. *Gonophylla* Meyr., *Trans. N.Z. Inst.* xviii, 184 (1886); type, *nelsonaria* Feld.

Face with projecting hairs. Antennae in ♂ thick, simple. Palpi rather long, rough-scaled. Thorax and femora hairy beneath. Forewings: 10 sometimes shortly anastomosing with 9, 11 separate.

A South American genus of considerable extent, with which (having acquired copious material) I find the New Zealand species entirely concordant; but it may be added that there are also other nearly related South American forms which show considerably diversified structure.

200. *A. ophiopa* Meyr., *Trans. Ent. Soc. Lond.* 1897, 387; Huds., *N.Z. Moths,* 93, pl. x, 26–28.

Ohakune, Wellington, Motueka. Larva on *Dicksonia.*

201. *A. fortinata* Guen., *Ent. M. Mag.* v, 41; Meyr., *Trans. N.Z. Inst.* xvi, 106; Huds., *N.Z. Moths,* 93, pl. x, 24, 25: *ziczac* Feld., *Reis. Nov.* pl. cxxxii, 4.

Ohakune, Tararua Range, Wellington, Nelson, Mount Arthur, Castle Hill, Akaroa, Invercargill. Larva on *Aspidium aculeatum.*

202. *A. gallaria* Walk., *Cat.* xx, 185; Butl., *Cat. N.Z. Lep.* pl. iii, 6, 7; Meyr., *Trans. N.Z. Inst.* xvi, 105; Huds., *N.Z. Moths,* 92, pl. x, 13–23: *palthidata* Feld., *Reis. Nov.* pl. cxxxii, 21, 22.

Ohakune, Palmerston North, Makatoku, Wellington, Christchurch, Dunedin, Stewart Island.

203. *A. nelsonaria* Feld., *Reis. Nov.* pl. cxxiii, 3; Meyr., *Trans. N.Z. Inst.* xvi, 104; Huds., *N.Z. Moths,* 90, pl. x, 3–6: *felix* Butl., *Proc. Zool. Soc. Lond.* 1877, 389, pl. xlii, 10.

Wellington, Nelson, Dunedin.

### 28. Declana Walk.

*Declana* Walk., *Cat.* xv, 1649 (1858); type, *floccosa* Walk. *Ipana* ib. 1661; type, *leptomera* Walk. *Argua* ib. xxviii, 448 (1863); type, *floccosa* Walk. *Detunda* ib. xxxii, 618 (1845); type, *atronivea* Walk.

Face rough. Antennae in ♂ usually bipectinated, sometimes simple. Palpi rather long, second joint ascending, with long hairs beneath, terminal joint long, slender, clavate, porrected. Thorax densely hairy above and beneath, with more or less developed median crest. Femora densely hairy. Forewings with raised scales; 10 sometimes out of 9, usually anastomosing with 9, 11 seldom out of 10, sometimes anastomosing with 10.

Endemic. The genus is very well characterized, and differs from all others known to me by the peculiar palpi; it therefore becomes unnecessary and undesirable to subdivide it.

*Section A.*—Antennae in ♂ simple.

204. *D. leptomera* Walk., *Cat.* xv, 1662; Huds., *N.Z. Moths,* 94, pl. x, 29–31: *crassitibia* Feld., *Reis. Nov.* pl. cix, 10.
Wellington. Larva on *Leptospermum.*

205. *D. griseata* Huds., *N.Z. Moths,* 98, pl. x, 32.
Wellington, Lake Wakatipu.

206. *D. niveata* Butl., *Cist. Ent.* 2, 500; Meyr., *Trans. N.Z. Inst.* xvi, 104; Huds., *N.Z. Moths,* 98.
Dunedin.

*Section B.*—Antennae in ♂ bipectinated.

207. *D. floccosa* Walk., *Cat.* xv, 1649; Meyr., *Trans. N.Z. Inst.* xvi, 102; Huds., *N.Z. Moths,* 96, pl. x, 39–47: *scabra* Walk., *Cat.* xxviii, 448: *feredayi* Butl., *Proc. Zool. Soc. Lond.* 1877, 398, pl. xliii, 5: *nigrosparsa* Butl., *Cist. Ent.* 2, 500.
Whangarei, Taranaki, Ohakune, Wellington, Christchurch, Dunedin. Larva on *Leptospermum ericoides* and *Aristotelia racemosa.*

208. *D. sinuosa* Philp., *Trans. N.Z. Inst.* xlvii, 197.
Orepuki, Queenstown, Hunter Mountains.

209. *D. hermione* Huds., *N.Z. Moths,* 98, pl. x, 36.
Wellington, Orepuki.

210. *D. junctilinea* Walk., *Cat.* xxxii, 643; Huds., *N.Z. Moths,* 98, pl. x, 37, 38: *verrucosa* Feld., *Reis. Nov.* pl. cxxxi, 22.
Wellington, Blenheim, Lake Wakatipu.

211. *D. glacialis* Huds., *Trans. N.Z. Inst.* xxxv, 245, pl. xxx, 2.
Mount Arthur, Arthur's Pass, Mount Cook, Lake Wakatipu.

212. *D. atronivea* Walk., *Cat.* xxxii, 619; Meyr., *Trans. N.Z. Inst.* xvi, 101; Huds., *N.Z. Moths,* 95, pl. x, 33, 34: *manixfera* Fer., *Trans. N.Z. Inst.* xii, 268, pl. ix, 1.
Napier, Otaki, Ohakune, Wellington. Larva on *Panax arboreum.*

213. *D. egregia* Feld., *Reis. Nov.* pl. cxxxi, 24; Fer., *Trans. N.Z. Inst.* xii, 268, pl. ix, 2; Meyr., *Trans. N.Z. Inst.* xvi, 101; Huds. *N.Z. Moths,* 96, pl. x, 35.
Nelson, Christchurch, Akaroa, Otira Gorge, Orepuki, Stewart Island. Larva on *Panax.*

## 5. SPHINGIDAE.

Antennae thickened towards middle or posteriorly, in ♂ ciliated with partial whorls. Thorax and femora densely hairy beneath. Forewings: 6 out of 8, 9 absent. Hindwings: 5 parallel to 4, 6 and 7 connate or stalked, 8 connected by oblique bar with margin of cell before middle, more or less approximated to 7 near beyond cell.

A numerous family of wide distribution, but in New Zealand only represented by two immigrants.

### 29. Deilephila Ochs.

*Deilephila* Ochs., *Schmett. Eur.* iv, 42 (1816); type, *lineata* Fabr. *Choerocampa* Dup., *Lep. Fr. Suppl.* ii, 159 (1835).

Tongue strongly developed. Antennae less than ½, gradually thickened to near apex, then pointed, apex slender, hooked. Abdomen smooth, broad, conical, pointed. Tibiae with appressed scales.

A large nearly cosmopolitan genus, chiefly in warm regions.

214. *D. celerio* Linn., *Syst. Nat.* 1, 491 (1758).

Titahi Bay (Wellington), Nelson; several specimens. Throughout Old World; common in Australia, whence it probably immigrated. Larva on grape-vine (*Vitis*).

### 30. Sphinx Linn.

*Sphinx* Linn., *Syst. Nat.* 1, 489 (1758).

Characters of *Deilephila*, but thorax with low double posterior crest.

A moderate cosmopolitan genus.

215. *S. convolvuli* Linn., *Syst. Nat.* 1, 490; Huds., *N.Z. Moths*, 99, pl. xiii, 1: *roseofasciata* Koch, *Ind. Austr. Lep.* 54: *distans* Butl., *Cat. N.Z. Lep.* 4, pl. ii, 11.

Rather common north of Napier, rare southwards; a cosmopolitan species. Larva on *Convolvulus*.

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## INDEX OF GENERA.

## Index of Species.

Index of Species—*continued.*

## Art. XVI.—*New Lepidoptera.*

By W. G. Howes, F.E.S.

[*Read before the Otago Institute, 1st August, 1916; received by Editors, 30th December, 1916; issued separately, 16th August, 1917.*]

**Adeixis parvitis** n. sp.

One specimen. Expanse 16 mm. Face and head milk-white. Palpi elongate. Thorax white. Forewings grey-white faintly irrorated with brown; a distinct brown band across wing at $\frac{2}{3}$, edged outwardly with white; faint brown irrorations follow, deepening towards termen, which is quite brown, especially at the apex: cilia long, grey, with a shorter row of brown cilia at base. Hindwings grey-white, deepening to grey at termen: cilia white.

This small but well-defined species is the second of the genus to be found in New Zealand, and, like the other species (*A. inostentata*), this may prove to be Australian also. The single specimen was taken by Mr. C. Clarke at Broad Bay, 18th December, 1915.

**Xanthorhoe subflava** n. sp.

Five specimens, all ♂. Expanse, 38–39 mm. Face and head reddish-ochreous. Antennae ochreous with brown pectinations well developed. Thorax uniform bright ochreous. Abdomen bright ochreous with two grey marks dorsally at the base of each segment. Wings ochreous faintly stippled with grey-brown; an indistinct line at base followed by an indistinct line at $\frac{1}{3}$; a very faint grey line at $\frac{1}{2}$, a better-defined but still faint line at $\frac{2}{3}$, followed by a paler area forming a band across the wing; subterminal line appears as a series of irregular somewhat crescentic marks between the veins; claviform almost obsolete: reniform appears as a slight dark-brown mark distinct, but little more than a dot. Hindwings pale ochreous, clouded on termen with pale grey between veins; underside pale ochreous, with lunule appearing as a well-defined dot.

This fine moth resembles in coloration and markings *X. aegrota*, but is one-third larger in size, and the underside is free from marking.

Seven specimens showing considerable variation in the extent of markings on the forewings were taken by myself at 4,000 ft. level, in the neighbourhood of Arthur's Pass, 1st February, 1915.

**Chloroclystis clarkei** n. sp.

♀. 25 mm. Head and appendages, thorax, and abdomen grey-brown. Forewings dark grey-brown, with the veins distinctly shown by being irrorated with black and grey to $\frac{2}{3}$ across wing, and from there to termen irrorated with yellow and black; a black line edges costa, interrupted by two white marks at $\frac{1}{3}$, followed by three white marks at $\frac{1}{2}$, two white marks at $\frac{3}{4}$, another close to apex: these marks all rather indistinct. Termen distinctly edged with a thin black line, interrupted by yellow dots at the ends of the veins. Hindwings grey suffused with darker grey, and with a rather indistinct series of transverse irregular lines; termen distinctly edged with a thin dark line, small yellow dots interrupting it on the veins: cilia light grey with a dark-grey line at base.

Taken on Flagstaff Hill, Dunedin, in March, 1915, by Mr. C. Clarke, whose keen steady work is worthy of appreciation.

## ART. XVII.—*Some Corals from Kermadec Islands.**

By THOMAS WAYLAND VAUGHAN, Geologist in charge of Coastal Plain Investigation, United States Geological Survey: Custodian of Madreporarian Corals, United States National Museum.

Communicated by Professor W. B. Benham, F.R.S.

[*Read before the Otago Institute, 1st August, 1916; received by Editors, 30th December, 1916; issued separately, 16th August, 1917.*]

Plates XVII–XX.

PROFESSOR W. B. BENHAM, in 1910, forwarded to me the collection of corals made by Mr. W. R. B. Oliver in the Kermadec Islands in 1908, with the request that I send him a report, but other duties obliged me to defer carefully studying it until May, 1916. The specimens on which the following notes or descriptions are based were presented to the U.S. National Museum by Professor Benham, except the paratype of *Goniastrea benhami*, which has been returned; duplicate specimens or parts of specimens were retained by him, and are deposited in the University of Otago, New Zealand.

In a paper entitled "Some Shoal-water Corals from Murray Island, Australia, Cocos-Keeling Islands, and Fanning Island," now in press as part of Publication 213 of the Carnegie Institution of Washington, the following species, which also occur in the Kermadec Islands, are considered in some detail and figured: *Pocillopora bulbosa* Ehrenberg, *Orbicella curta* Dana, *Cyphastrea serailia* (Forskal), *Leptoria tenuis* (Dana). As the memoir mentioned is not yet in proof, references to the pages on which the descriptions will appear and references to the plates and figures cannot now be given.

GEOGRAPHIC DISTRIBUTION OF CORALS FROM KERMADEC ISLANDS.

| Name. | Distribution. |
|---|---|
| *Pocillopora bulbosa* Ehrenberg | From Cocos-Keeling Islands to Fiji Islands; represented in the Hawaiian Islands by the closely related if not specifically identical *P. cespitosa* Dana. |
| *Orbicella curta* Dana .. | Great Barrier Reef, thence eastward to the Paumotus. |
| *Cyphastrea serailia* (Forskal) .. | Red Sea; Indian Ocean; Great Barrier Reef; Philippine Islands. |
| *Goniastrea benhami* n. sp. .. | Formosa; probably Singapore. |
| *Leptoria tenuis* (Dana) .. | South Philippines; Fiji Islands. |
| *Sclerophyllia margariticola* Klz. | Red Sea; west Indian Ocean. |
| *Turbinaria crater* (Pallas) .. | Torres Strait; Amboina. |
| *Montipora caliculata* (Dana) Bernard | Torres Strait; New Guinea; Macclesfield Bank; Kandavu. |

All the species are widely distributed Indo-Pacific corals; five of the eight are known from eastern Australia, while another occurs both east and west of the Great Barrier Reef. Two of the species are known from the Philippines or Formosa, but as yet have not been authentically reported from Australia.

* Published by permission of the Director of the U.S. Geological Survey. The illustrations for this paper were furnished by the U.S. Geological Survey.

### Pocillopora bulbosa Ehrenberg (*fide* Dana).

1846. *Pocillopora bulbosa* Dana, *U.S. Expl. Exped., Zooph.*, p. 527, pl. 49, figs. 5, 5*a*.

1907. *Pocillopora acuta* Bedot, *Madréporaires d'Amboine*, p. 152, pl. 7, figs. 14–17.

As it seems to me actual intergradation between *P. bulbosa* and *P. acuta* has not been established. I am following Dana's usage. However, it is entirely probable that *P. bulbosa* Ehrenberg (as identified by Dana), *P. subacuta* Milne-Edwards, and *P. cespitosa* Dana will ultimately be referred to the synonymy of *P. acuta*.

The terminal branchlets of the Kermadec Island specimen are up to a little over 1 cm. long, but at that length are already subdividing into from two to four young branchlets. The greater diameter of the ends of the summit incipient branchlets is from 3·5 mm. to 5·5 mm.; the lesser from about 2 mm. to 3 mm. These measurements show that the branchlets are not greatly attenuate. The calicular and coenenchymal characters are as usual in the species.

*Locality.*—Meyer Island: on rock; depth, 1 fathom.

### Orbicella curta Dana. (Plate XVII.)

1846. *A. Orbicella curta* Dana, *U.S. Expl. Exped., Zooph.*, p. 209, pl. 10, figs. 3, 3*a*–3*c*.

1846. *A. Orbicella coronata* Dana, *ibid.*, p. 211, pl. 10, figs. 4, 4*a*–4*f*.

1899. *Orbicella wakayana* Gardiner, *Proc. Zool. Soc. Lond.*, p. 753, pl. 49, fig. 2.

1914. *Favia wakayana* (and synonymy) Matthai, *Trans. Linn. Soc. Lond.*, 2nd ser., Zool., p. 104, pl. 25, fig. 4.

The specimen from Kermadec Islands has a somewhat glomerate upper surface, with many of the calices greatly deformed. Maximum length of the deformed calices, up to 10·5 mm.; width, 5 mm. Some of these undergo fission. A large slightly deformed calice is 7 mm. by 8 mm. in diameter, and 5·5 mm. deep. The diameter ranges down to 5 mm. or 5·5 mm. Asexual reproduction usually (normally) by intercalicular gemmation.

At one time it seemed to me that this specimen should be referred to another species, but its resemblances to *O. curta* are too many, especially when the good suite of specimens from the Paumotus, in the U.S. National Museum, is considered.

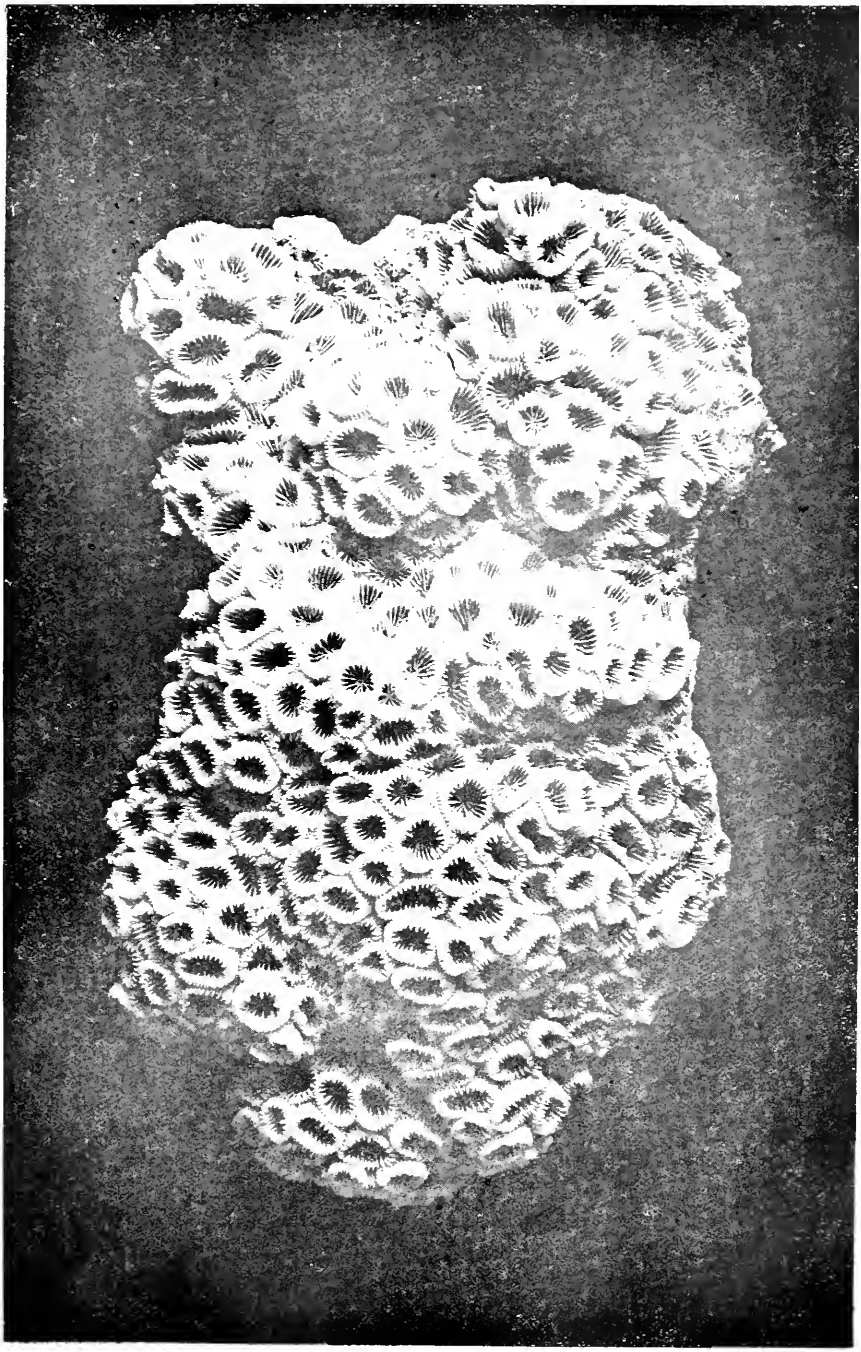
*Locality.*—Meyer Island: on rock; depth, 1 fathom.

### Cyphastrea serailia (Forskal).

1914. *Cyphastrea serailia* Matthai, *Trans. Linn. Soc. Lond.*, 2nd ser., Zool., vol. 17, p. 39, pl. 7, fig. 4; pl. 11, figs. 1–9; pl. 13, fig. 8; pl. 38, figs. 1, 5.

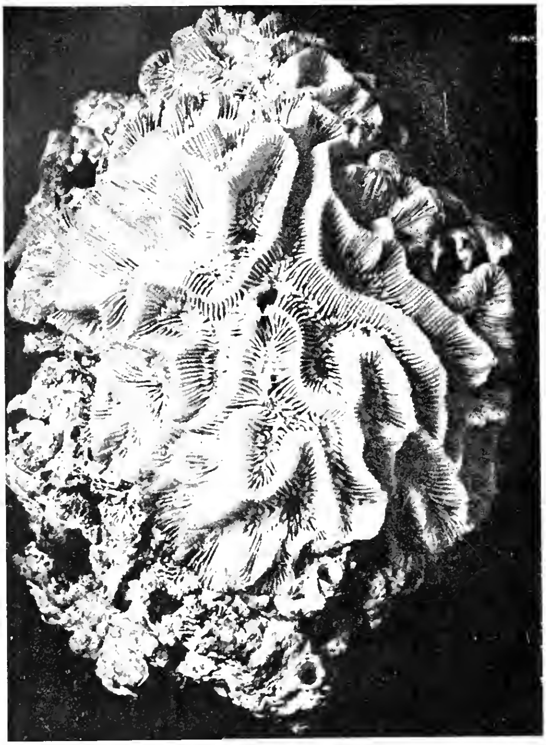
The specimen forms an incrustation (about 14 mm. thick) over *Lithothamnium*, which in its turn incrusts dead coral (*Montipora*). Many of the calices are completely typical of *C. serailia*—*i.e.*, with 3 cycles of septa, the tertiaries small but with distinct costae corresponding to them; but many others have from 1 to 5 principal septa which are really elongate tertiaries: in other words, from 13 to 17 septa extend to the columella.

*Locality.*—Denham Bay, Sunday Island: dredged in about 20 fathoms.



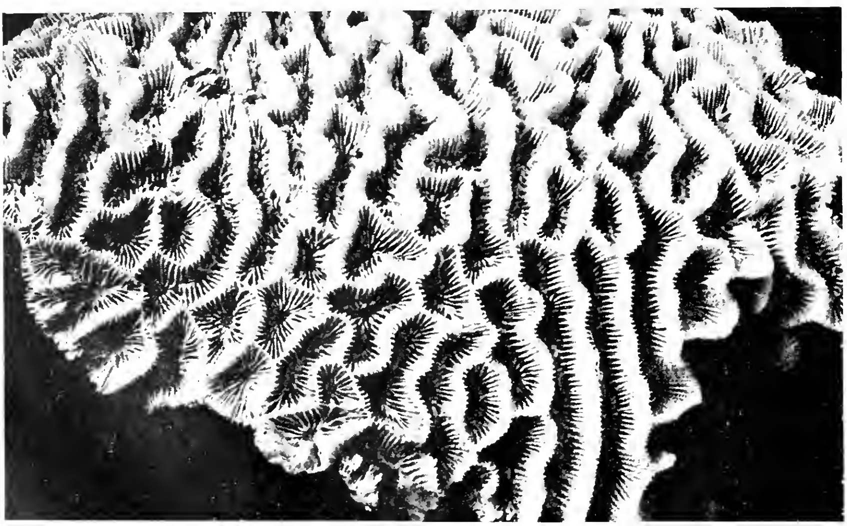
*Orbicella curta* Dana.

Face p. 276.]



1

2

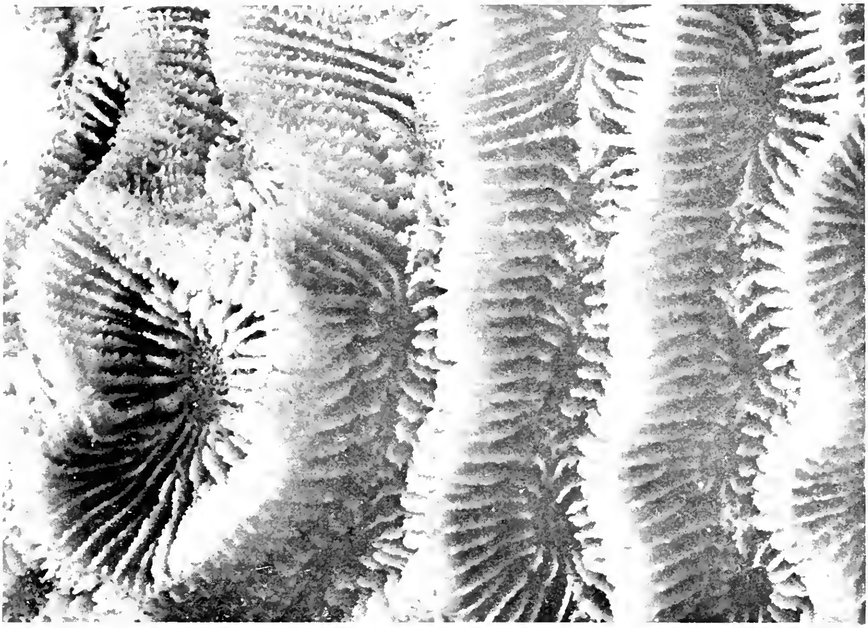


2 a

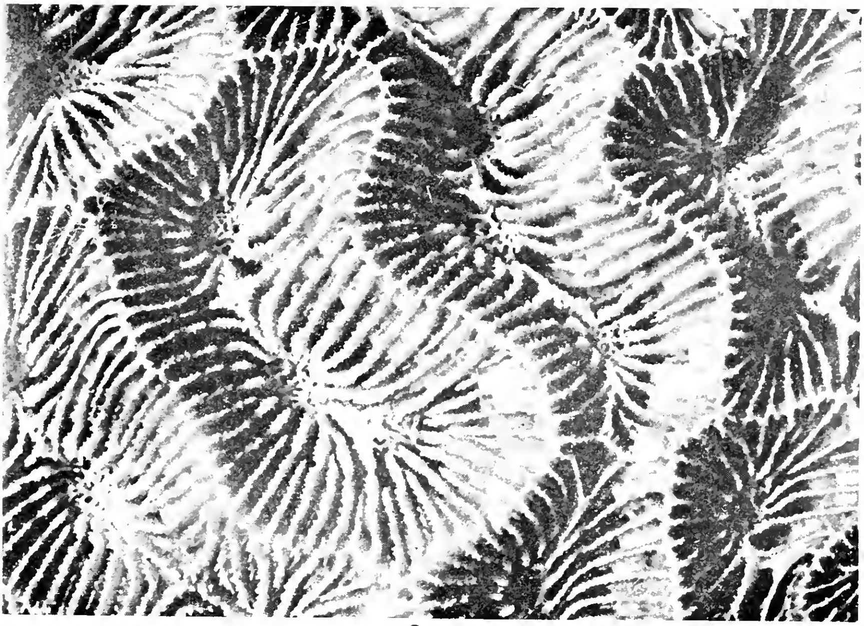
*Goniastrea benhami* Vaughan n. sp.

Fig. 1.—Paratype; natural size.

Figs. 2, 2*a*.—Holotype; views, natural size, of two areas on the surface of the same specimen to show variation in the characters of the collines and valleys.



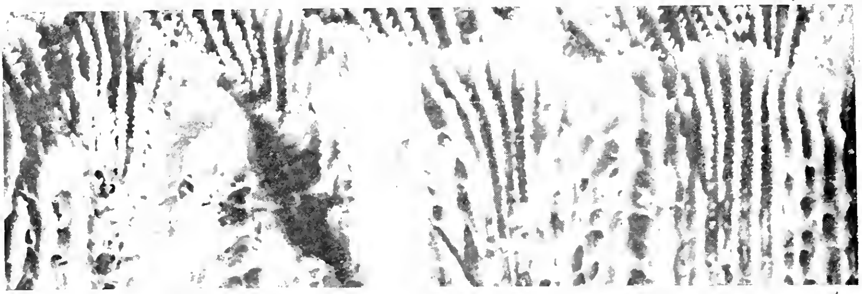
1 ×4



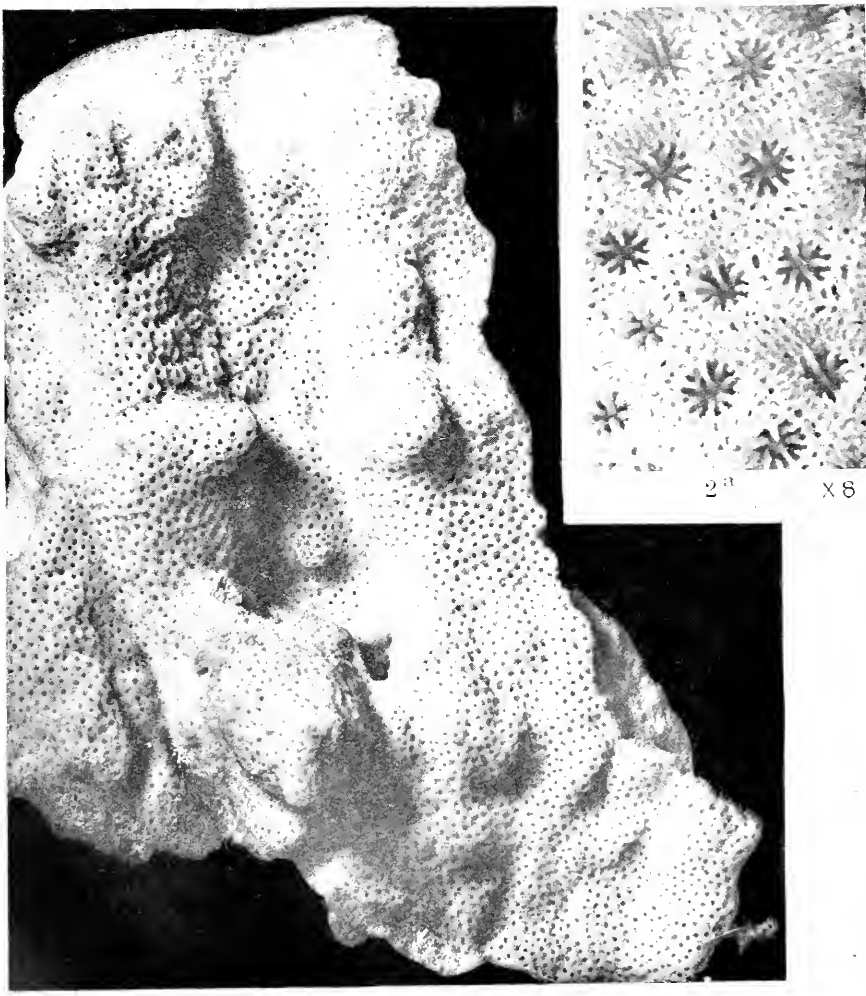
1a ×4

*Goniastrea benhami* Vaughan n. sp.

Figs. 1, 1a.—Holotype; views of two areas on the surface, each × 4.



1 × 4



2a × 8

2

FIG. 1. *Goniastrea benhami* Vaughan n. sp. Longitudinal of corallites of holotype. × 4.
FIGS. 2, 2a. *Montipora caliculata* (Dana). Fig. 2, upper surface, natural size; fig. 2a, calices of upper surface. × 8.

**Goniastrea benhami** n. sp. (Plate XVIII, figs. 1, 2, 2*a*; Plate XIX, figs. 1, 1*a*; Plate XX, fig. 1.)

*Description of Holotype* (Plate XVIII, figs. 2, 2*a*; Plate XIX, figs. 1, 1*a*; Plate XX, fig. 1).—Corallum with a small basal attachment, from which it grows outward with an upwardly inclined, subhorizontal, or undulate lower surface. Epitheca distinct, thin, wrinkled, finely striate. Upper surface curved, with one small hump. Length of radius of corallum, 9 cm. (diameter, about 18 cm.); thickness at centre, 5 mm.; thickness at edge, from a mere basal membrane at the ends of valleys up to 5 mm.; the height of a colline. Texture light. Intercorallite walls thin, sometimes with slits between the septa. Calices circumscribed or in series, but where they occur in series the calicinal centres are distinct. Circumscribed calices about 7 mm. by 8 mm. in diameter; the series range from 9 mm. wide and 17 mm. long to 6 mm. wide and 44 mm. long. Range in width, from 6 mm. to 9 mm.; in length, from 8 mm. to 44 mm.; depth, from 5 mm. to 6 mm. Distance from the edge of one columella to the edge of the next in the series, from 2 mm. to 5·5 mm. Septa thin, 10 to 12 within 5 mm.—*i.e.*, 20 to 24 within 1 cm.; alternately larger and smaller with fair regularity; opposed outer septal ends meet in an angle on the colline summit (a larger usually but not invariably opposite a smaller). Below this angle the septa are narrow and fall steeply within the narrow valleys, but slope more gradually within wide valleys. Between the wall and the inner ends of the septa there are from about 12 to about 14 pectinations; those near the lower ends of the septa somewhat larger and more or less divided on their tips. Thin erect paliform lobes well developed. Their inner edges fall steeply to the periphery of a columella composed of fine, rather delicate septal trabeculae. Septal faces beset with delicate, pointed granulations. Endotheca highly developed, very vesicular.

*Description of Paratype* (Plate XVIII, fig. 1).—This differs from the holotype chiefly in having a more distinctly hillocky surface; and some septa are thicker.

*Localities.*—Meyer Island: on rock; depth, 1 fathom (holotype). Meyer Island: rocky and gravel bottom; depth, 12 fathoms (paratype). Dayrell Islet: volcanic submarine beds.

*Remarks.*—This coral is a species of *Goniastrea*, and except that it has meandroid calicinal valleys it bears considerable resemblance to some specimens of *G. pectinata* (Ehrenberg), which I have illustrated rather elaborately in my paper on the shoal-water corals from Murray Island, &c. *G. planulata* Milne-Edwards and Haime has meandroid corallites, but its skeleton is much heavier. I know of no described coral species to which the one here considered is referable, but that it has a rather wide distribution in the Pacific Ocean is shown by a specimen from Formosa (according to label) in the U.S. National Museum.

Studer* has described a coral from Singapore, to which he applies the name *Scapophyllia lobata*, which may be the same as this: but he gives the number of septa for it as 13–15 to 1 cm., while the number for *Goniastrea benhami* is 20–24 to 1 cm. If Studer meant 13–15 to apply to the larger septa the number per centimetre would be nearly the same as in the latter. A good photographic illustration of Studer's species is needed.

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* *Naturforsch. Gesellsch. Bern., Mitth.*, Jhr. 1880, p. 34, 1881.

### Leptoria tenuis (Dana).

1846. *Meandrina tenuis* Dana, *U.S. Expl. Exped., Zooph.*, p. 262, pl. 14, figs. 7, 7a–7d.

This species is discussed and the type is refigured in my paper on the shoal-water corals from Murray Island, &c.

*Localities.*—Kermadec Islands: Napier Islet; included in lava-flow; altitude, 200 ft.: Dayrell Islet; volcanic submarine beds.

### Sclerophyllia margariticola Klunzinger.

1879. *Sclerophyllia margariticola* Klunzinger, *Korallenth. Roth. Meer.*, pt. 3, p. 4, pl. 1, fig. 12.

1907. *Sclerophyllia margariticola* Vaughan, *Proc. U.S. Nat. Mus.*, vol. 32, p. 258.

*Locality.*—Kermadec Islands: Dayrell Islet; volcanic submarine beds (two specimens).

### Turbinaria crater (Pallas).

1896. *Turbinaria crater* Bernard, *Cat. Genus Turbinaria*, p. 23, pl. 1; pl. 31, fig. 1.

Corallum represented by a peripheral fragment; apparently crateriform when entire. Radial length of fragment, 34 mm.; thickness at inner, broken edge, 4·5 mm.; thickness at peripheral edge, 2 mm.; margin rounded. Corallites unifacial, confined to upper surface; about their diameters apart; inclined outward; length of upper wall up to 3·5 mm.; lower edge of calice elevated up to 1·5 mm. above the coenenchyma; at the periphery the lower edge is immersed; upper edge of calice up to between 3 mm. and 3·5 mm. above the coenenchyma. Basal diameter of corallites up to 3·25 mm. measured along a tangential line; calicular diameter along tangential line up to 2·5 mm., in a radial plane up to 3 mm. Walls rather dense; externally granulate, without definite costules. Calicular apertures up to about 1·5 mm. by 2·25 mm. in diameter, somewhat compressed radially, and directed outward. Twelve septa extend to the columella; there may be from 2 to 6 tertiary septa, which are usually introduced in the interseptal loculi next beyond those on the sides of the directive septum at the proximal end of the calice. In other words, septa of the tertiary cycles are added bilaterally, and usually at one end of the plane of symmetry. The columella fossa in a radial plane is about half the diameter of the calicular aperture; in a tangential plane about one-third the calicular diameter; and is relatively deep, up to about 1·5 mm. The columella is lamellate, lying along the directive plane, the septa joining it by radial processes. There is often a distinct ring of synapticulae outside the columella. The coenenchyma is relatively dense. There are almost solid lower layers supported by trabecular pillars or short spines; above this is a layer in which new corallites have formed; and above the more spongy zone another compact layer, which forms the upper surface. The coenenchymal surfaces, both lower and upper, are granulate, rather flaky, and indefinitely costulate.

*Locality.*—Kermadec Islands; probably from Denham Bay, Sunday Island, at a depth of 3 fathoms.

*Remarks.*—This coral differs from Bernard's description of *T. crater* by having relatively deep calices, whereas the latter is said to have a shallow fossa. Otherwise there seems to be no difference of importance.

### Montipora caliculata (Dana) Bernard.

1897. *Montipora caliculata* Bernard, *Cat. Genus Montipora*, p. 57, pl. 9; pl. 32, fig. 14.

The specimen agrees in all particulars with Bernard's description and figures of *M. caliculata* except that the secondary septa although uniformly well developed are distinctly smaller than the primaries. Dana's type of *M. caliculata* should be in the U.S. National Museum (No. 335), but I have failed to find it.

*Locality.*—Meyer Island: on rock; depth, 1 fathom.

### Acropora sp.

Two worn fragments, not positively identifiable.

*Locality.*—Kermadec Islands: Titi Knob, Sunday Island; volcanic submarine agglomerate.

### Alveopora sp.

A worn fossilized specimen.

*Locality.*—Kermadec Islands: Dayrell Islet; volcanic submarine beds.

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## ART. XVIII.—*On the Origin of a New Species by Isolation.*

By HENRY SUTER.

[*Read before the Philosophical Institute of Canterbury, 1st November, 1916; received by Editors, 30th December, 1916; issued separately, 16th August, 1917.*]

IN April, 1907, Captain J. Bollons, of the Government s.s. "Hinemoa," brought back from the Great King Island a number of large snails, some containing the live animal, which I described under the name of *Placostylus bollonsi* (12, vol. 40, 1908, p. 340, pl. xxv; 11, p. 763, pl. 30, figs. 11, *a*, *b*). I pointed out that this species offered a splendid example of the origin of a new species by isolation, and I now propose to go more fully into this interesting subject.

The genus *Placostylus* occurs with us in the northern part of the North Island only, which points to its immigration from the north, and, geologically speaking, most likely in comparatively recent times. *Placostylus* is found in New Zealand, Lord Howe Island, New Caledonia, Solomon Islands, Fiji, and a stray species in New Guinea. Hedley (4, p. 335) considers this *Placostylus* area, New Guinea excluded, as a zoological province, a unity explicable only on the theory that these islands form portions of a scattered continent and are connected by shallow banks formerly dry land. This continental area he calls the "Melanesian Plateau" (later named "Antarctica" by Forbes). New Caledonia is, with about thirty-five species of *Placostylus*, the metropolis of the genus, and some of its species are closely allied with those of Lord Howe Island and New Zealand. Subfossil, one species is known from Koutoumo Island, New Caledonia (*P. sessilis* Gassies), and two from the Loyalty Group; post-Tertiary, one from Lord Howe Island; and *P. hongii ambagiosus* Sut. is found in large numbers subfossil on Cape Maria van Diemen.

According to Hedley (6, p. 98), Heurteau was the first to recognize the geological connection between New Caledonia and New Zealand, and the subject was reviewed by Crosse (1, p. 443). I give here a translation of some of his remarks: "Considered from a geological standpoint, New Caledonia is a direct continuation of New Zealand, despite the enormous expanse of sea now separating the two countries. We find the same Triassic, Jurassic, and Cretaceous formations, disposed in similar order, containing analagous fossils, and there is an abundance of eruptive rocks." There also exists a close relationship between the animals and plants of New Caledonia and New Zealand. In the Recent fauna there is the same absence of all mammals, except bats and rats, and the same poverty of reptiles. Snakes are absent from both, and the Amphibia consist of one in New Zealand and none in New Caledonia. There is a close correspondence between *Melanopsis*, *Placostylus*, *Rhytida*, Athoracophoridae, the *Charopa* group of *Endodonta*, and some of the Phenacohelicidae, *Rhytidopsis* being nearly allied to our *Phenacohelix*, and *Monomphalus* to our *Allodiscus*. The land Mollusca of Lord Howe Island have a close affinity to those of New Caledonia (7, p. 403).

Speaking of the Great Glacier Epoch of New Zealand, Hutton (8, pp. 176, 182) comes to the conclusion that an elevation of 3,000 ft. to 4,000 ft. would be sufficient to produce the phenomena of the period of glaciation. In the older Pliocene came the last great upheaval, all the islands were joined together, and the land stretched away to the south, east, and north, reaching, in a north-westerly direction, Lord Howe Island. A bank submerged to a depth of about 1,000 fathoms extends from New Zealand to Lord Howe Island, and represents the former Pliocene land extension.

These short geological and faunistic considerations clearly indicate where we have to look for the home of the ancestors of our *Placostyli*, which is beyond a doubt Lord Howe Island, and indirectly New Caledonia. In 1854 Gaskoin described *Placostylus bivaricosus* (13, p. 25, pl. 12, figs. 1–4) from Lord Howe Island, a species which is closely allied to the New Zealand *P. hongii*, which had the name of the Maori chief Hongi Ika (born 1787; died 1828) given to it by Lesson. The resemblance of the two species is so great that Hedley was fully justified in writing, "This species (*P. bivaricosus*) speaks eloquently of a recent land connection extending on the one side to New Caledonia, on the other to New Zealand" (3, p. 140). Etheridge holds that the nearest allies in New Caledonia are *P. caledonicus* Petit and *P. porphyrostomus* Pfr. (2, p. 132). As already mentioned, Lord Howe Island has a post-Tertiary *Placostylus*, which is found embedded in coral-sand rock of aerial, not sedimentary, origin, and which was called *P. bivaricosus solidus* by Etheridge (10, p. 27; 2, p. 131). This variety is distinguished by the peculiarity of the peristome; the outer and inner lip broaden, exposing repeated laminae of growth; the callosity on the body-whorl thickens greatly, supporting strong tubercles and emarginations. We must, of course, conclude that this variety is the forerunner of *P. bivaricosus*.

Now, we have in New Zealand a shell which, though somewhat larger, corresponds very well with the subfossil Lord Howe variety—*P. hongii ambagiosus*, which I described and figured in 1906 (11, p. 768). This subspecies is found subfossil, but also still living, and this no doubt represents the form which reached New Zealand from Lord Howe Island when the former stretched far out to the north-west. On Lord Howe Island also occurs a variety, *P. bivaricosus etheridgei* Brazier, which is a large, thin, elongated form, with a simple, very little thickened peristome, which is not notched (10, pl. v, figs. 1, 2, 7, 8). New Zealand possesses a similar example, the *P. hongii ambagiosus* gradually losing its incrassate notched peristome, the shell getting somewhat thinner, forming the species known as *P. hongii*; and the farther these snails have gone from the north southwards the more simple the outer lip has grown. However, we must not forget that the species of *Placostylus* are polymorphic, and variations in the characters of the shell are not rare. Why heavy, massive snails should go on slowly evolving lighter and more simply constructed shells I cannot explain; the fact only remains.

I beg leave to bring forward here a hypothesis regarding a similar development in marine shells. The genus *Pugnellus* Conrad has nearly the whole of its shell covered by a thick calcareous deposit, so that only a small part of it can be seen. Species of this genus are found in the Cretaceous of Austria, southern India, North America, North Africa, Borneo, Chile, Patagonia, and in the older Tertiary of New Zealand (Wangaloa). We have in New Zealand the genus *Conchothyra* Hutton, which is nearly allied to *Pugnellus*, but has a tremendous calcareous covering, hiding nearly the whole shell. This I consider as an extreme form of *Pugnellus*, and it is peculiar to the Cretaceous and older Tertiary of New Zealand. *Pugnellus* is followed by *Tylospira*, which has part of the body-whorl and spire covered with a thick enamel. There is one Recent species in Australia; it also occurs in the Miocene of Australia and New Zealand. At last we come to the most simple genus of the series, *Struthiolaria*, which has only a thin broad inner lip, and a thickened sinuous outer lip. It is found in the Cretaceous, Eocene, and Oligocene of Patagonia; Miocene of Australia; Miocene, Pliocene, and Recent in New Zealand; &c. I am well aware that Cossmann includes *Pugnellus* in the family Strombidae, and *Tylospira* with *Struthiolaria* in the family Struthiolariidae. Zittel, however, unites them all in the former family. My opinion is that we have to class all these genera either under Strombidae or under Struthiolariidae, and I am more in favour of the latter, as I consider *Pugnellus* to be the ancestor of *Tylospira* and *Struthiolaria*.

To return to our subject. Lesson and Martinet, in their work *Les Polynésiens*, say that *Bulimus hongii* was plentiful amongst flax-bushes near the North Cape, and that *Bulimus vibratus* was abundant on the Three Kings. The latter species (*Placostylus fibratus* Martyn) is a somewhat related New Caledonian species, and our *P. hongii* was sometimes, though wrongly, going under that name. However, the use of two specific names shows that at one time it was known that the Three Kings harboured a species distinct from that on the mainland, but the curious thing is that not a single collection in New Zealand contained an example of the Great King *Placostylus*. If I had not made a note of Lesson and Martinet's statement, had not asked Captain Bollons to look for *Placostylus* on the Great King, and if he had not been successful in finding it, this interesting shell would still be unknown.

The characteristic features of *Placostylus bollonsi* are its rather thin large shell, its simple aperture, its network-like sculpture, the large obtuse broadly rounded apex or protoconch with its peculiar ornamentation, the total absence of a spermatheca in the animal, and the large calcareous egg, which involves a large embryonic shell. The thimble-shaped large protoconch with its fine oblique axial riblets distinguish *P. bollonsi* from all the other species of the genus.

When *Placostylus* reached New Zealand from the north-west the Three Kings were united with what is now the North Island, and must have been populated by the same species we still find in the north, *P. hongii am-*

*bagiosus*, which so closely resembles *P. bivaricosus solidus*. It is generally admitted by geologists that the separation of the Three Kings took place at about the time when Cook Strait came into existence. The depth of the sea between the Three Kings is estimated at about 40 to 50 fathoms (12, vol. 23, p. 420). Mr. P. G. Morgan, Director of the New Zealand Geological Survey, kindly informed me that "probably the late Pliocene was a period of elevation in New Zealand, and during early Pleistocene subsidence began. By the middle of the Pleistocene much of New Zealand was some hundreds of feet below its present level. This is shown by raised beaches on many parts of the coast-line."

No trace of a shell resembling the *Placostylus* of the mainland has been found on the Great King, and it is evident that *P. bollonsi* is the result of a slow and gradual evolution from a form resembling *P. hongii ambagiosus* which has been going on ever since the isolation of the Three Kings.

Wherever *Placostylus* occurs it is gregarious, and our *P. hongii* is known to lay a considerable number of calcareous eggs—twenty to thirty, or even more. *P. bollonsi* was found by Captain Bollons in one place only, under dead leaves of a grove of karaka-trees, and the decomposed leaves of that tree form its chief food. The specimens I kept alive for some time never touched a fresh, green karaka-leaf. There is no doubt that the supply of food was limited, and this will assist us to solve the question how the new species was evolved. We only know the kind of snail that was living on the Great King when separation from the mainland took place, and the result of the evolution—*P. bollonsi*. What went on during the thousands of years we do not know, but I may be allowed to propose a hypothesis. There is no doubt that if the snails went on laying the comparatively large number of eggs in the restricted area of their food-supply there would be some day overcrowding, and the struggle for existence would begin. Those who kept on producing a large number of offsprings might see them starving, but those who began to reduce the number of eggs would be better off. The laying of fewer eggs may have been accompanied by an increase in their size, and so this process may have been going on and on till the large-sized shell of *P. bollonsi* was evolved. This snail lays, no doubt, only one egg, measuring 13 mm. by 18 mm., whereas the eggs of *P. hongii* measure only about 5 mm. by 6 mm. That the laying of only one egg has been going on for a very long period is proved by the fact that the spermatheca or receptaculum seminis of the animal was completely lost, not even a rudiment of it could I find in the five specimens I dissected. It had become useless, there being only one egg to fertilize. *P. hongii*, on the other hand, has a very well developed spermatheca.

To give an idea of the long time that must have passed since the isolation of the Three Kings, I quote here the estimate based on the radio-activity of the earth's crust—one million years since the Quaternary Period, which, of course, is considerably younger than the Pleistocene. I do not belong to those who think this to be correct, as I very much doubt whether it will ever be possible to calculate the age of the earth in a manner approaching accuracy. I merely mention it to show what a long space of time we have to reckon with, and if we take it to be only one hundred thousand years, that allows ample time to comprehend the evolution of this species.

I mentioned the fact that the species of *Placostylus* are living together in considerable numbers, and yet Captain Bollons found only about a dozen live snails. He has been in the locality several times since to look for more specimens, but found only dead shells, and he considers the species to be now extinct. That a species laying only one egg would not increase in number is evident, yet Lesson and Martinet say that in the last century these snails were abundant on the Great King. I cannot find any record that there are rats on the island. These, of course, would dispose of some snails. Then we have to remember that Maoris were at one time living on the Great King, and they may have eaten a good number of these snails, but I am unable to say whether Maoris ever used *Placostylus* as an article of food. Remembering the terrible wreck of the "Elingamite" at 10 a.m. on the 9th November, 1902, and that a party of those saved had to live without food for several days on this island, I think it is possible that some person or persons may have discovered these snails and eaten all those they found. It would gladden my heart if I knew this had been the case.

The most interesting question, however, is, How did the snails know that they produced too many eggs? How did they perceive that laying fewer eggs, increasing most likely their size, and finally sticking to one egg only, would be their salvation? We are only too ready to underestimate the mental faculties of the lower animals, and there is no likelihood that we shall ever get an approximately correct knowledge of what is going on in their small brains. We cannot deny that they possess *mind*, which means will and intelligence, and may be described as accumulated consciousness and accumulated faculty. And a still more interesting fact is that thousands and thousands of years back the *Placostylus* on the Great King practised Malthus's "principle of population." There is nothing new under the sun.

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## ART. XIX.—*Notes on the Occurrence and Habits of the Fresh-water Crustacean* Lepidurus viridis *Baird.*

By Miss E. M. HERRIOTT, M.A.

Communicated by Dr. Charles Chilton, C.M.Z.S.

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### INTRODUCTION.

IN some of our rain-water pools formed in gravel or shingle pits during the spring rains the interesting crustacean *Lepidurus viridis* occasionally makes a sudden appearance. For a few weeks it flourishes and may be collected in large numbers, then as the hotter months of summer come the pool dries up and the animal disappears, to reappear perhaps in a similar way at the same time of the following year, or, it may be, to be seen no more in that locality for several years. In this paper are recorded observations made recently on collections of living specimens kept for two or three weeks in the Biological Laboratory at Canterbury College, and the information available from previously published records is collected. These records are apparently very scanty.

### HISTORICAL.

*Lepidurus viridis* belongs to a group of the crustaceans commonly known as the Phyllopoda, and is interesting not only on account of its size and structure, but also because Bernard (1892) attempts to make of the group a connecting-link between the Annelida and the higher types of Crustacea. The Phyllopoda (so called because the numerous appendages are membranous and foliaceous, thus serving the double purpose of limbs and respiratory organs) is further subdivided into families, to the lowest of which—namely, to the Apodidae—this genus belongs. This is a small family consisting of only two genera, *Apus* and *Lepidurus.* These agree in having a long segmented body, from $\frac{3}{4}$ in. to $2\frac{1}{2}$ in. or 3 in. long, partly covered with an oval shield-like dorsal carapace, and bearing at the posterior end of the body two jointed appendages, or "cercopoda," which vary in length. The chief difference between the two genera is the presence in *Lepidurus* of a long produced telson and a larger carapace (Packard, 1882, p. 316). This large plate or caudal lamella of the telson is shaped "like a beaver's tail, and must give it an advantage over *Apus* in extricating itself from muddy places" (Packard, 1882, p. 380).

The species *Lepidurus viridis* was described and figured by W. Baird (1850, p. 254). His description was based on the examination of one animal from Tasmania, 2 in. long and 1 in. broad, "of a fine green colour."

In 1866 two more specimens were sent to Baird from "rain-pools on the Gawler Plains, north of Adelaide, South Australia" (1866, p. 122). This animal was just 1 in. in length: the caudal setae were rather more than half the length of the body, and in spirit the carapace was a pale horny colour. Baird therefore made of it a new species, *Lepidurus angasii.*

G. M. Thomson (1879, p. 260) described two new species based on specimens obtained from three different localities in New Zealand. The first, *L. kirkii*, from Wellington, was pale olive-green in colour, with carapace broadly oval, very membranous, caudal setae more than half the length of the body, total length 1·25 in. The second, *L. compressus*, from Waikouaiti and Queenstown, Otago, was dark olive-green, with carapace oval and more or less arched, caudal setae not half the length of body, and a total length of only 0·8 in. Thomson expressed some hesitation in forming these new species, and considered it likely that they, with *L. angasii* Baird, might well be only varieties of a very widespread species, *Lepidurus viridis*.

Tate described (*Proc. Roy. Soc. S. Aust.*, 1878–79, p. 136) a species which he called *Lepidurus viridulus*. I have not been able to consult this paper, but probably the species is only a variety of *L. viridis*, being given as a synonym by Sayce (1903, p. 242).

Spencer and Hall, in their *Report of the Horn Expedition to Central Australia* (1896, pt. ii, "Zoology," p. 234), mention *Lepidurus viridis* as being found near the coast and not inland.

In 1903 Sayce mentions the species in his list of Phllyopoda of Australia, and gives synonyms (1903, p. 242); and it is again cited in Hutton's *Index Faunae Novae Zealandiae* (1904, p. 267).

## DISTRIBUTION.

Sayce (1903, p. 242) has been followed in classing *L. angasii*, *L. kirkii*, *L. compressus*, and *L. viridulus* all as synonyms of *L. viridis* Baird. The species, therefore, appears to be widely distributed in Australia and New Zealand.

The earliest recorded specimen, as already mentioned, was from Tasmania (Baird, 1850). Sayce (1903, p. 242) gives its distribution thus: "Inland and coastal areas of N.S.W.; northern and southern areas of Victoria; southern area of South Australia; Tasmania; and New Zealand."

The only published record of the species given in New Zealand is that given by G. M. Thomson (1879, p. 260), and he gives the habitat as Wellington, Waikouaiti, and Queenstown.

In the collections of the Biological Laboratory of Canterbury College are specimens received from Ashburton (October, 1902), Cashmere (December, 1904), Linwood (September, 1916), Springston (October, 1916). Dr. F. W. Hilgendorf has found them at Lincoln, and Mr. G. E. Archey in pools near New Brighton.

## OCCURRENCE AND HABITS.

*Lepidurus viridis*, in common with most of the Phyllopoda, is found in stagnant shallow water in pools sometimes "only a few square yards in area" (Calman, 1909, p. 161). These pools are formed by the spring rains in gravel-pits or clay mudholes. Dr. Hilgendorf has found specimens of *Lepidurus* at Lincoln in very small holes formed by the hoof of a horse or cow. The sudden appearance of these animals is due to the rapid development of the "winter" or "resting" eggs. Their rate of growth must be very great, for Spencer and Hall (1896, p. 228) speak of collecting full-grown specimens of the allied genus *Apus*, 2 in. or 3 in. in length, "certainly not more than two weeks after a fall of rain"; and Packard (1882, p. 328) speaks of *Apus himalayanus*, a species found in North India, as being collected from a stagnant pool in a jungle, four days after a shower of rain had fallen, following a drought of five months. The animals make the most of their brief existence by producing numbers of parthenogenetic eggs, so that the pools swarm with animal life for a short time, and then, to preserve the species, the "winter" or "resting" eggs are produced, which can resist desiccation for many months.

As the pools dry up in the hotter weather the density of the water increases considerably, but these animals seem adapted to withstand such increase. This was noticed of the living specimens kept in the laboratory. The water was not renewed at all, and there was a decided scum formed on the surface of the water, possibly of calcium carbonate from the water. The animals did not seem to suffer in any way from this.

Spencer and Hall (1896, p. 229) have recorded of *Apus* a tendency on the part of the animals, as the water receded in the pool, to swim out towards the shallower edges and bury themselves in the mud, instead of keeping in the deeper parts of the pool. Probably, as is suggested, the eggs are protected in this way, although the animals themselves die.

When once the pool is quite dry the mud may remain caked and hard, and the eggs therefore stay embedded in it till next rainy season and then develop. Sometimes it may happen that the mud is broken up into dust through various agencies, and the dust so formed scattered by the wind. Then the eggs are carried from this spot to one far distant, and next year there may be no sign of the animal in this particular pool, though in another locality where it was formerly unknown it may be found in abundance. This accounts for its intermittent appearance. Wind is not the only means of dispersal of the eggs. Wading-birds and water-birds may remove them in the mud which cakes on their legs, and so carry them to another of their haunts.

It seems necessary, however, that the eggs should be subjected to longer or shorter periods of desiccation for their proper development. "The eggs should be dried first and afterwards placed in water. Many eggs float when placed in water after desiccation, the development taking place at the surface of the water" (Weldon, 1909, p. 32).

All the attempts to hatch out the eggs in October, 1916, in the laboratory have been unsuccessful.

In New Zealand *Lepidurus viridis* usually makes its appearance about September or October, though those collected at Cashmere bear the date December, 1904. There is, however, no further record of them. Mr. G. E. Archey tells me that in 1912 he saw in shallow pools near New Brighton many specimens of *Lepidurus* swimming about under a thin coating of ice, but he has kept no record of the month.

The first collection brought alive into the laboratory consisted of about eighteen animals from Linwood on the 23rd September, 1916. Six of these were placed in a large aquarium-jar containing water about 3 in. deep, together with a small quantity of river-weed, *Elodea canadensis*. The jar was left in a window facing south. Most of the specimens were females bearing a large number of deep-orange-coloured eggs in the ovisacs. Some of these eggs were discharged into the water, and it was noticed that the animals that discharged them died very shortly afterwards. These conditions were evidently not suitable, for all the animals were dead within five days.

The greater number of this first collection was left in a large enamel bowl on a bench in the centre of the large laboratory away from direct window-light. A small quantity of mud from an aquarium-jar was also added, as no direct information concerning the proper food could be found. On the mornings of the 25th and 26th four cast exoskeletons were found in the water, only one of them, however, being perfect. All these animals lived for over a week, then began to die off, and were removed as soon as they were noticed to be dead. The last one died on the 13th October, having lived in the laboratory just three weeks.

On the 14th October another larger supply of *Lepidurus viridis* was brought in from Springston, and all were put together into a large enamel bowl with plenty of mud. These specimens were much smaller than those of the last collection, and varied considerably in size and colour. The number was roughly estimated to be about thirty-five. On the 18th nine specimens were put in another smaller bowl in clear water. On the following day one animal (A) was noticed to be dead, and on closer observation one side of its carapace was seen to be very irregular in outline. Another animal (B) was apparently dying, lying on its back and moving its legs very feebly. Two hours later another animal was noticed in close proximity to A, and when it moved away more than an hour later the other side of the carapace of A was quite broken and irregular. Before long A was visited by two others, and by that time more than half of it had disappeared. The suspicion aroused by the great decrease in numbers since the collection had been brought in was now confirmed. There could be no doubt that the animals, deprived of their natural food, were eating the bodies of their fellows. As this promised to be interesting, four others were taken from the large bowl, in which the water was too muddy for observation, and placed in a third bowl of clear water.

The numbers were carefully counted next day, with the following results: The original bowl (I) now contained seven animals; in the second bowl (II) only seven out of the nine put in two days before were alive, nothing was left of A, and only part of the head of B: in bowl III there were still four, but one of them was lying on its back, moving its legs very feebly, most active whenever any other animal came near it, as though conscious of its danger. This made a total of eighteen left out of the original thirty-five after six days. There could be no doubt about *Lepidurus* being carnivorous. On each of the following days the numbers were counted and were found to be less and less, till on the 27th there were three left, one in each bowl. Of the four originally put into bowl III the smallest was left, a dark-green animal. In the other two bowls the largest were left, and both were mottled green. On the 28th the one in bowl III died; on the 30th that in bowl II was found to be dead; the last one, in the original bowl (I), died on the 3rd November, having lived in the laboratory three weeks.

These animals had, of course, been living under unnatural conditions, and this may have induced this method of preying on one another. References to their natural food are very scanty, there being, in fact, no references to *Lepidurus* itself, but in describing *Apus lucasanus*, a species of the allied genus, Packard says (1882, p. 324), "The food of this species appears to be Crustacea, as in dissecting the mouth-parts of one of this species the legs of an Asellus-like crustacean were found partly swallowed. Hence they are quite predaceous in their habits." Weldon (1909, p. 19) describes the food of the Branchiopoda as consisting of "suspended organic mud, together with Diatoms and other Algae and Infusoria; the larger kinds, however, are capable of gnawing objects of considerable size, *Apus* being said to nibble the softer insect larvae and even tadpoles. Many *Cladocera* may be seen to sink to the bottom of the aquarium with the ventral surface downwards and to collect mud, or even to devour the dead bodies of their fellows." Bernard, in his work on the Apodidae (1892), endeavours to trace the origin of the Crustacea through the Apodidae from a carnivorous annelid; consequently it is evidently taken as a fact that the Apodidae are carnivorous, but so far no record has been given of their food other than in general terms as given in the quotation above.

The animal when feeding usually lies on its back, with its food above it. All the limbs are kept moving. Whether the posterior ones just serve to keep the animal in its inverted position by their paddling movements, and only those near the mouth are used for preparing the food, cannot quite be ascertained, but this is probably the case. In seeking for smaller pieces of food the animal burrows into the mud with its shovel-shaped carapace, and the mud is passed along the central groove underneath the body. This groove is formed between the closely ranked legs of either side, and closed above by the segmented body. When the animal is on its back the movement of the legs is seen to begin from the posterior limbs and pass on in regular waves to the anterior. Any particles of food would be passed on in this way to the mouth.

The water in the bowls in which the animals were kept was about 1 in. deep. They seemed to prefer to move about ventral surface down, though occasionally they would swim about on their back or on the side. When placed in a bowl of fresh water they would often hang to the surface almost suspended on one side, part of the carapace being out of the water. At other times they moved along at the bottom of the bowl, head down and body inclined at an angle as though standing on the front flattened portion of the head. When they were very active they were most interesting to watch: their movements were very quick; they darted about guiding themselves by the caudal segments, which twisted and turned in every direction as the animal pleased. On one occasion one was seen to turn a complete somersault several times. They did not appear to interfere with each other, except that one would sometimes seem to be nibbling at the caudal setae of another and would be quickly shaken off, the victim swimming away. Still, the gradual and unequal shortening of these tail setae, which was noticed even among the first specimens, before it was discovered that the animals did actually eat the dead bodies of their fellows, must have been due to their attempts to appease their hunger. The length of the caudal setae, therefore, can hardly be considered as a good distinguishing specific character, since accidental shortening may easily take place.

## Colour.

The colours varied considerably amongst individuals brought from the same pool. Those brought from Linwood were perhaps the most uniform in their green colour. Among them, however, were three or four which showed some variation in the way of mottled markings of the carapace, and these proved to be the longest lived. Still more variety was shown amongst the individuals from Springston. These were dark green, lighter green, mottled green, and several small ones were of a uniform pale colour, perhaps the horny colour of *L. angasii* (Baird, 1866, p. 122). As in the previous case, the mottled individuals were the last to die. Specimens from Melbourne in spirit in the Biological Laboratory show a uniform pale colour. The New Zealand specimens remain green.

## SIZE.

The sizes varied considerably also. In the following measurements the total length has been taken from the front ridge of the head to the posterior end of the caudal lamella, the caudal setae, as mentioned before, being frequently broken or eaten off by other animals; where these have apparently not been injured in any way their measurements have been given also.

| | Length, Total. | Length, Carapace. | Length, Caudal Setae. | Breadth. |
|---|---|---|---|---|
| | Mm. | Mm. | Mm. | Mm. |
| Linwood specimens | 38 | 25 | .. | 15 |
| | 38 | 28 | 24 | 17 |
| | 23 | 20 | .. | 12 |
| | 28 | 20 | 18 | 11 |
| | 19 | 18 | .. | 9 |
| | 27 | 18 | 23 | 12 |
| Springston specimens | 31 | 23 | 18 | 10 |
| | 19 | 15 | 12 | 10 |
| | 20 | 13 | 13 | 10 |
| | 27 | 17 | .. | 10 |
| Ashburton specimens | 28 | 24 | .. | 13 |
| | 29 | 23 | .. | 13 |
| | 32 | 23 | .. | 14 |
| | 27 | 25 | 23 | 13 |
| Cashmere specimens | 29 | 21 | 20 | 12 |
| | 31 | 21 | 20 | 13 |
| | 21 | 18 | 20 | 9 |

## ECDYSIS.

Another interesting performance of which some notes were taken was the process of ecdysis, or moulting. As mentioned above, several cast shells were found on certain mornings, the process of casting them having taken place, as is usual in such cases, during the night. One morning, however, a small pale-coloured animal was discovered to be just in the act of casting its exoskeleton, and a close watch was kept. When first noticed it had freed the posterior portion of the body from the old shell, including ten body-segments, the caudal lamella, and the caudal setae, and was then busily engaged in the task of freeing its sixty-odd pairs of limbs. The caudal setae were bent, and appeared to be attached to the lamella. The segments were pale grey in colour, with lighter markings at the division of the segments. The exoskeleton had apparently been torn just about the level of the seventh segment to allow these parts to be drawn out.

At first the animal was very active. Lying on its back, it moved the appendages one after another, beginning with those at the posterior end. After a minute or two of these movements it would jerk the body violently, at the same time moving the tail portion very rapidly round and round. Then the first position was resumed, and again the jerking and twisting followed. The animal seemed to be endeavouring to free its body from the exoskeleton by its series of movements, and apparently tested the results at intervals in its violent struggles to draw some of its limbs out of their covering. While it was watched it made some progress. As far as could be seen with the aid of a magnifying-glass, all the limbs were finally freed from the exoskeleton, though only about half of them were drawn out. At the end of four hours the movements were growing very feeble, and at the end of the fifth hour, as a fairly long struggle produced little result, the animal evidently was too exhausted to continue. There was just a feeble movement kept up for another hour, and then the struggle was over and the animal dead. With its partially cast shell it has been preserved carefully for future reference.

The following morning, in another bowl, another animal was seen to be dragging round with it an exoskeleton attached to one corner of its carapace. The exoskeleton was rather imperfect, as though in its endeavours to free itself the animal had become entangled in it and broken it. An attempt to assist the animal to get rid of its burden resulted in its death; probably the soft tissues of the carapace were injured. In this case the animal remained on its back, feebly kicking, for more than a day, and then died

In one or two instances the cast shells removed from the water were complete; in other cases the carapace had broken away from the body-cuticle. In one such case, on removing the carapace-cuticle from the water, it was seen to be in two layers, which were joined at the posterior end but completely separated right round the edge of the curve from one posterior angle to the other. In the lower layer was a tear in the tissue to allow of the body being drawn through.

I have not been able to find any record of the method of moulting for *Lepidurus* or *Apus*, but Packard (1882, p. 412), quoting from a letter from Dr. Gissler, "who has raised the young *Apus* from the egg," says, "I am certain that the larvae of *Apus* (from skins examined) split across or just in front of the eyes, and with two or three jerks the animal rids itself of the underlying skin." According to Packard, then, this corresponds to the method of moulting in *Limulus*.

## Movements.

Most of these lower forms of Crustacea usually swim on their back, a method adopted probably for the protection of the soft tissues of their limbs from the attack of their fellows or other inhabitants of the water. Spencer and Hall (1896, p. 228) report an instance of this from Australia: "While watching *Apus* swimming about, one was seen to come suddenly to the surface struggling violently, and on being caught was found to have three water-beetles tearing its soft appendages. These beetles are always darting up and down in search of food, and if the *Apus* swam with its ventral surface downwards it would probably more often fall a prey to such voracious enemies."

In the case of the living animals of the genus *Lepidurus* kept in the laboratory, they were more often to be seen ventral surface downwards, swimming or paddling along in the mud at the bottom of the bowl. At first some of them were very active, and their movements were interesting to watch as they darted here and there in the water, steering themselves by the posterior portion of the body, and avoiding as far as possible their fellows. Occasionally they would attempt to nibble at the cercopoda or caudal setae of another, and would then be shaken off.

In conclusion, it might be well again to draw attention to the fact that several zoologists have expressed the opinion that the number of the species of *Lepidurus* would bear reduction. Some of the specific characters used vary considerably in individuals taken from the same locality and even from the same pool, and are probably only different stages in the development, due to the age of the individual. This is borne out in the study on which this paper is based.

Lubbock (1863, p. 206) notes in the case of a character Baird used—namely, the extent to which the body of the animal is covered by the carapace—that his specimens taken from gravel-pools in the north of France showed a great amount of variation in this respect. In some instances the carapace left seven posterior segments uncovered, in others it covered part of the caudal lamella. He notes that the shape even of the caudal lamella varied.

G. M. Thomson (1879, p. 261), at the very time of describing his two new species, expresses as his opinion that these may be only varieties of a widespread species, and would "be inclined to include under one species *L. productus* Bosc., from Europe, *L. viridis* Baird, from Tasmania, *L. angasii* Baird, from South Australia, and perhaps even *L. glacialis* Kroyer, from North America."

Spencer and Hall (1896, p. 233), after examining a large number of specimens of *Lepidurus*, come to the same conclusion, that a comparative study of all the species known from different parts of the world "would result in materially reducing the number of species."

The specific characters used by different writers appear to be—(1) Size of animal; (2) extent to which carapace covers body; (3) shape and thickness of carapace; (4) colour; (5) shape of caudal lamella; (6) length of caudal setae or cercopoda. Most of these have been mentioned, and have been shown not to be constant characters, but in this paper I make no attempt to discuss the specific distinctions of the specimens examined.

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# Art. XX.—*The New Zealand Sand-hoppers belonging to the Genus* Talorchestia.

By Charles Chilton, M.A., D.Sc., LL.D., F.L.S., C.M.Z.S., Hector Medallist, Professor of Biology, Canterbury College.

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The sand-hoppers or shore-hoppers that are so abundant on the shores of New Zealand are Amphipoda belonging to the family which Stebbing has named the Talitridae, though it was long formerly known, and is perhaps better known even now, as the Orchestidae. They present many interesting points in structure, and are specially worthy of study because they are undoubtedly forms that have arisen from marine ancestors and have gradually become adapted to a life on the seashore. Some members of the family are still almost entirely marine, spending the greater part of their life in the sea-water; others live at or above high-water mark almost beyond the reach of ordinary tides. Between these two extremes we have numerous transitional stages in structure and in habits, so that the family offers a favourable opportunity for studying the effects of altered conditions on the structure of the animals. One member of the family, *Parorchestia sylvicola* (Dana), has become quite terrestrial in habits, and is found all over New Zealand far from the coast.

Similarly the terrestrial Isopoda belonging to the Oniscidae and allied families, commonly known as slaters, woodlice, &c., are descended from marine ancestors and present a series of transitional forms strikingly parallel to the Talitridae, though with the isopods the terrestrial forms are much more numerous and more perfectly adapted to terrestrial conditions. In their antennae and mouth-parts these isopods show many resemblances to the shore-hoppers, and a detailed comparison of the two groups, as an example of convergent evolution, would be instructive and fruitful in results. It is possible also, as I pointed out in 1884 (p. 156),* that forms now included in the same species or genera may have arisen independently in different places from the same widely distributed marine ancestor.

The New Zealand sand-hoppers are grouped under several genera, such as *Talorchestia*, *Orchestia*, &c. Their classification is difficult owing to the close general resemblance of all of them and the consequent use of minute and apparently trivial characters in distinguishing the genera and species, and particularly owing to the fact that nearly all show marked sexual dimorphism, the females of different species being very much alike while the fully grown males may be quite different. Again, the sexual characters of the male appear in most cases to be fully developed only at a late stage, the immature males being more like the females, and in the absence of a mature male it may be very difficult to say to what species any particular specimen belongs.

The Orchestidae of New Zealand have already received a good deal of attention. The species were originally described by Milne-Edwards,

* The references are made by the year of publication to the bibliographic list at the end of this article.

Dana, Spence Bate, and others. In 1881 (p. 208) G. M. Thomson gave a critical review of some of the species, and in 1899 he published a "Synonymy of the New Zealand Orchestidae." In 1906, in *Das Tierreich Amphipoda,* Mr. Stebbing included the New Zealand species and gave brief diagnoses of them. In preparation for his paper Mr. Thomson had made many drawings of the different species, but these were not published, nor is Stebbing's list illustrated. Mr. Thomson has since handed over to me all his specimens, drawings, and notes. Some of these have been used in the preparation of this paper, and the others will be of great use when it is possible to compile a complete and critical list of the New Zealand Orchestidae.

At present, however, I deal only with the species of the genus *Talorchestia.* Of these there are three, and for them I accept the names as given by Stebbing in 1906, adding figures and notes on their distribution and habits which will, I hope, be sufficient to enable local collectors to identify their specimens.

All three species, with the possible exception of *P. tumida,* are endemic to New Zealand, and appear to be pretty distinct from the species of the genus found in other countries.

## Genus TALORCHESTIA Dana, 1852.

*Talorchestia* Stebbing, 1906, p. 543.

Stebbing defines *Talorchestia* by its differences from *Orchestia,* which he places before it in the list, and *Orchestia* is defined by reference to *Talitrus.* The three genera are very close to one another and to *Talitroides* and *Orchestoidea,* the five together forming a fairly well defined group of the Orchestidae.

The following definition of the genus will perhaps be sufficient for the New Zealand species; I omit, of course, the characters common to the family.

> Antenna 1 shorter than peduncle of antenna 2; antenna 2 often strongly developed, especially in adult males. Gnathopod 1 small, simple in the female, subchelate in the male owing to the production of the propod into a narrowly rounded pellucid lobe, a similar lobe being usually present on the hind margin of the carpus near the distal end. Gnathopod 2 small and feeble in the female, the propod being produced into a rounded pellucid lobe beyond the minute chela-forming finger. Gnathopod 2 in the male very large and powerfully subchelate. Peraeopod 2 with the finger notched or otherwise modified and differing from that of peraeopod 1.

While the three genera are undoubtedly very closely related, *Talitrus* is distinguished by having the second gnathopod small and feeble in the male and similar to that of the female. In *Orchestia* the first gnathopod is usually subchelate in the female as well as in the male, and in the male the pellucid lobes on the carpus and propod are broader than in *Talorchestia* and differently shaped; in *Orchestia,* again, the finger of the second peraeopod is usually the same as that of the first.

The genera *Talitroides* and *Orchestoidea* are ill defined; the first should probably be united with *Talitrus,* and it is difficult to distinguish *Orchestoidea* from *Talorchestia.* Another genus, *Talitriator,* was established in 1913 (p. 109) by Methuen, who says in his diagnosis, "Like *Talitrus* except for the fifth side-plate . . ." The type is a truly terrestrial species widely distributed in South Africa. In 1916 (p. 222) Barnard adopts the genus, transfers to it the Australian species *Talitrus sylvaticus* Haswell and *T. kershawi* Sayce, and gives a fresh diagnosis.

It seems probable that *Talitriator* will be found to be identical with *Talitroides* Bonnier, and this name has priority if the genus is retained as separate from *Talitrus*.

All the New Zealand species of *Talorchestia*, and, so far as I know, all the foreign species also, are confined to sandy beaches, where they may be found under decaying seaweed or driftwood, or burrowing into the sand about high-water mark. Some species of *Orchestia* may occur in similar situations, but many are found under stones, &c., on rocky shores.

Owing to the differences between the sexes and to the changes passed through by the males in attaining the adult form it is very difficult to give any artificial key for readily distinguishing the species, but perhaps the following will be useful :—

| | | |
|---|---|---|
| 1 | Antenna 2 as long or longer than the head and first three segments of the peraeon, fourth and fifth peraeopoda not modified in male .. | *T. quoyana* |
| | Antenna 2 shorter than the head and first three segments of peraeon, fourth or fifth peraeopod modified in male .. .. .. | 2 |
| 2 | Body very broad; carpus of fourth peraeopod irregularly dilated in male, fifth peraeopod normal .. .. .. .. | *T. tumida* |
| | Body rather compressed; carpus of fifth peraeopod dilated in male into a large, rounded plate concave on inner side, fourth peraeopod normal .. .. .. .. .. .. .. | *T. telluris.* |

### Talorchestia quoyana (Milne-Edwards). (Figs. 1 to 5.)

*Talitrus brevicornis* and *Orchestia quoyana* H. Milne-Edwards, 1840, vol. 3, pp. 15, 19. *Orchestia quoyana* G. M. Thomson, 1899, p. 202. *Talorchestia quoyana* Stebbing, 1906, p. 547 (with synonymy).

*Specific Diagnosis.*—Back broad. Antenna 1 reaching a little beyond end of penultimate joint of peduncle of antenna 2. Antenna 2 in female as long as head and first three segments of peraeon, in male becoming longer

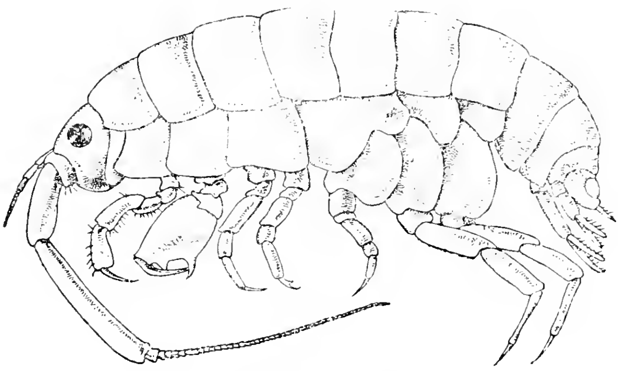

Fig. 1.—*Talorchestia quoyana*, male.

and stouter, often more than half the body-length and with last joint of peduncle twice as long as the preceding. Gnathopod 1 in male with carpus much longer than propod, not lobed, propod very spinose, with small postero-distal lobe, palm transverse, finger reaching beyond it. Gnathopod 1 in female similar but with propod narrowing distally so that the end is scarcely broader than the base of the finger. Gnathopod 2 in male with basal and ischial joints channelled in front, propod very large and massive, palm

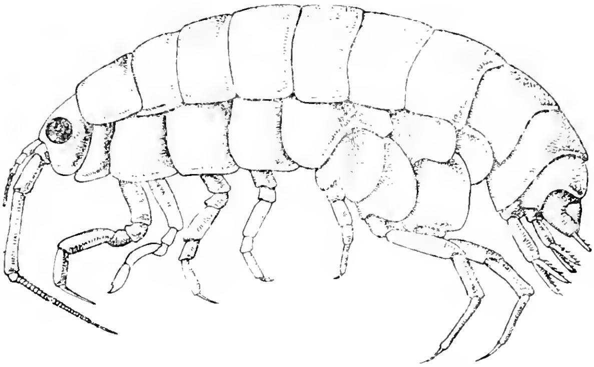

FIG. 2.—*Talorchestia quoyana*, female.

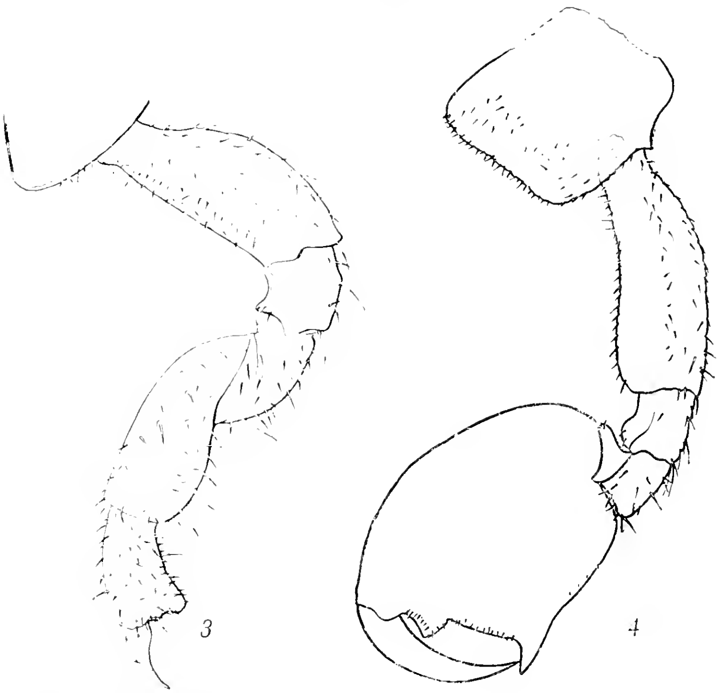


FIG. 3.—First gnathopod of adult male.
FIG. 4.—Second gnathopod of adult male (less enlarged than fig. 3).

oblique, spinose, with broad rectangular tooth near the finger, and prominent acute defining tooth. Gnathopod 2 in female not presenting characteristic features, basal joint elongate-oval, carpus longer than propod. Peraeopoda normal.

*Length* of male reaching 29 mm.; females smaller.

*Occurrence.*—On sandy beaches all round the coasts of New Zealand.

*Remarks.*—This is the largest and commonest sand-hopper in New Zealand; it occurs in great abundance on all sandy beaches under decaying seaweed or burrowing in the sand about high-water mark, usually a little below extreme high-water mark. It is probably somewhat nocturnal in habit, seldom being seen in large numbers during the day unless disturbed from its burrows, when it leaps about with great agility. The colour is usually a light-yellowish brown with marbled markings of a darker brown, generally assimilating to the appearance of the sand.

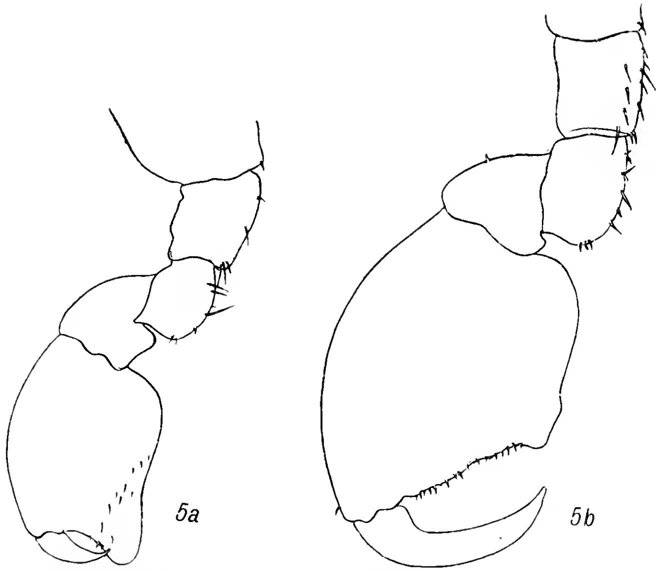


FIG. 5*a*.—Second gnathopod of young male.
FIG. 5*b*.—Second gnathopod of older but immature male.

Immature males have the second antenna shorter and more slender, resembling those of the females, and the second gnathopod small and feeble like that of the female except that the carpus is shorter and the propod broader. Two transitional stages are shown in figs. 5*a* and 5*b*.

### Talorchestia tumida (G. M. Thomson). (Figs. 6 to 13.)

*Talorchestia tumida* G. M. Thomson, 1885, vol. 2, p. 577, and 1899, p. 203; Chilton, 1892, p. 259; Stebbing, 1906, p. 550 (with synonymy).

*Specific Diagnosis.*—Back broad and body swollen, especially in old males. Antenna 1 reaching to end of penultimate joint of peduncle of antenna 2, short, flagellum shorter than peduncle. Antenna 2 less than one-third the length of the body, last joint of peduncle about twice as long as the preceding, flagellum rather shorter than the peduncle. Gnathopod 1 in male spinose, carpus much longer than the propod, its hind margin with a narrowly rounded lobe near the distal end, propod with a similar lobe at distal end forming a transverse or slightly projecting palm. Gnathopod 1 in female similar but without the lobes, though the postero-distal angle of the propod forms a slightly projecting blunt tooth. Gnathopod 2 in male varying much in appearance at different stages of development; in old males propod much swollen, widening distally, palm transverse or slightly oblique, spinose, not defined but forming at the junction with the

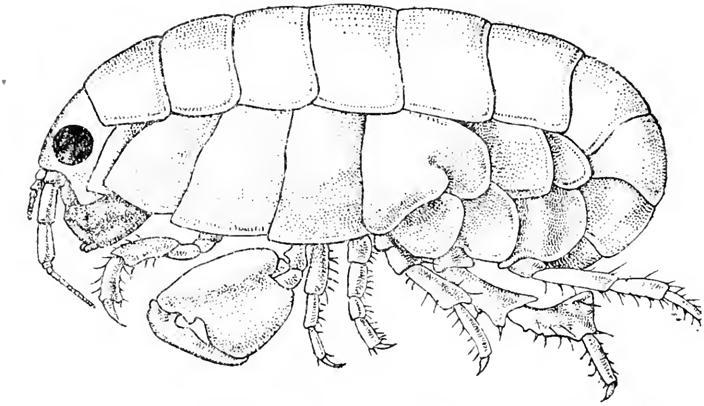

FIG. 6.—*Talorchestia tumida*, male.

hind margin a broadly rounded projecting lobe, near the base of the finger on the inner side is a stout tooth-like projection; in younger males this process is nearer the middle of the palm and divides it into two deep excavations; finger stout, with a rounded projection on concave side, end

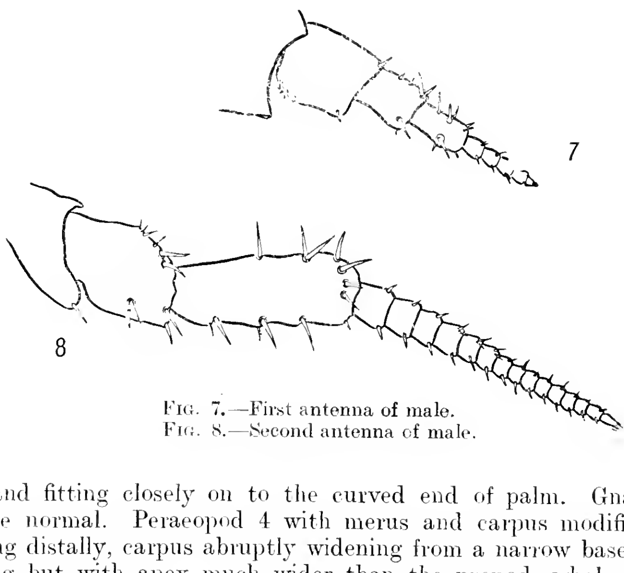


FIG. 7.—First antenna of male.
FIG. 8.—Second antenna of male.

curved and fitting closely on to the curved end of palm. Gnathopod 2 in female normal. Peraeopod 4 with merus and carpus modified, merus expanding distally, carpus abruptly widening from a narrow base and then narrowing but with apex much wider than the propod, whole limb very spinose. Fifth peraeopod rather stout but otherwise normal.

*Length* of largest specimens about 15 mm.

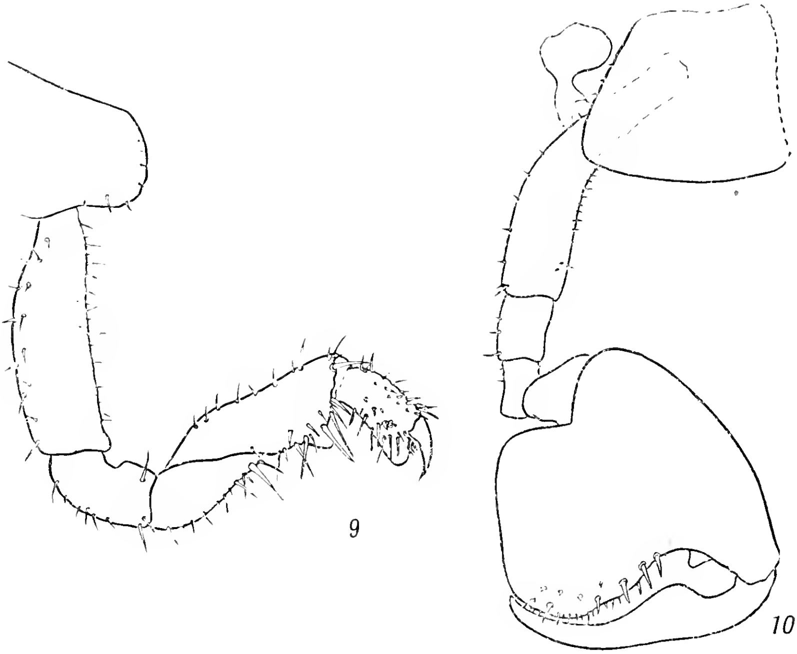

Fig. 9.—First gnathopod of adult male.
Fig. 10.—Second gnathopod of adult male (less enlarged than fig. 9).

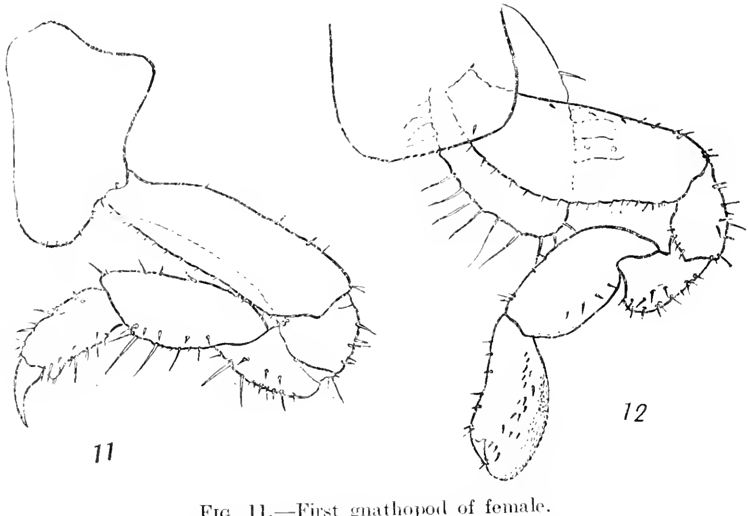

Fig. 11.—First gnathopod of female.
Fig. 12.—Second gnathopod of female.

*Occurrence.*—On sandy beaches at numerous points on the New Zealand coasts, and at Chatham Islands.*

*Remarks.*—This species is smaller and less common than *T. quoyana*, but is found at suitable spots all round the coast. Mr. Thomson says that it occurs "on sandy beaches and sandhills, usually at some distance from the sea." Most of my own specimens, however, have been taken near high-water mark; at Moeraki, on the east coast of Otago, I found it burrowing in the sand in places similar to those where *T. quoyana* is usually found. It closely resembles that species in colour, but may be readily distinguished by the short antenna and the greatly swollen body.

FIG. 13.—Fourth peraeopod of adult male.

In young males the second gnathopoda have the propod small and the palm regularly rounded as in some species of *Orchestia*; in older males the form differs very much at various stages, and it is possible there may be more than one adult form, though I think not. Fig. 13 is taken from a large specimen collected at Moeraki; other specimens have the palm more like that shown by Stebbing (1887, pl. 39, fig. A, gn. 2); it has the basal joint very long, and its anterior surface channelled to fit the large propod when reflexed.

## Talorchestia telluris (Bate). (Figs. 14 to 18.)

*Orchestia telluris* Bate, 1862, p. 20, pl. 3, fig. 6; pl. 4, fig. 4: G. M. Thomson, 1899, p. 200. *Talorchestia telluris* Stebbing, 1906, p. 551 (with synonymy).

*Specific Diagnosis.*—Body rather compressed. Antenna 1 reaching rather beyond penultimate joint of peduncle of antenna 2. Antenna 2 variable, in *first form* short, about as long as head and first segment of peraeon, flagellum rather shorter than peduncle; in *second form* longer, especially in adult males. Gnathopod 1 in male with carpus longer than propod and bearing a small rounded pellucid lobe near middle of its free hind margin, propod with a rather larger lobe at distal angle forming a transverse palm; whole limb rather spinose. Gnathopod 1 in female similar but without the lobes, propod narrowing distally. Gnathopod 2 in the male of two forms. In the *first form* (fig. 16) with propod large, oval, palm oblique, spinose, concave between the base of the finger and an acute

* In Mr. G. M. Thomson's collection are one large female and three smaller ones from Pirates' Bay, Tasmania, which appear to belong to this species, but without a male the identification is somewhat uncertain.

triangular tooth near the middle of palm, not defined, the end passing insensibly into the convex hind margin, finger with concavity near the hinge, then a broad protuberance, extremity curved to fit the end of the palm.

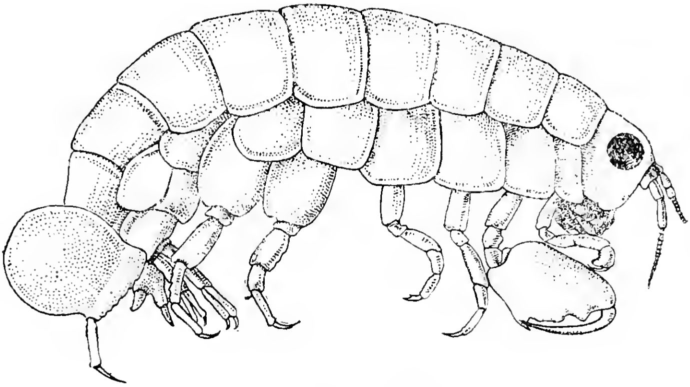

Fig. 14.—*Talorchestia telluris*, male.

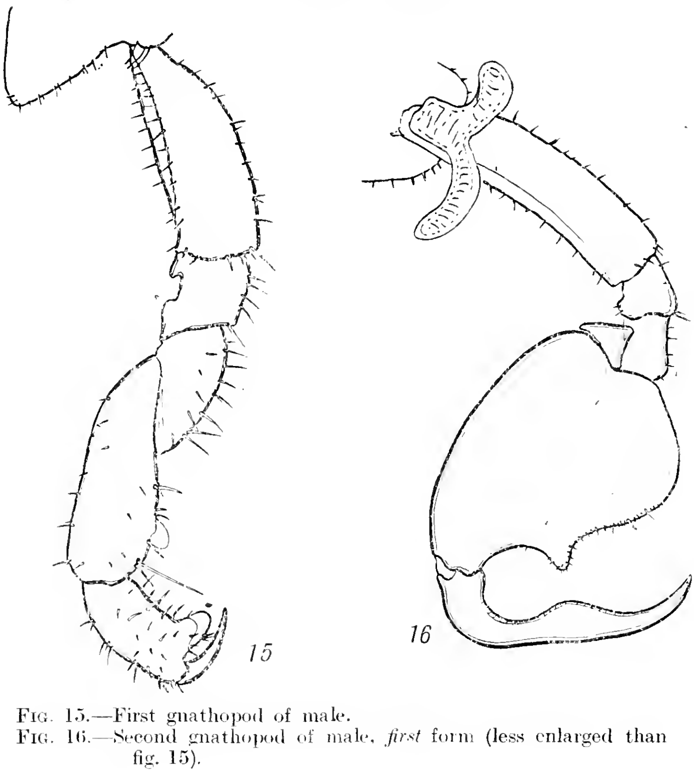


Fig. 15.—First gnathopod of male.
Fig. 16.—Second gnathopod of male, *first* form (less enlarged than fig. 15).

In the *second form* the palm is oblique but well defined by a stout tooth on the outer side, while on the inner side there is a short blunt thumb-like process, the end of the finger fitting in between the two, near the base of the finger the palm bears a rounded spinose process which is followed by a long flat spinose protuberance separated by a concavity from the defining tooth, finger thickened on inner side near the base (fig. 17). Gnathopod 2 in the female normal. Peraeopod 5 in male with merus triangular, widening distally, carpus expanded posteriorly into an enormous oval plate, concave on the inner side (fig. 18).

*Length.*—About 12 mm.

*Occurrence.*—Sandy shores of New Zealand and Chatham Islands, about high-water mark.

*Remarks.*—This species is smaller than the other two, and appears to be less common, though it has been taken at several widely separated places from the North Cape of New Zealand to Stewart Island. In Chatham Islands it seems to be relatively more abundant, as it occurs in most of the few collections I have had from those islands. In a few cases I have taken it not far from the mouth of a fresh-water stream, but this may be purely accidental.

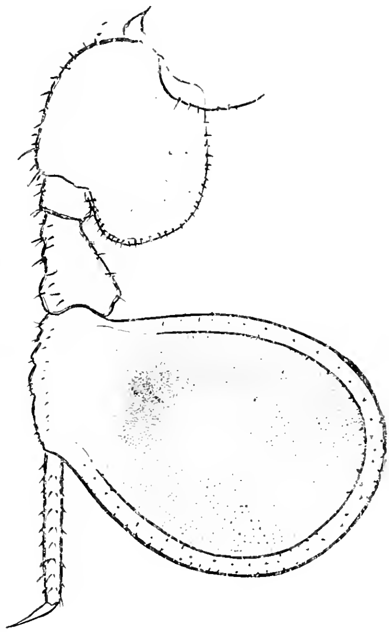

FIG. 17.—Second gnathopod of male, *second* form (less enlarged than fig. 15).

The male can be easily recognized by the extraordinary process on the fifth peraeopod; all stages may be found between a slight flat expansion of the hind margin of the carpus and the huge process shown in fig. 18. A somewhat similar process is found in *Talorchestia scutigerula* (Dana), but in that species it arises as an expansion of the second or basal joint.

I have described this species as having two forms of the male, so far as the second gnathopods are concerned. It is possible, of course, that the second form should be considered a separate species, as its second gnathopod in the male differs very markedly from that of the first form. The animal has, however, the greatly expanded carpus of the fifth peraeopod, and in most other points agrees so closely both in structure and in habits that I prefer to group both forms under the one species. The description and figure of the gnathopod of this second form is taken from a Chatham Island specimen, and apparently all the Chatham Island specimens belong to this form. I have one specimen also, from Ross Beach, Westland, which has the second gnathopod like the Chatham Island form, particularly in the small thumb-like process on the inner side of the defining tooth, but it has the rounded protuberance on the palm near the base of the finger much broader than in the Chatham Island specimens. In the Ross specimen the fifth peraeopod is not fully developed, the carpus being considerably expanded but not having developed into the great oval plate characteristic of the species. In the first gnathopod of the Ross specimen the pellucid lobe on the propod is moderately well defined, but there is no sign of the similar small lobe on the carpus, and apparently this lobe on the carpus and the full expansion of the carpus of the fifth peraeopod are not developed until after the characters of the second gnathopod have been attained. In the Ross specimen the second antenna is much longer than in form 1. or than it is in the Chatham Island specimens of form 2, being longer than the second gnathopod, while in the Chatham Island specimen it is distinctly shorter. It was this difference in the length of the second antenna, combined with the differences in the first and second gnathopods and in the fifth peraeopod, which made me first think that the Ross specimen must be a different species, but comparison with the Chatham Island specimen as above described forced me to the opposite opinion. From the

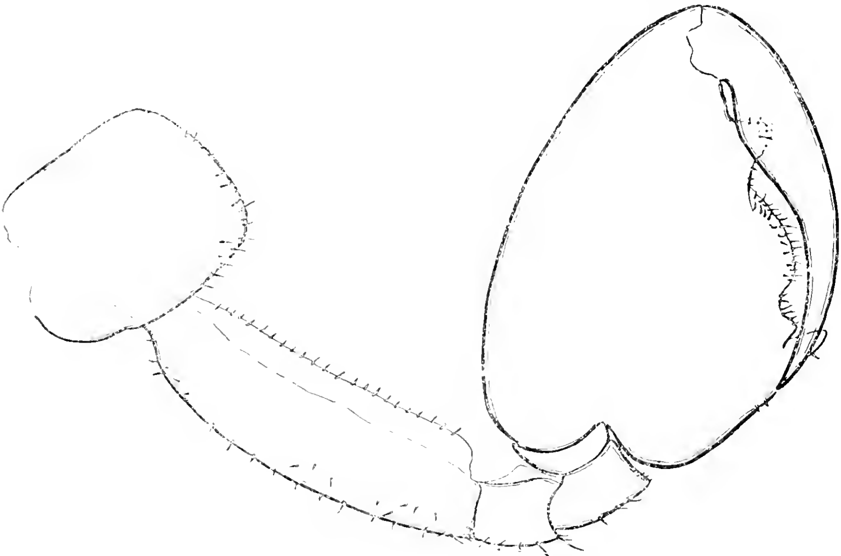

Fig. 18.—Fifth peraeopod of adult male.

Kaiapoi Beach, near the mouth of the Waimakariri, I have several specimens similar to the Ross one, but all more immature and having the special characters of the second gnathopod less marked. I have also one specimen from Waiwera, Auckland, which appears to belong to this form, though the palm of the second gnathopod is not precisely the same as that figured; the rounded spinose process near the base of the finger is present as in form 2, but the palm is without the defining tooth, in this respect resembling form 1; pellucid lobes are present on the carpus and propod of the first gnathopod, and the carpus of the fifth peraeopod is more expanded than in the Ross Beach specimen, while the second antennae are short. This Waiwera specimen thus shows intermediate characters, and affords an additional reason for retaining forms 1 and 2 in the same species.

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## ART. XXI.—*The Lithobiomorpha of New Zealand.*

By GILBERT ARCHEY, M.A., Assistant Curator, Canterbury Museum.

[*Read before the Philosophical Institute of Canterbury, 18th October, 1916; received by Editors, 30th December, 1916; issued separately, 24th August, 1917.*]

THIS paper contains an account of various Lithobiomorpha collected from time to time in different parts of New Zealand. Hitherto only six species of the suborder have been known from this country—*Lithobius argus* Newport, *Henicops maculatus* Newport, *H. impressus* Hutton, *Lamyctes emarginatus* (Newport), *Haaseilla insularis* (Haase), and *Anopsobius neozelanicus* Silvestri. In the following pages three new species of *Lamyctes* are added, including one from the Kermadec Islands and another from the Chatham Islands: the genus *Paralamyctes*, hitherto unknown in New Zealand, is represented by two new species; and a new genus, *Wailamyctes*, with two new species, is described from specimens collected in Canterbury and Stewart Island.

### KEY TO THE FAMILIES.

1. Sternite of prehensorial segment absent, labrum tridentate, no tibial spurs .. .. .. .. .. .. .. Lithobiidae.
2. Sternite of prehensorial segment well marked, labrum unidentate, tibial spurs present on most of the legs.
   *a*. Spiracles on first pedigerous segment .. .. .. Henicopidae.
   $a^1$. No spiracles on the first pedigerous segment, coxal pores on the last two segments .. .. .. Anopsobiidae.

The family Zygethobiidae (Chamberlain), which is not represented in New Zealand, stands near the Anopsobiidae, from which it differs in having coxal pores on the last four segments.

## Family LITHOBIIDAE.

### Genus Lithobius Leach, 1815.

*Lithobius* Leach, *Trans. Linn. Soc.*, vol. 11, p. 381 (1815). Hutton, *Index Faunae Novae Zealandiae*, p. 235 (1904).

Head with numerous ocelli, labrum tridentate. Sternite of prehensorial segment absent. Legs without a tibial spur.

Type: *L. forficatus* Leach.

### 1. **Lithobius argus** Newport, 1845.

*Lithobius argus* Newport, *Trans. Linn. Soc.*, vol. 19, p. 369 (1845). Hutton. *Index Faunae Novae Zealandiae*, p. 235 (1904).

"Ferrugineus, capite parvo subconvexo, antennis pilosis, ocellis parvis brunneis utrinque 28–30, labio angustato emarginato polito: denticulis 10 nigris. Long. unc. 9/10."—(Newport.)

"Hab. in Nova Zelandia, prope Wellington. (v. in Mus. D. Hope.)"

I have not seen any specimens of this species, or of any other species of the genus Newport's description is the only account of its occurrence.

## Family HENICOPIDAE.

Key to the Genera.

| | |
|---|---|
| 1. First to 13th legs with tarsi triarticulate, 14th and 15th pairs with tarsi 6-jointed .. .. .. .. | *Henicops* Newport. |
| 2. First to 12th legs with tarsi uniarticulate, 13th to 15th legs with tarsi biarticulate. | |
| *a*. Prosternum with dental edges rounded and narrow, teeth 1.2 + 2.1 .. .. .. .. | *Lamyctes* Meinert. |
| *a*¹. Prosternum with dental edges straight and broad, teeth 4 + 4 to 6 + 6 .. .. .. | *Wailamyctes* nov. |
| 3. All the legs with tarsi biarticulate .. .. .. | *Paralamyctes* Pocock. |
| 4. Coxal pores reduced to one on each side; 15th pair of legs much shorter than 14th and without protarsal segment .. | *Haaseilla* Pocock. |

### Genus Henicops Newport, 1845.

*Henicops* Newport, *Trans. Linn. Soc.*, vol. 19, p. 372 (1845). Hutton, *Ann. Mag. Nat. Hist.*, 4th ser., vol. 20, p. 114 (1877); id., *Trans. N.Z. Inst.*, vol. 10, p. 288 (1878). Pocock, *Ann. Mag. Nat. Hist.*, 7th ser., vol. 8, p. 453 (1901). Hutton, *Index Faunae Novae Zealandiae*, p. 235 (1904).

Head with one pair of eyes. Antennae with from 30 to 37 joints. Tergites (fig. 1) in the anterior region with posterior angles rounded, and slightly emarginate, becoming increasingly emarginate, and with the angles less rounded posteriorly. Mandibles (figs. 2 and 2*a*) with complex teeth, a set of pectinate processes above the teeth and a fringe of fine hairs below them. Labrum (fig. 3) unidentate, inner edges of lateral pieces fringed with small hairs. First pair of maxillae (figs. 4 and 4*a*): inner rami separated to a considerable extent, provided with plumose and simple hairs; outer rami with plumose hairs along the inner edge, and simple hairs elsewhere. Prosternum narrowed anteriorly, teeth distinct. Stigmata on the 1st, 3rd, 5th, 8th, 10th, 12th, and 14th segments. Legs of the 1st to 13th pairs with tarsi biarticulate: of the 14th and 15th pairs with protarsus divided into 2 segments and tarsus into 4. Tibial spur on legs 1 to 14.

Type: *H. maculatus* Newport.

Chamberlain (*Bull. Mus. Comp. Zool. Harvard*, vol. 57, No. 1, p. 4, 1912) has given the absence of plumose hairs on the inner ramus of the first pair of maxillae as one of the characters distinguishing the Henicopidae from

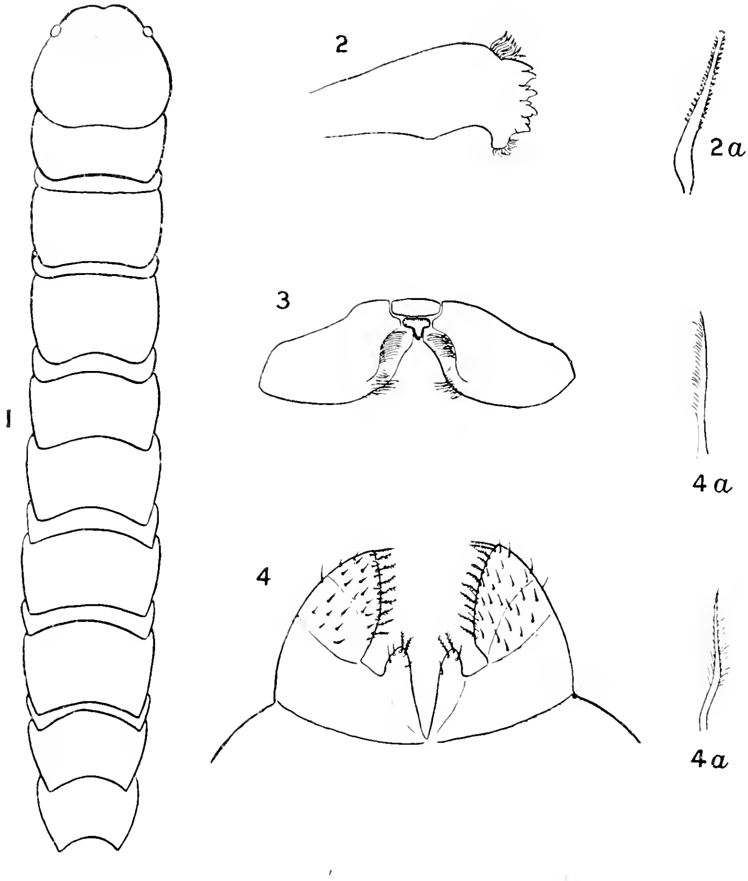



FIG. 1.—Dorsal view of body.
FIG. 2.—Mandible.
FIG. 2*a*.—Pectinate process of mandible.
FIG. 3.—Labrum.
FIG. 4.—First pair of maxillae.
FIG. 4*a*.—Hairs on outer rami.

the Lithobiidae. In all the specimens which I have examined of *H. maculatus* there are two or three plumose hairs as well as simple hairs on the inner ramus. The presence of these plumose hairs may perhaps be used to distinguish *Henicops* from the other genera of the family.

1. **Henicops maculata** Newport, 1845. (**Figs.** 1 to 5.)

*Henicops maculata* Newport, *Trans. Linn. Soc.*, vol. 19, p. 372, pl. 33, fig. 37; pl. 40, fig. 3 (1845): id., *Cat. Myr. Brit. Mus.*, p. 22. Haase, *Die indisch-austral. Chilopoden. Abhand. Dresden Mus.*, No. 5, p. 36 (1887). Pocock, *Ann. Mag. Nat. Hist.*, 6th ser., vol. 8, p. 154 (1891): id., 6th ser., vol. 11, p. 125 (1893); id., 7th ser., vol. 8, p. 453 (1901). Hutton, *Index Faunae Novae Zealandiae*, p. 235 (1904).

Colour (in spirit) above yellowish-brown, each tergum with an irregular broad dark edging and a median broad dark band. The general appearance of the dorsal surface is thus a light groundwork with three longitudinal dark bands. The head is also dark around the margin.

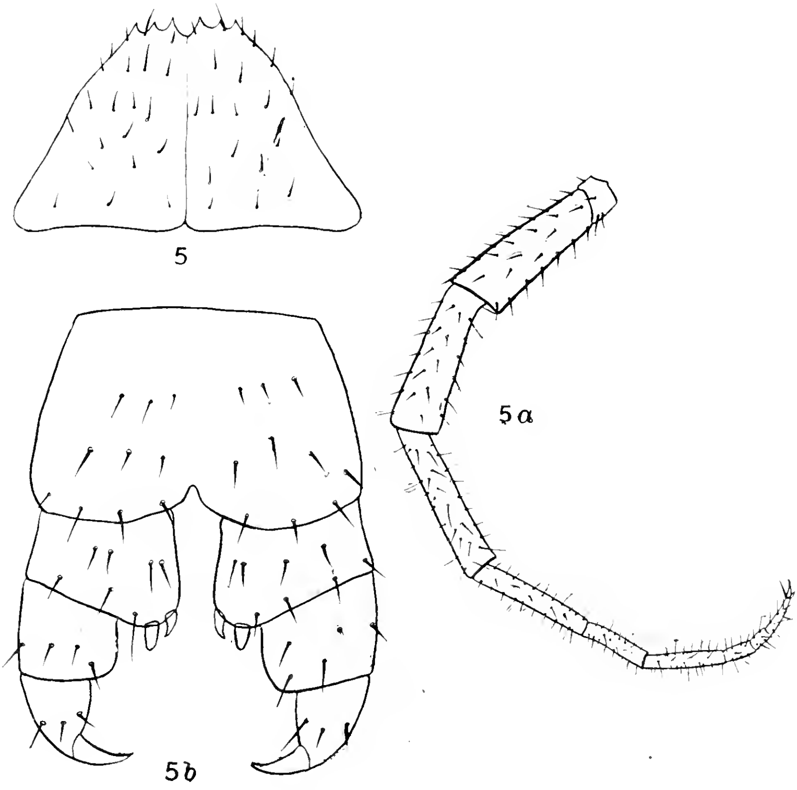



Fig. 5.—Prosternum. Fig. 5*a*.—15th leg. Fig. 5*b*.—Gonopods of ♀.

Antennae: the joints range in number from 30 to 37, varying evenly around 34. Prosternum (fig. 5) with praecoxal processes rounded anteriorly, teeth uniformly 3 + 3. Tergites anteriorly with rounded angles and with the posterior borders slightly emarginate, the emargination and the acuteness of the angles increasing posteriorly. Tibial spur on legs 1 to 14. Legs long and hairy, the tarsi with 2 + 2 spinules beneath, set at the distal ends of the subsegments; the 15th pair (fig. 5a) much the longest. Coxal pores small, varying in number, usually 4, 5, 5, 5. Gonopods of ♀ (fig. 5b) with the outer basal spur larger and blunt, and the inner slightly curved and sharper; terminal claw curved.

Length 15 mm.

*Loc.*—Mount Algidus, Mount Dick, Ben Lomond, Hollyford River (T. Hall); Wooded Peak, Nelson (F. G. Gibbs); Hawke's Bay (W. W. Smith); Lake Rotoiti, Nelson, and Cass, Canterbury (G. A.).

*Hab.*—Australia and New Zealand.

### 2. Henicops impressus Hutton, 1877.

*Henicops impressus* Hutton, *Ann. Mag. Nat. Hist.*, 4th ser., vol. 20, p. 114 (1877); id., *Trans. N.Z. Inst.*, vol. 10, p. 288 (1878). Pocock, *Ann. Mag. Nat. Hist.*, 7th ser., vol. 8, p. 453 (1901). Hutton, *Index Faunae Novae Zealandiae*, p. 235 (1904).

"Head broadly ovate, narrowed towards the front, with an elevated margin behind, and an impressed curved transverse line, convex backward, on the top before the eyes; space between the antennae concave. Dental lamina with eight acute teeth. Antennae tomentose, with 34–36 joints. Segments 15 (without the head), alternately large and small; but the small segment between the 7th and 8th, and between the 14th and 15th, absent; each segment with a raised margin. Above olive-brown, generally more or less marbled with black; legs pale-bluish; feet yellow. Under-surface of head and region of anus reddish. Some scattered hairs on the legs. Length 0·6 in.

"*Hab.*—Dunedin and Queenstown.

"It is astonishing with what rapidity this creature runs."—(Hutton.)

The type of this species has been lost, and I have not seen any specimens corresponding exactly with the above description. Hutton does not mention any characters at present regarded as critical which would distinguish it from *H. maculatus*, except the number of praecoxal teeth. I take Hutton's "eight acute teeth" to be equivalent to 4 + 4. From the specimens I have examined of *H. maculatus*, it appears to have 3 + 3 teeth uniformly, and so, in the absence of definite information, I do not think it advisable to combine *H. maculatus* and *H. impressus* at present.

### Genus LAMYCTES Meinert, 1868.

*Lamyctes* Meinert, *Nat. Tidsskr.*, vol. 5, p. 226 (1868). *Henicops* Latzel, *Die Myr. öst-ung. Mon.*, vol. 5, 1, p. 132 (1880). *Lamyctes* Pocock, *Ann. Mag. Nat. Hist.*, 7th ser., vol. 8, p. 449 (1901). Hutton, *Index Faunae Novae Zealandiae*, p. 235 (1904). Chamberlain, *Bull. Mus. Comp. Zool. Harvard*, vol. 57, No. 1, p. 5 (1912).

Labrum unidentate. Inner branch of first pair of maxillae with simple hairs only, outer branch with simple and plumose hairs. One pair of eyes present. Antennae short, with 24 to 31 joints. Prosternum narrowed anteriorly, and with rounded dental edges, teeth commonly 1.2 + 2.1. Dorsal plates with posterior angles rounded, and with only slight posterior emarginations. Spiracles on segments 1, 3, 5, 8, 10, 12, 14. Tarsi of 1st to 12th legs entire, of 13th to 15th legs biarticulate. Tibial spur on legs 1 to 11 or 1 to 12. Coxal pores on the last four pairs of legs.

Type: *L. fulvicornis* Meinert.

### Key to New Zealand Species.

1. Tibial spur on legs 1 to 11.
   - *a.* Colour dark brown, coxal pores 3, 3, 3, 3 .. 1. *L. emarginatus* (Newp.).
   - *b.* Colour light brown, coxal pores 2, 2, 2, 2. .. 2. *L. neozelanicus* sp. n.
2. Tibial spur on legs 1 to 12.
   - *c.* Coxal pores small, 1st tarsal joint of 15th leg 7 times as long as wide .. .. .. 3. *L. chathamensis* sp. n.
   - *d.* Coxal pores large, 1st tarsal joint of 15th leg 9 times as long as wide .. .. .. 4. *L. kermadecensis* sp. n.

### 1. Lamyctes emarginatus (Newport), 1844. (Figs. 6 to 9.)

*Lithobius emarginatus* Newport, *Ann. Mag. Nat. Hist.*, vol. 13, p. 96 (1844). *Henicops emarginatus* Newport, *Trans. Linn. Soc.*, vol. 19, p. 372 (1845). Pocock, *Ann. Mag. Nat. Hist.*, 6th ser., vol. 8, p. 154 (1891). *Lamyctes emarginatus* Pocock, *Ann. Mag. Nat. Hist.*, 7th ser., vol. 8, p. 450 (1901). Hutton, *Index Faunae Novae Zealandiae*, p. 235, (1904).

Colour dark purple-brown, in spirit reddish-brown.

Antennae 25 joints, varying. Prosternum (fig. 6) 1·5 times as wide as long; teeth 1.2 + 2.1, the outer tooth very small. Coxal pores 3, 3, 3, 3.

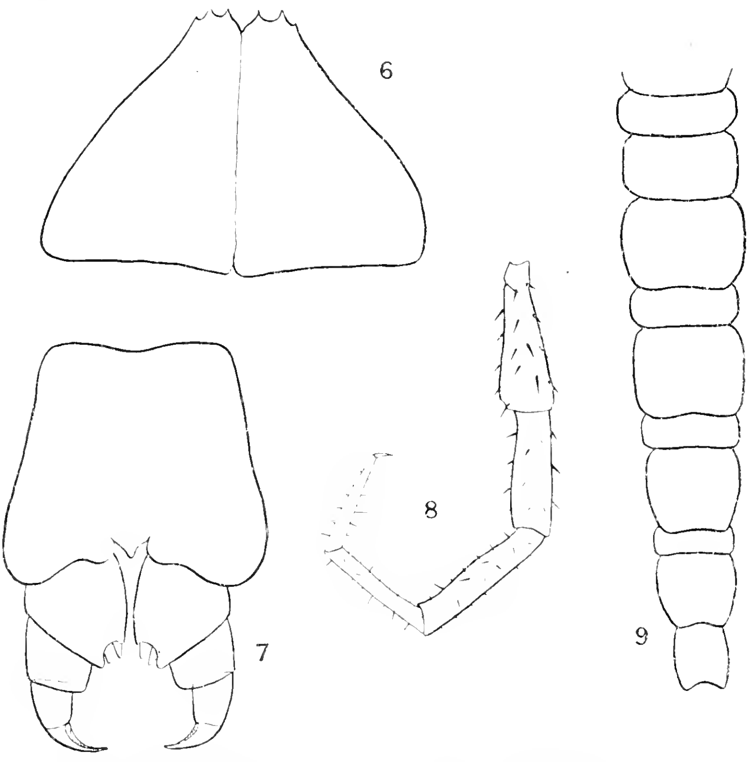


Fig. 6.—Prosternum.
Fig. 7.—Gonopods of ♀.
Fig. 8.—15th leg.
Fig. 9.—Posterior tergites.

Gonopods of ♀ (fig. 7) with moderately sharp basal spurs and curved sharp terminal claw. First tarsal joint of 15th leg (fig. 8) 6·6 times longer than wide; femur 1·6 times as wide as tibia. Tibial spur on legs 1 to 11. Tergites (fig. 9) with anterior and posterior angles all rounded: a slight posterior emargination is evident on the 8th tergite, increasing in depth in posterior segments.

Length 9 mm.

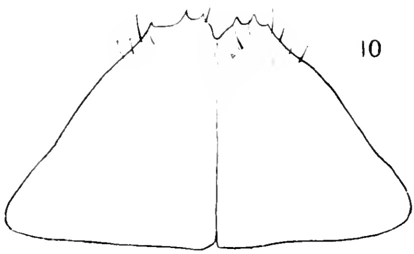
*Loc.*—Riccarton, Christchurch (G. A.).

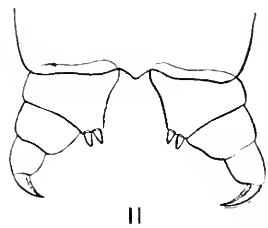
*Note.*—I have identified the specimens included under this name on the colour alone. The type specimen appears to have been lost, and the character used by Newport to define the species—*i.e.*, the dentition of the prosternum—is common to many species of the genus, if, indeed, it be not a generic character. Newport examined a preserved specimen when he described *L. emarginatus*, and the specimens here included under this name were the only preserved ones in my collection which retained the ferruginous colour. The determination is as unsatisfactory as can be, and can only be regarded as a compromise until the type is found or the matter is otherwise settled.

2. **Lamyctes neozelanicus** sp. n. (Figs. 10 to 12.)

Colour light brown, in spirit yellowish-brown.

Antennae 25 joints. Prosternum (fig. 10) 1·73 times as wide as long; teeth 1.2 + 2.1, arranged as in the preceding species. Coxal pores 2, 2, 2, 2. Gonopods of ♀ (fig. 11) with straight blunt basal spurs, and curved



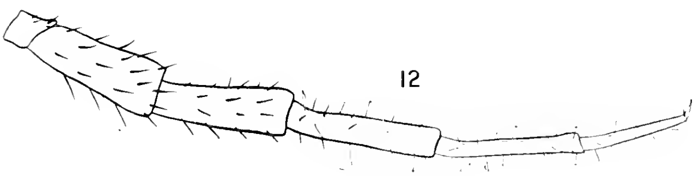




FIG. 10.—Prosternum. FIG. 11.—Gonopods of ♀. FIG. 12.—15th leg.

sharp terminal claw. First tarsal joint of 15th leg (fig. 12) 8 times longer than wide: femur 1·8 times as wide as tibia. Tibial spur on legs 1 to 11. Tergites as in *L. emarginatus*.

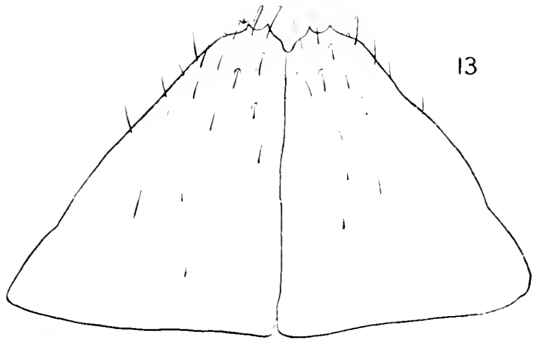
Length 9 mm.

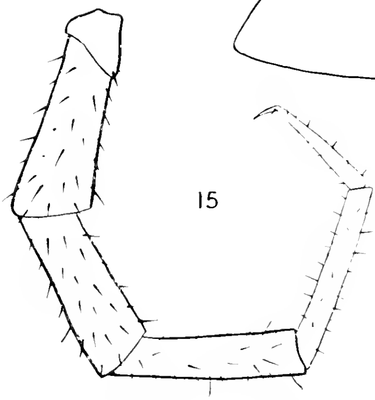
*Loc.*—Waipara, Canterbury (G. Brittin).

3. **Lamyctes chathamensis** sp. n. (Figs. 13 to 15.)

Colour (in spirit) light brown, the antennae a darker reddish-brown.

Antennae 27 joints. Prosternum (fig. 13) 1·7 times as wide as long, well supplied with hairs; teeth 1.2 + 2.1, the outer tooth exceedingly small.



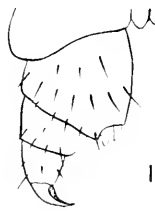




Fig. 13.—Prosternum. Fig. 14.—Gonopod of ♀. Fig. 15.—15th leg.

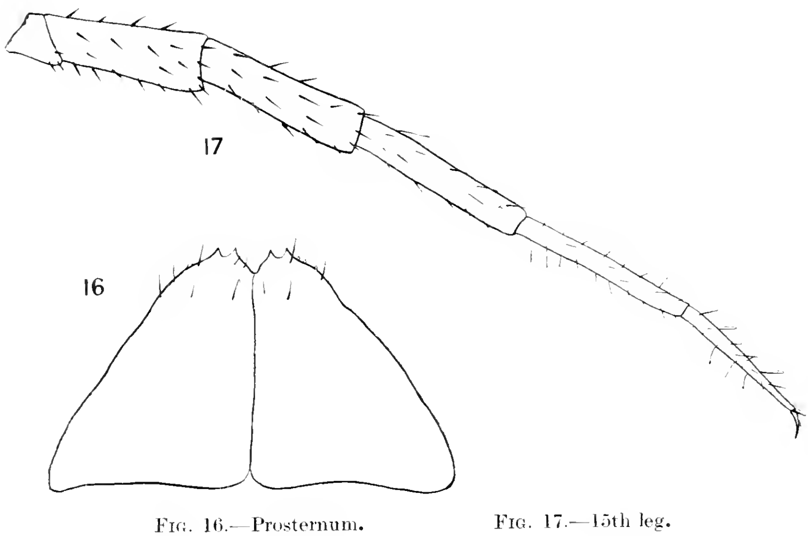



Fig. 16.—Prosternum. Fig. 17.—15th leg.

Coxal pores small, 3, 3, 3, 2, or 2, 3, 3, 3. Gonopods of ♀ (fig. 14) with inner basal spurs sharp, and slightly shorter than the outer, which are blunt; terminal claw curved and sharp. First tarsal joint of 15th leg (fig. 15) 7·1 times as long as wide: femur 1·7 times as wide as tibia. Tibial spur on legs 1 to 12. Tergites with a slight posterior emargination on 3rd and 5th segments, otherwise as in *L. emarginatus*.

Length 10 mm.

*Loc.*—Chatham Islands (Miss S. D. Shand).

### 4. **Lamyctes kermadecensis** sp. n. (Figs. 16 and 17.)

Colour (in spirit) dark brown.

Antennae broken. Prosternum (fig. 16) 1·72 times as wide as long, very sparsely hairy: teeth 1.2 + 2.3 (the usual arrangement, with the addition of two very small teeth on the right side). Coxal pores large, 3, 3, 3, 3. Gonopods of ♀ as in *L. chathamensis*. First tarsal joint of 15th leg (fig. 17) 9 times as long as wide: femur 1·77 times as wide as tibia. Tergites as in *L. emarginatus*.

Length 10 mm.

*Loc.*—Sunday Island (Kermadec Group).

### Genus WAILAMYCTES nov.

Fifteen leg-bearing segments. Head with or without eyes. Labrum (fig. 18) unidentate, the lateral pieces provided with a fringe of hairs.

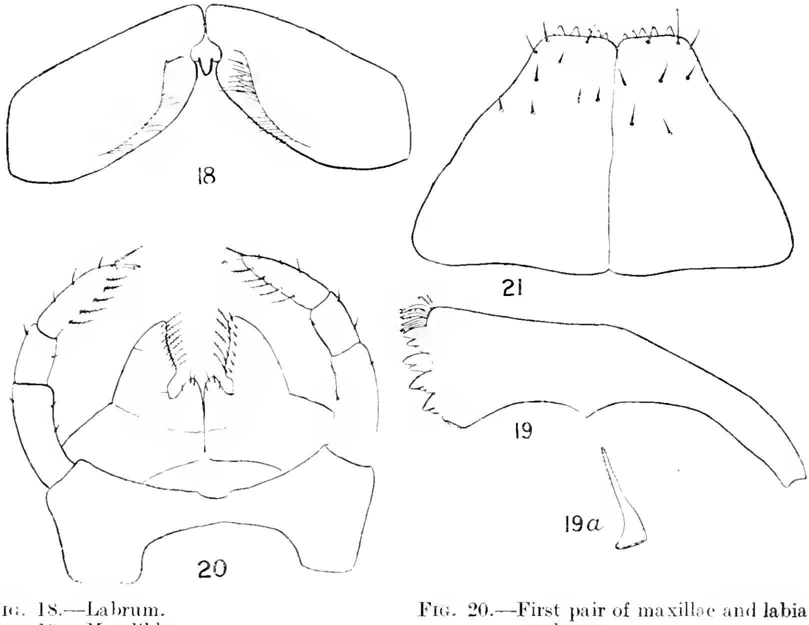



FIG. 18.—Labrum.
FIG. 19.—Mandible.
FIG. 19*a*.—Plumose process on mandible.
FIG. 20.—First pair of maxillae and labial palp.
FIG. 21.—Prosternum.

Mandible (figs. 19 and 19*a*) with four complex teeth, a set of plumose processes above them, and a fringe of smaller simple hairs below. First pair of maxillae (fig. 20): inner ramus small, with a few simple hairs; outer ramus provided on the inner edge with a row of plumose hairs, and with numerous simple hairs elsewhere. Labial palp 3-jointed, terminal segment with plumose hairs on the inner side, terminal claw complex. Prosternum (fig. 21) produced forward, narrowing slightly, with straight dental edges, separated by a median sulcus and armed with from 4 + 4 to 6 + 6 even-sized teeth. Tergal plates with angles distinctly rounded and posterior margins straight, except in the posterior segments, where there is a slight emargination. Spiracles as in *Lamyctes.* First to 12th pairs of legs with tarsi entire, 13th to 15th pairs with tarsi biarticulate. Tibial spur present 1st to 13th legs. Coxal pores on the last four pairs of legs.

Type: *Wailamyctes trailli* sp. n.

KEY TO THE SPECIES.

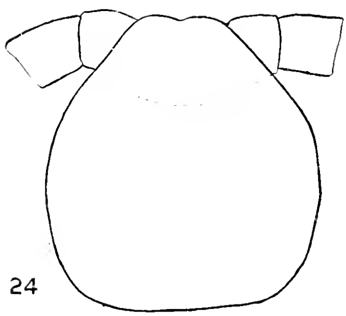
| | |
|---|---|
| Eyes absent .. .. .. .. .. | 1. *W. trailli* sp. n. |
| Eyes present .. .. .. .. .. | 2. *W. halli* sp. n. |

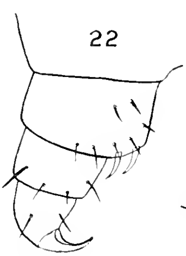
The two species given in the key are in all respects, except in the presence and absence of eyes, so much alike that I have no hesitation in assigning them to the same genus. Both differ from *Lamyctinus* Silvestri (*Boll. Lab. Zool., R. Scuola Superiore d'Agric., Portici*, vol. 4, p. 38, 1909) in the presence of tibial spurs on the 13th leg, and in the form of the prosternum, which in *Lamyctinus* is of the usual form found in *Lamyctes.*

### 1. Wailamyctes trailli sp. n. (Figs. 18 to 24.)

Colour (in spirit) light yellowish-brown.

Head (fig. 24) without eyes. Antennae with 21 joints. Prosternum (fig. 21) 1·45 times wider than long, dental edges straight, teeth 4 + 4 to 6 + 6. Coxal pores 2, 2, 2, 2. Gonopods of ♀ (fig. 22) with basal spurs and



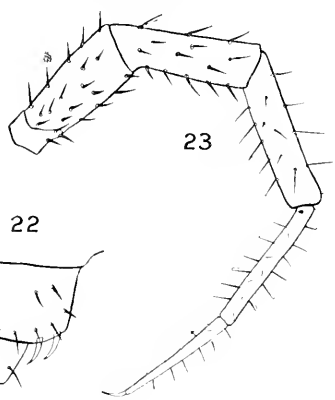




FIG. 22.—Gonopods of ♀. FIG. 23.—15th leg. FIG. 24.—Head.

claws sharp and curved. First tarsal joint of 15th leg (fig. 23) 8·8 times longer than wide; femur 1·68 times as wide as tibia. Tibial spurs on legs 1 to 13.

Length 9 mm.

*Loc.*—Stewart Island (Walter Traill) and Waipara (G. Brittin).

2. **Wailamyctes halli** sp. n. (Figs. 25 to 27.)

Colour (in spirit) brown.

Head (fig. 25) with a pair of eyes. Antennae with 19 joints. Prosternum (fig. 26) 1·72 times as wide as long, teeth 4 + 4. Coxal pores

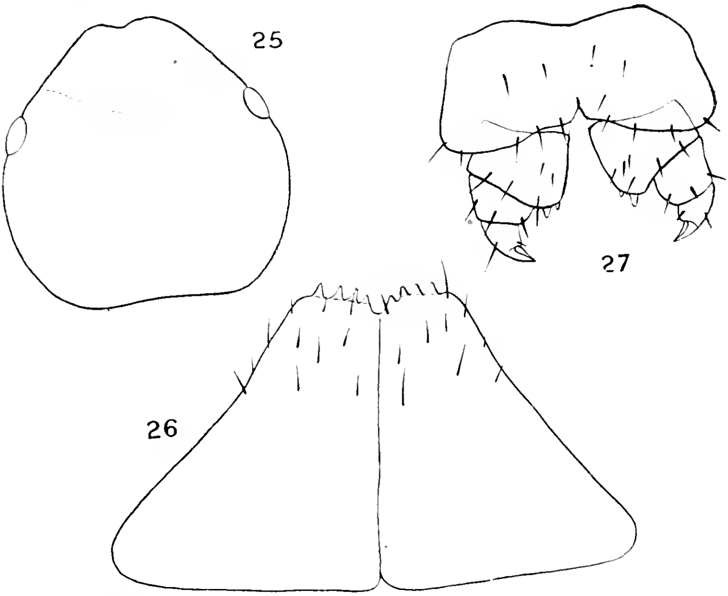



FIG. 25.—Head. FIG. 26.—Prosternum. FIG. 27.—Gonopods of ♀.

2, 2, 2, 2. Gonopods of ♀ (fig. 27) with basal spurs and claw blunt and straight. Tibial spurs on legs 1 to 13. 15th pair of legs unknown.

Length 8 mm.

*Loc.*—Mount Algidus, Rakaia Gorge (T. Hall).

### Genus PARALAMYCTES Pocock, 1901.

*Paralamyctes* Pocock. *Ann. Mag. Nat. Hist.*, 7th ser., vol. 8, p. 450 (1901). Verhoeff, *Bronn's Klass. und Ord. Tierreichs*. Myriapoda, p. 238 (1907).

Fifteen pedigerous segments, with tergites either simply rounded behind, or with produced posterior angles on some segments. Spiracles on segments 1, 3, 5, 8, 10, 12, 14. A pair of eyes on the head (fig. 28). Antennal segments 19 to 43. Labrum (figs. 32 and 32*a*) unidentate, with a fringe of plumose hairs on the lateral pieces. Teeth on prosternum even-sized, 2 + 2 to 10 + 10. Mandible (fig. 29) with complex cutting-teeth, laciniate processes, and a row of plumose hairs on the inner side. First pair of maxillae (fig. 30) with plumose hairs on the outer ramus, and simple hairs on the inner. Labial palp (fig. 31) with plumose and simple hairs. All the tarsi biarticulate. Tibial spur on legs 1 to 13. Coxal pores on the last 4 pairs of legs. Gonopods 3-jointed.

Type: *P. spenceri* Pocock.

KEY TO NEW ZEALAND SPECIES.

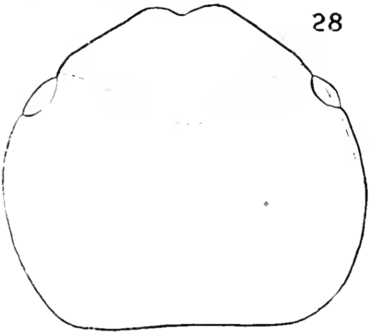
*a.* Larger, prosternum with 10 + 10 teeth .. 1. *P. validus* sp. n.
*b.* Smaller, prosternum with 5 + 5 teeth.. .. 2. *P. dubius* sp. n.

### 1. Paralamyctes validus sp. n. (Figs. 28 to 35.)

Colour (in spirit) dull brown, with richer brown edging to the tergites.

Antennae with 25 to 28 joints, the distal joints long and narrow. A pair of eyes present on the head (fig. 28). Prosternum (fig. 33) with broad dental edges, armed with 8 + 8 main teeth, with two or three smaller teeth

28



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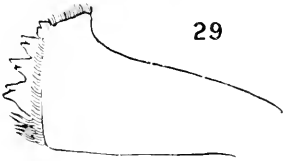

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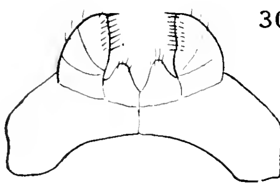

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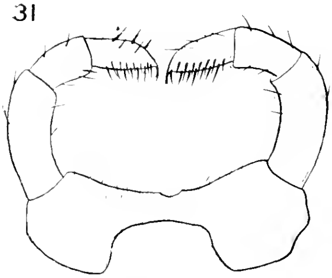

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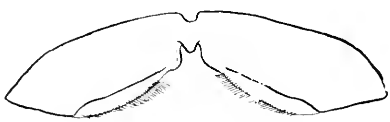

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Fig. 28.—Head.
Fig. 29.—Mandible.
Fig. 30.—First pair of maxillae.
Fig. 31.—Labial palp.
Fig. 32.—Labrum.
Fig. 32a.—Plumose hair of labrum.

interposed between the main teeth, making 10 + 10 or 11 + 11 in all. Gonopods of ♀ (fig. 34) with strong blunt basal spurs, and moderately sharp terminal claw. Tibial spur on legs 1 to 13. Fifteenth pair of legs (fig. 35) with 1st tarsal joint 7 times as long as broad; femur 1·9 times as wide as tibia. Coxal pores 4, 4, 4, 5.

Length 15 mm.

*Loc.*—Ohikaka (W. R. Gray); Ohakune (J. B. Mayne).

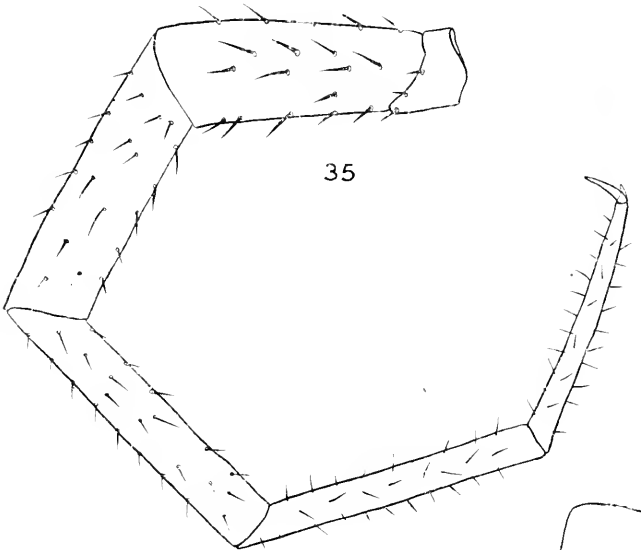
### 2. Paralamyctes dubius sp. n. (Fig. 36.)

Colour (in spirit) brown.

Antennae broken. A single pair of eyes on the head. Prosternum (fig. 36) very broad, shortly truncated anteriorly, dental edges not separated but forming a straight line; teeth 5 + 5. Coxal pores 2, 2, 2, 2. Tarsi of legs 1 to 11 biarticulated, other legs unknown. Tibial spur on legs 1 to 11, others unknown.

*Loc.*—Rhodes's Bush, Port Hills (G. A.).

I have described this species from a single mutilated specimen, but the distinctive character of the prosternum is sufficient to distinguish it from the other species.



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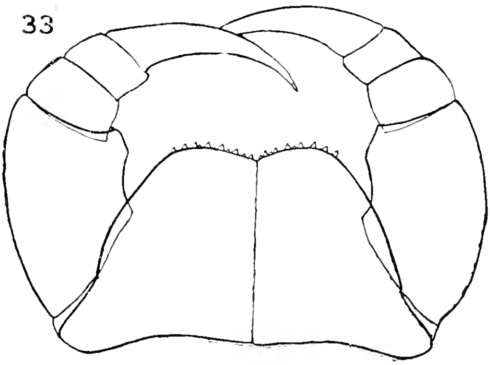

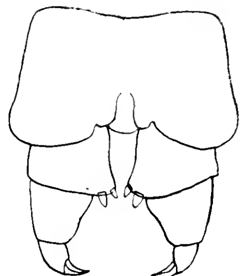

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FIG. 33.—Prosternum. FIG. 34.—Gonopods of ♀. FIG. 35.—15th leg.

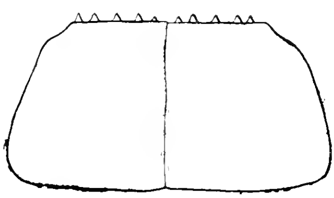

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FIG. 36.—Prosternum.

### Genus Haaseilla Pocock, 1901.

*Henicops* Haase, *Abh. Zool. Mus. Dresden*, No. 5, p. 36, pl. 3, fig. 41 (1887). *Haaseilla* Pocock, *Ann. Mag. Nat. Hist.*, 7th ser., vol. 8, p. 449 (1901). Verhoeff, *Bronn's Klass. und Ord. Tierreichs*, Myriapoda, p. 237 (1907).

Coxal teeth 5 + 5. Coxal pores reduced to one on each side. Fifteenth pair of legs much shorter than 14th, and without protarsal segment.

#### 1. Haaseilla insularis (Haase), 1887.

*Henicops insularis* Haase, *Abh. Zool. Mus. Dresden*, No. 5, p. 36, pl. 3, fig. 41 (1887). *Haaseilla insularis* Pocock, *Ann. Mag. Nat. Hist.*, 7th ser., vol. 8, p. 449 (1901).

*Loc.*—Auckland.

As I have not had access to Haase's original paper, and have not seen any specimens of this species, I cannot add anything further to the above description of the genus.

## Family ANOPSOBIIDAE.

### Genus Anopsobius Silvestri, 1899.

*Anopsobius* Silvestri, *Rev. Chilena Hist. Nat.*, v, 3, p. 143 (1889); id. (descr. emend.), *Rendiconti della R. Accademia dei Lincei*, vol. 18, ser. 5, 1st sem., fasc. 6, p. 750 (1909). Attems, *Die Fauna Sudwest-Australiens*, Myriapoda, p. 154 (1911).

Body similar to the Henicopinae in appearance, and with the same number of segments. Spiracles on segments 3, 5, 8, 10, 12, and 14. Eyes absent. Antennae moniliform. Labrum (fig. 37) free, with median sulcus, unidentate. Mandible (fig. 38) with toothed blade, provided with small laciniate processes. First pair of maxillae (fig. 39) triarticulate, with plumose and simple hairs on the outer rami, and with simple hairs only on the inner rami. Toxicognaths with coxae much produced, dental edges straight and inclined inwards. Tibial spur on legs 1 to 12. Tarsi of the 1st to 12th legs uniarticulate, of the 13th to 15th biarticulate. Coxal pores (fig. 40) on the last two pairs of legs. Coxae of the last pair of legs (fig. 40) and, to a less extent, of the penultimate pair, produced infero-posteriorly into an acute tooth.

#### 1. Anopsobius neozelanicus Silvestri, 1909. (Figs. 37 to 46.)

*Anopsobius neozelanicus* Silvestri, *Contrib. conosc. Chilop.*, iii, Descr. di alcuni generi e specie di Henicopidae, Portici, p. 45 (1909).

Colour pale yellowish-brown.

Antennae (fig. 42) with 15 joints, provided with numerous bristles. Prosternum (fig. 41) with 5 + 5 teeth, dental edges inclined inwards. Coxal pores 2, 2. Gonopods of ♀ (fig. 43) with two stout basal spurs, and strong sharp curved terminal claw. First pair of maxillae (fig. 39) with simple hairs on the inner rami, and with simple and plumose hairs on the outer. Last pair of legs (figs. 44 and 44*a*) with a small inferior spine on the 2nd joint, and a large sharp inferior spine situated anteriorly on the 3rd joint. Penultimate legs with a sharp spine (smaller than on the last pair) on the 3rd joint. Terminal claw of the last pair with a small hair, and one accessory claw, the other legs (fig. 45) with a simple hair and two accessory claws.

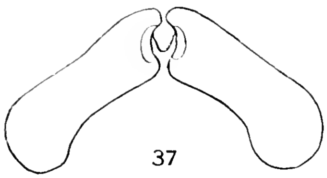


FIG. 37.—Labrum.

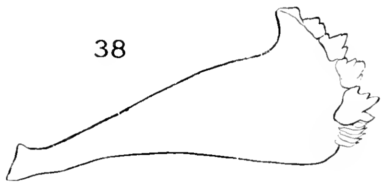


FIG. 38.—Mandible.

*Loc.*—Ben Lomond, Mount Algidus, the Remarkables, and Otarama (T. Hall); Waipara (G. Brittin); Cass, and Port Hills, Christchurch (G. A.); and " Wellington et Hokianga (W. W. Smith) " (Silvestri).

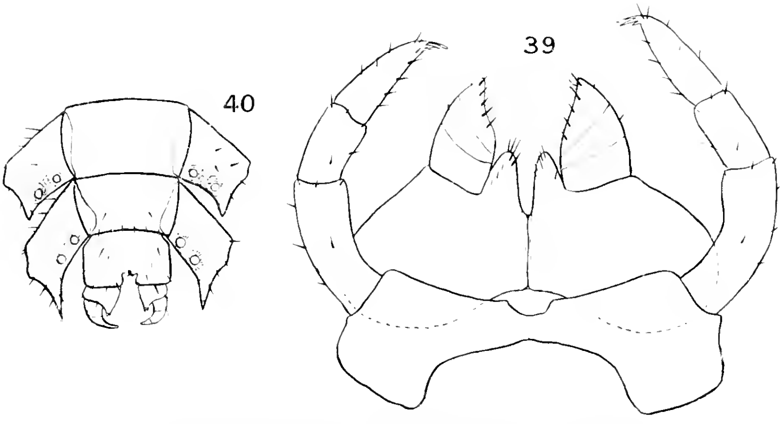


FIG. 39.—First pair of maxillae, and labial palp.
FIG. 40.—Last two body segments.

A few collecting notes may perhaps be added here. *Henicops maculatus* was found only under stones on a hillside, and not in the bush. It runs with amazing speed, so much so that it was usually necessary to obtain the assistance of a friend, who would turn the stone over while the collector concentrated his attention upon the swiftly disappearing centipede. This recalls the remark of Hutton upon the speed of *H. impressus.* The species of *Lamyctes* were generally found under the stones or logs in the bush, although the specimens of *L. emarginatus* all came from my garden at Riccarton, and were found under any board which had been left lying on the ground for a week or two. These centipedes made use of a subterfuge in attempting to escape. They would rush under the nearest leaf or piece of bark, with all the appearance of intending to go as deep as possible; but instead of doing this they curled up at once under the leaf, and one's hurried digging usually gave them a good chance of escape, until the trick was discovered. *Anopsobius neozelanicus* is much smaller than the other centipedes, and moves comparatively slowly. It was found only at the

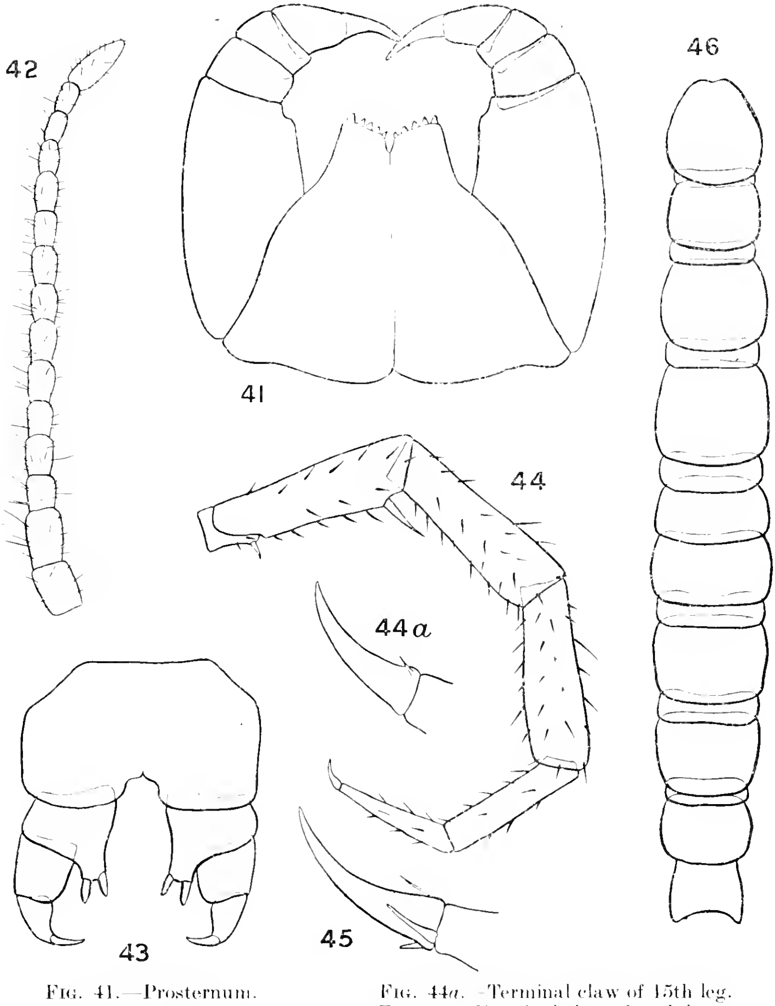


FIG. 41.—Prosternum.
FIG. 42.—Antennae.
FIG. 43.—Gonopods of ♀.
FIG. 44.—15th leg.
FIG. 44a.—Terminal claw of 15th leg.
FIG. 45.—Terminal claw of 14th leg.
FIG. 46.—Dorsal view of body.

edge of the bush, never far in, and never outside altogether. Its habit when disturbed varies: sometimes it will feign death, and at other times it will run about wildly in every direction in its attempts to escape

## ART. XXII.—*The Occurrence in New Zealand of* Craterostigmus tasmanianus *Pocock (Chilopoda).*

By GILBERT ARCHEY, M.A., Assistant Curator, Canterbury Museum.

[*Read before the Philosophical Institute of Canterbury, 7th June, 1916; received by Editors, 30th December, 1916; issued separately, 24th August, 1917.*]

THE genus *Craterostigmus* has hitherto been known from only two specimens, collected on the summit of Mount Rumney, Tasmania, in 1892, by Mr. G. M. Thomson, of Dunedin. It was described in 1902 by Pocock,* who pointed out its great importance, in that it occupies an intermediate position between the Scolopendromorpha and the Lithobiomorpha. The former have 21 body-segments, each with tergum, sternum, and a pair of legs; the latter have only 15 of such segments. *Craterostigmus*, however, has 21 terga, but only 15 sterna and 15 pairs of legs. Certain other characters show the relationship of the genus to one or other of the groups Lithobiomorpha, Scolopendromorpha, and Geophilomorpha; and in one or two characters, particularly in the presence of a bivalved sclerite at the posterior end, bearing the genito-anal aperture, the genus is unique. It therefore takes rank equally with the above-mentioned groups, and is the sole representative of the order Craterostigmomorpha. For full particulars of these details reference must be made to Pocock's important memoir cited above.

I am now able to record the species from the South Island of New Zealand, where it has been found in several localities.

A description of the species, mainly taken from Pocock's paper, is given here for the convenience of New Zealand workers who may not have access to the *Quarterly Journal of the Microscopical Society.*

### Order CRATEROSTIGMOMORPHA Pocock, 1902.

#### Genus CRATEROSTIGMUS Pocock, 1902.

**Craterostigmus tasmanianus** Pocock, 1902. R. I. Pocock, *Quart. Journ. Micr. Soc.*, vol. 45, p. 423, pl. 23, 1902.

Colour (in spirit) greenish-yellow, head and toxicognaths dark reddish-brown. Integument sparsely hairy and punctured. (Pocock describes the colour as yellowish-brown: this may be due to the use of a different preservative.)

Cephalite (fig. 1) parallel-sided, its posterior border convexly rounded: frontal area with its sides converging between the eyes and the base of the antennae. Eyes some distance behind the antennae; frontal sulcus projecting posteriorly between the eyes, with strongly convex backward curvature. Antennae with 18 segments, the segments hirsute, especially towards the distal end of the appendage, subcylindrical, longer than wide. Praecoxal processes of toxicognaths (fig. 2) long, armed apically and externally with 7 teeth, inner side of femur and femoral processes armed with about 5 teeth, inner side of the trochanter armed with 1 tooth just behind the suture marking the line of union of trochanter and femur. Basal plate with posterior angles rounded. Terga without longitudinal grooves, with posterior border straight, posterior angles rounded, and unthickened

* R. I. POCOCK, *Quart. Journ. Micr. Soc.*, vol. 45, pp. 417–48, pl. 23, 1902.

margins. Sterna without grooves, those of the posterior somites granular: sternal area of last marked anteriorly on each side with an oblique shallow groove. Legs shortish, hairy, armed with a single inferior tibial and tarsal spine. Claw with 2 basal spinules, one inferior and one posterior. Posterior legs long and slender, about one-third the length of the body and head, without spines, protarsal and tarsal segments subequal. Trochanter of the 13th and 14th armed below with a horny spike, which is shortest on that of the 13th; coxa of 15th similarly armed. Genito-anal sclerite (figs. 3 and 4) is about one-half the length of the last leg-bearing somite. When

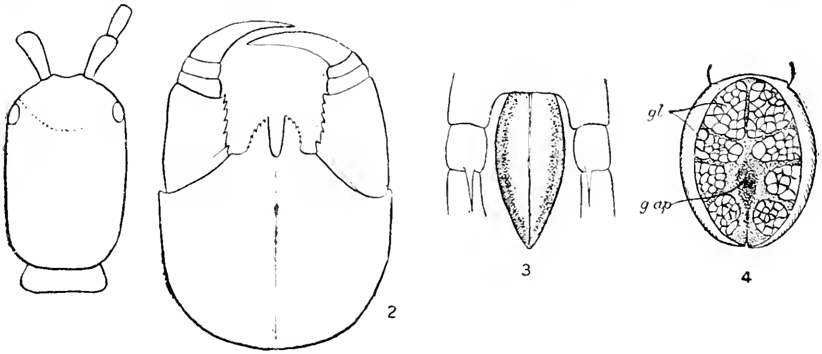


FIG. 1.—Cephalite, dorsal view.
FIG. 2.—Toxicognaths, showing teeth on praecoxal processes and femora.
FIG. 3.—Genito-anal sclerite, ventral view, valves closed.
FIG. 4.—Genito-anal sclerite, ventral view, valves open, showing genito-anal aperture (*g. ap.*) and gland-like bodies (*gl.*).

viewed from the dorsal or ventral aspect its sides are seen to be convex, and to converge posteriorly to a point. From the lateral aspect its upper edge, which is compressed, is straight and horizontal; its inferior edge convex, the two meeting at an acute angle of about 45°. When the valves are open (fig. 4) they are seen to border a shallow oval cavity, in the centre of which is the genito-anal aperture (*g. ap.*), with a row of 4 gland-like bodies (*gl.*) on either side.

Length, 20–45 mm.

*Localities of New Zealand Specimens.*—Mount Starveall, Nelson (G. Kidson); Mount Dick, Ben Lomond, and Kingston, Otago (T. Hall); Mount Algidus (T. Hall); Cass, and Hawdon Valley, Canterbury (G. A.); Staircase, the Remarkables, and Routeburn, Otago (T. Hall).

*Hab.*—Tasmania and South Island of New Zealand.

The occurrence of such an archaic form as *Craterostigmus* in both New Zealand and Tasmania is of considerable interest, for it may be regarded as having some significance in connection with the question of a former land connection between these two countries. *Craterostigmus* is fairly common within its range in New Zealand, and is easy to find, and therefore it is not likely to be overlooked by a collector. Centipedes have been collected in the North Island of New Zealand and over a considerable part of Australia, so that, as far as Australia and New Zealand are concerned, it is fairly safe to assume that it is confined to the southern portion of these two regions. If later search proves this to be the case, the occurrence of the same species in New Zealand and Tasmania will have greater value as evidence for the existence of the supposed former land connection.

# ART. XXIII.—*The Stratigraphy of the Tertiary Beds of the Trelissick or Castle Hill Basin.*

By R. SPEIGHT, M.Sc., F.G.S., Curator of Canterbury Museum.

[*Read before the Philosophical Institute of Canterbury, 6th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th October, 1917.*]

Plates XXI, XXII.

TABLE OF CONTENTS.



## A. INTRODUCTORY.

THE Trelissick or Castle Hill Basin, which is situated in the heart of the mountain region of Canterbury, has attracted considerable attention on account of the interesting outlier of Tertiary sediments located therein. It is somewhat surprising that no adequate reference is made to it in the writings of Haast, but its leading physical and geological features, with lists of fossils, have been given by McKay* (with map by Hector) and by Hutton,† and in connection with the former Hector gave a summary of results in the Progress Report introducing the results of the geological explorations for the year. A brief reference is also made to the locality by Marshall, Speight, and Cotton,‡ and to its features as an intermontane basin by the present author.§ There is a reference to the occurrence of certain fossils in this locality, with descriptions, in various lists by Hutton.||

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* A. MCKAY. *Reports of Geological Explorations during 1879–80.* 1881, p. 53.

† F. W. HUTTON, Geology of the Trelissick or Broken River Basin. *Trans. N.Z. Inst.*, vol. 19, 1887, p. 392.

‡ P. MARSHALL, R. SPEIGHT, and C. A. COTTON, The Younger Rock-series of New Zealand, *Trans. N.Z. Inst.*, vol. 43, 1911, p. 390.

§ R. SPEIGHT, The Intermontane Basins of Canterbury, *Trans. N.Z. Inst.*, vol. 47, 1915, p. 341.

|| F. W. HUTTON, *Catalogue of the Tertiary Mollusca of New Zealand*, **1873**; Mollusca of the Pareora and Oamaru Systems, *Proc. Linn. Soc. N.S.W.*, vol. 1, 2nd ser., 1887, **p. 205.**

This comprises all that has been written on the locality, and the present paper is an attempt to add to the record of fact in regard thereto, especially in its bearing on the conformity of our Tertiary series.

The situation of the basin almost midway between the classic districts of Amuri Bluff and Waipara on the one hand, and Pareora and Oamaru on the other, adds to its interest and importance and value as a critical locality, even though its stratigraphy is complicated by volcanic action and by structural movements. It may be urged that if the resolution of our problems of conformable or unconformable succession are a matter of such serious difficulty in areas where these disturbing factors do not exist little help can be obtained from such a disturbed area. There are some features, however, which render it peculiarly useful for study in this connection. The position taken by the author in this paper is that the locality has not furnished up to the present any positive evidence of uncontrovertible value of the *physical* unconformity in the Tertiary sequence; but this statement is not to be interpreted as indicating that none will be subsequently demonstrated. There are difficulties which can be explained on a basis of unconformity, though other explanations are equally applicable; but the position of the breaks will be chiefly determined on palaeontological grounds, and in order to do this it is necessary that systematic and complete collections be made from well-defined horizons. Great as were the services rendered to New Zealand science by Mr. J. D. Enys during his residence in this remote locality, he would have materially helped geological investigation had he realized the importance of this point. It is extremely unfortunate that his collections were inadequately labelled as regards place of origin, and the result is that the fine collection of New Zealand fossils in the Canterbury Museum identified and described by Hutton—many of them types—cannot be assigned with certainty to a particular bed, such indefinite place-names as "Porter River" or "Broken River" conveying little information of value from the standpoint of stratigraphical geology.

This deficiency has been remedied to some extent by the kindness of Dr. Allan Thomson, who has furnished me with a list of the fossils collected by McKay and at present in the Geological Survey collection, as well as a list of those collected by Enys; also of the fossils collected by himself in conjunction with the author in November, 1914—all recently identified by Mr. H. Suter. The last-named has most kindly identified for me a number of specimens collected in the summer of 1915–16.

## B. GENERAL PHYSICAL FEATURES.

The general physical features of the district have been described by both McKay and Hutton in their accounts of its geology, and a reference to the origin of the basin has been made by myself in the paper on the intermontane basins of Canterbury referred to above. The general sequence of events indicated therein is as follows: The Trias-Jura sedimentaries, of which the encircling mountains are composed, were folded by lateral pressure into a mountain area probably in early Cretaceous times. This was reduced to a peneplain by the end of the period, or perhaps a little later, and the land was then depressed below sea-level, the submergence continuing during the greater part of the Tertiary era, and on the eroded surface of Trias-Jura rocks a series of sedimentaries, including sands, greensands, limestones, calcareous sands, and conglomerates, were laid down in conformable sequence. The whole area was then elevated with differential movements, either of faulting or folding, or both combined, which resulted in the formation of a basin-shaped hollow, some five miles by three, in which the Tertiary sedimentaries were preserved from the active eroding agents which removed the weaker beds from exposed positions either on the elevated country in the neighbourhood or in the valleys more directly subject to glacier and river erosion. In all probability the area was a snow-field at the height of the glaciation; but there is little sign of glacier action in the area itself, except in the conchoidal hollows at high elevations in the mountains, where corrie glaciers probably nestled, and at the northern and southern end of the basin, where the truncation and faceting of spurs does suggest that glaciers invaded the area from the Waimakariri Valley


Fig. 1.—Geological sketch-map of the Castle Hill Basin. (Scale, 1 mile to ½ in. approx.) 1, greywacke; 2, sands, greensands, marls, &c.; 3, tuff beds; 4, limestone; 5, sands, sandy clays, and shales—Pareora beds.

on the north and the Rakaia on the south (Plate XXI, fig. 1). But this evidence is not supported by the other signs of glaciation, such as lateral and terminal moraines, rounded and scratched surfaces, *roches moutonnées*, &c., and it is therefore possible that the truncation of the spurs may be due to faulting and the facets may be fault scarps of recent origin. These would be preserved at the ends of the spurs, while the course of the faults across the intervening valleys would be masked by the rapid and enormous accumulations of waste.

The general surface of the floor of the middle of the basin consists of a series of flat benches, sometimes half a mile in breadth, planed by stream action from the less resistant sedimentaries, and covered with a thin veneer of gravel either washed out of the upper beds, which are composed of conglomerate, or derived from the encircling mountain ring and deposited by the present streams when they ran at a higher level. This is bordered on the eastern and western side, and to a certain extent on the northern side, by limestone hills, which project through the floor to a height of several hundred feet. The whole area is deeply dissected by streams which flow in beds incised at times hundreds of feet below the general floor, and bordered by narrow terraces cut in the Tertiary sediments and covered with thin veneers of gravel (Plate XXI, fig. 2). When cutting through the limestones the river-channels are narrow and gorge-like, and the sections thus furnished enable a clear insight to be obtained into the structure of the borders of the basin; but the mantle of river-gravels renders the exact interpretation of the central part a matter of extreme difficulty and a subject for speculation; this especially applies to the farm land immediately to the east of Castle Hill and to the country in the angle between the Thomas River and Hog's Back Creek, one of the largest feeders of the Broken River in its higher reaches.

## C. STRATIGRAPHY.

### 1. STATEMENTS OF PREVIOUS WORKERS.

The most interesting problems suggested by a consideration of the stratigraphy of the area are those connected with the question of conformity and the correlation of the beds. In order to have a basis of discussion it will be best to state the respective opinions of McKay and Hutton, and indicate the points on which they differed. McKay's classification, no doubt influenced largely by the ideas of Hector, is as follows:—

TABLE OF FORMATIONS.

| Age. | Formation. | Character of the Beds. |
|---|---|---|
| Lower Miocene | 1. Pareora formation .. | Principally loose sandy beds, with shell beds and beds of shelly sandstone. |
| Upper Eocene.. | 2. Mount Brown limestone | Shelly and coralline limestone. |
| | 3. Hutchinson Quarry beds (fan-coral bed) | Volcanic tufa and conglomerate with abundance of marine shells. |
| Cretaceo-Tertiary | 4. Ototara limestone .. | Close-grained calcareous sandstone. |
| | 5. Lower tufa .. .. | Intensely dark fine-grained and rubbly tufas. |
| | 6. Chalk marls .. .. | Chalk marls representing the Amuri limestone. |
| | 7. Concretionary greensands | Bright-coloured greensands with concretions. |
| | 8. Boulder sands.. .. | Sands overlying the coal. |
| | 9. Black grit and coal .. | Black oyster bed, sandstone, grey sands, shale, coal, &c. |

The substantial discrepancies between this table of formations and that of Hutton are—(1) the latter did not recognize the existence of a volcanic-tuff bed below the lower limestone—that is, the Ototara limestone of McKay; (2) McKay correlated the chalk marls with the Amuri limestone,

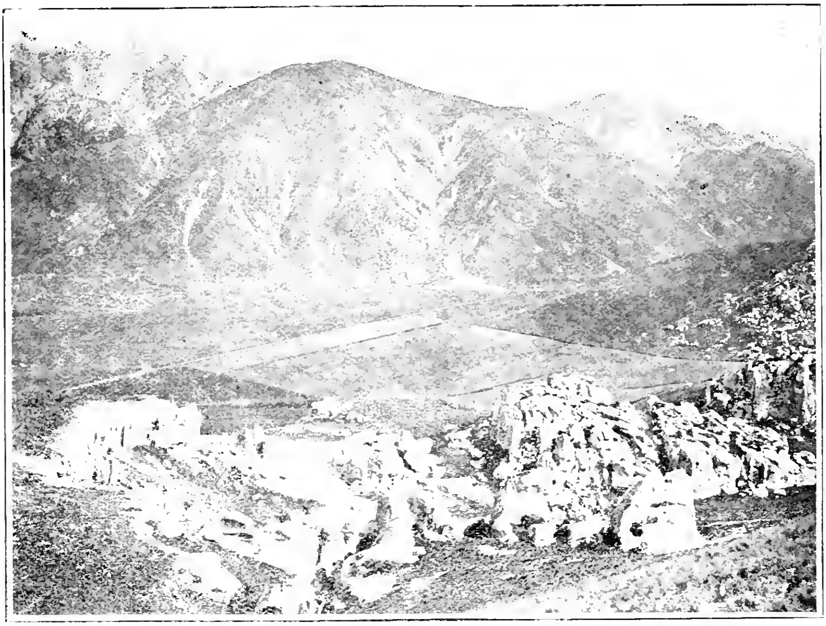

Fig. 1. View of the basin taken from the summit of Castle Hill, looking south-east. The limestone in the foreground is dipping towards the observer, the fields in the middle distance are probably based on greensands and tuff beds, and the distant hills are the greywackes of Mount Torlesse, the ends of the spurs of which are faceted either by glacial action or by faulting—in all probability the latter.

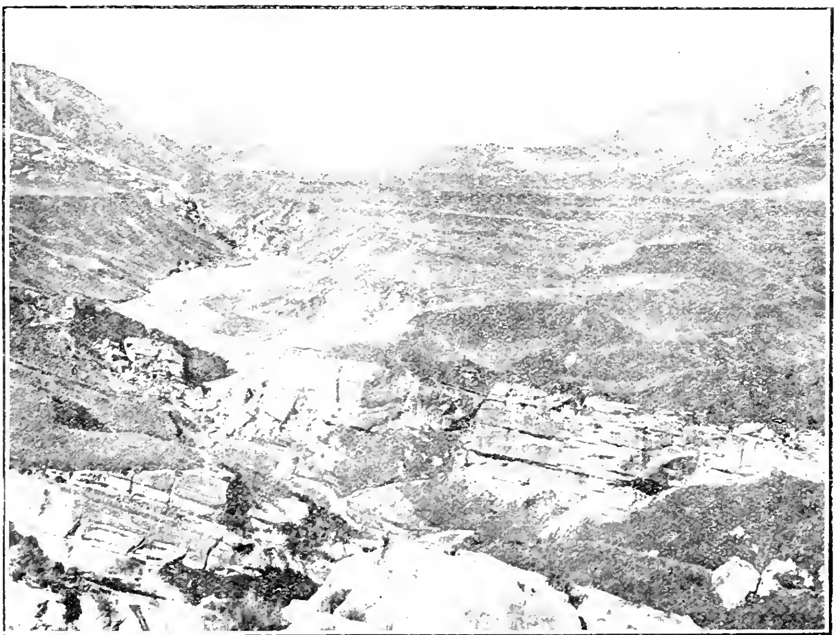

Fig. 2. View of the basin looking south-west from the hill between Broken River and Porter River. The limestone in the foreground forms here the lower gorge of the Porter River, but it appears again farther up-stream after making a swing round to the left, and is seen again in the distance forming the eastern face of Castle Hill. The Pareora beds are seen between the two gorges; the characteristically terraced landscape reposes on these beds. The general conformity of the stratification is clearly seen. Text fig. 4 follows along the eastern face of Castle Hill as seen in the plate.

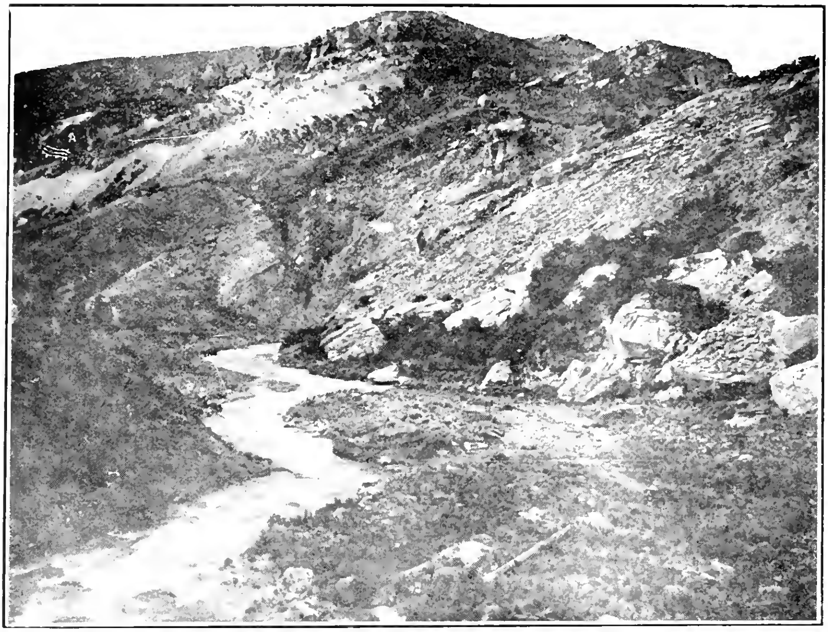

Fig. 1.—View of Porter River, showing two beds of limestone with interstratified tuff. The angle of the river is just at the point of inflow of Home Creek.

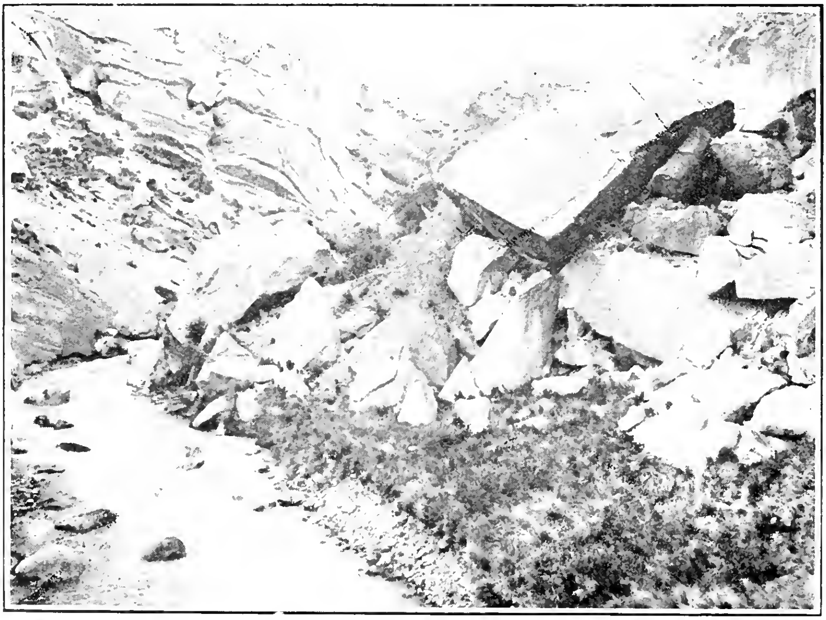

Fig. 2.—Great fall of limestone rocks at lower gorge of Porter River. The small debris slope on the middle, as well as the surface of the large block above it, is full of shells. The shell bed as it lies in position is near the top of an inaccessible cliff to the right. The tuff beds underlying the upper limestone are to be seen on the left side of the picture, just across the stream, and the limestone appears in position above them.

whereas Hutton correlated what McKay calls the Ototara limestone with the Amuri limestone; (3) following on from this, McKay correlated the upper limestone of Hutton with the Mount Brown limestone, whereas the latter associated it with the Weka Pass stone; (4) they both put unconformities above the lower limestone, but on different evidence.

The present author considers that there is strong evidence of physical conformity in the whole sequence, and that there are not two limestones but only one, which is divided apparently in some parts of the district into two parts by ash beds from contemporaneous volcanoes.

## 2. Sequence, Thickness, and Arrangement of Beds in Particular Areas.

### (*a*.) *Lower Members of the Tertiary Sequence.*

The part of the district where the lower members of the sequence can be studied best lies on the east side of the basin. Here the Broken River and its large tributary on the south, the Porter River, cut across the strike

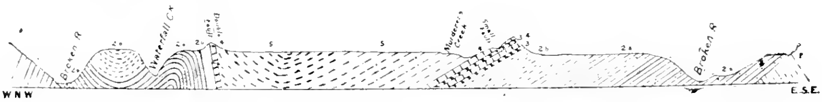


Fig. 2.—Section along Broken River. Distance, about 4 miles. Direction, W.N.W.–E.S.E. 1, greywacke; *2a*, sands, greensands; *2b*, marls, &c.; 3, tuff beds; 4, limestone; 5, sands, sandy clays, shales, and conglomerates—Pareora beds.

of the beds, and good sections are to be observed on the high banks of the rivers. We get in the Porter River and in the Broken River below the junction the following sequence, in descending order, underneath the limestone (fig. 2):—

| | |
|---|---|
| Volcanic tuffs and calcareous tuffs .. .. | 70 ft. |
| Marl .. .. .. .. .. .. | 150 ft. |
| White quartz sand .. .. .. .. | 8 ft. |
| Concretionary calcareous sand .. .. .. | 2 ft. |
| White quartz sand .. .. .. .. | 20 ft. |
| Concretionary band .. .. .. .. | 6 in. |
| White quartz sand .. .. .. .. | 12 ft. |
| Marl .. .. .. .. .. .. | 4 ft. |
| White quartz sand .. .. .. .. | 3 ft. |
| Marl .. .. .. .. .. .. | 28 ft. |
| White quartz sand .. .. .. .. | 50 ft. |
| Marl .. .. .. .. .. .. | 100 ft. |
| Concretionary greensand.. .. .. .. | 500 ft. |
| Sands, &c., including the oyster and shell bed .. | 800 ft. |
| Sulphur sands, white quartz sands, sands with impure lignite, light greensands, sandy clay, and white sands, following in that order .. .. | 300 ft. |
| Greywacke. | |

The beds strike N. 30° W., and dip S. 60° W. at angles approximately 15° above the junction of the two rivers, but which become slightly steeper on tracing the beds east. Throughout the series of beds enumerated above there is no sign of unconformity, as has been admitted by all who have examined the section. A similar sequence also occurs in the Broken River between its junction with the Porter and the Broken River limestone gorge, but the clarity of the section is somewhat obscured by slips from the dominating limestone scarp above it: there is, however, no evidence of unconformity.

Hector and McKay have correlated the marl with the Amuri limestone, whereas Hutton placed it on a lower horizon, since he correlated the lower Trelissick limestone with the Amuri limestone. There is strong evidence, which will be referred to later, that Hutton's contention is incorrect. The stratigraphical position of the marl, the fact that in places it is lithologically indistinguishable from typical Amuri stone, and its close resemblance in parts to a rock formed from Globigerina ooze, owing to the numerous Foraminifera that it contains,* render it extremely probable that Hector and McKay were right in placing it as they did. The characters of the deposit show that it was laid down in fairly deep sea, but the interstratification with sands in its lower portions shows clearly that some land was adjacent. It is the higher parts, however, which have a true deep-sea facies. The palaeontological evidence furnished by other localities in the neighbourhood indicates that the marl and the beds immediately associated with it are of Lower Tertiary age, which is not inconsistent with its correlation with the Amuri limestone.

The beds exposed near the junction of Broken River and the Porter are continued round the east and south of Prebble Hill under the tussock-clad slopes, and there is no clear-cut section till the neighbourhood of the upper limestone gorge of the Porter is reached. In swinging round the hill the beds are bent up into a bowl-shaped form, which is tilted towards the west; on the edge of the southern rim a magnificent section is exposed. Near the river the beds strike N. 80° E., with a northerly dip at an angle of 50°, the river cutting directly across them.

The section exposed at the river consists of the following, in descending order:—

*Limestone.*

*Volcanic tuff.*

*Marl*, whiter in the upper portion and greyer in the lower.

*White quartz sand*, with two concretionary bands similar to those in the section lower down the river.

*Greensands.*

These last apparently form the solid base of the western terrace of the Porter River for some distance up above the gorge, but a fairly heavy covering of shingle renders a proper examination impossible. The beds just above the gorge are apparently involved in a small fault with a downthrow to the north; but the section is somewhat obscure, and the appearance may be really due to a surface slip, the greensands having moved forward. If a fault really occurs, the throw is small.

Owing to the close covering of well-grassed soil, and talus from the overlying limestone, no good exposure of these beds can be obtained on the east side of Castle Hill; the lower bed of limestone, however, outcrops in a small slip north-west of Mr. Milliken's house.

Following the basin round, the next important section where the lower members of the formation are exposed is in Whitewater Creek, a tributary

* P. Marshall, The Younger Limestones of New Zealand. *Trans. N.Z. Inst.*, vol. 48, 1916, pp. 94, 95.

of the Porter coming in from the west and junctioning with the main stream close to the road-crossing. This tributary rises in Mount Enys and

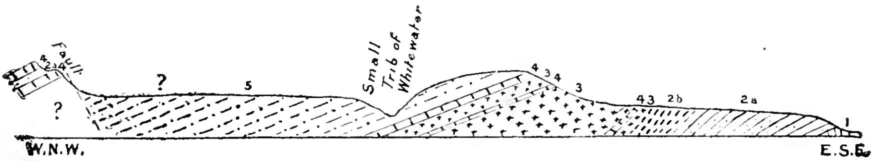


FIG. 3.—Section along Whitewater Creek. Distance, 2½ miles. Direction, W.N.W.–E.S.E. 1, greywacke; *2a*, sands, greensands; *2b*, marls, &c.; 3, tuff beds; 4, limestone; 5, sands, sandy clays, shales, and conglomerates—Pareora beds.

Mount Olympus, peaks of the Craigieburn Range, and flows in a south-easterly direction across the whole series. The section exposed below the limestone is as follows (see fig. 3):—

*Limestone.*

*Volcanic tuff*, of uncertain thickness but probably over 1,000 ft.

*Calcareous greensand*, more calcareous in its lower portions—in fact, it is in its lower portions an argillaceous limestone, flaky and hard, and showing some resemblance to the lower bed of limestone; indeed, it is extremely probable that it actually represents that bed in this section. It is 12 ft. thick, strikes north-east, and has a dip to the north-west of 45°.

*Volcanic tuff*, containing numerous fragments of rock, and glauconitic in character owing to decomposition, and passing down into a true tuff, the total thickness being 60 ft.

*Marl*, fine-grained and flaky at times, containing a proportion of sandy material, sometimes decidedly sandy. The dip is here steeper, reaching 65°, and the thickness of the bed 500 ft.

*Greensands* and *sands*, the latter sometimes concretionary, with thin beds of coal in their lower levels, striking N. 80° E., and dipping in a northerly direction at an angle of 45°, the total thickness being 950 ft. Although there is thus a variation in dip between this and the overlying marl, there is no evidence of a break. These beds rest unconformably on greywacke exposed in the channel of the creek.

The series here enumerated is somewhat different from that recorded by Hutton, the discrepancy arising, no doubt, through the obscuring of parts of the section by covering gravels, different observers having an opportunity of examining only portions of the sequence. I can see, however, no sign of an unconformity, any variations of the dip and strike being what might be expected from the circumstances of the deformation of the beds by folding. It is natural under those circumstances that both will slightly vary from place to place.

In Coleridge Creek, the westerly extension of Porter River, the volcanic-tuff beds become more important. The following sequence occurs in the lower part of the creek:—

*Limestone.*

*Marl* and *ash* beds interstratified, the former being both grey and white, and the latter in places calcareous and with fossils.

*White sands*, interstratified with volcanic beds, the sands passing down into greensands.

The special interest in this section is that it shows clearly that volcanic action was going on while the sands and marls were being laid down. The beds strike N. 30° W., and dip S. 60° W. at an angle of 60°, the beds striking in the direction of those in Whitewater Creek.

In the upper part of Coleridge Creek, lying on the greywacke, are the greensands; above these again the marl, running almost along the creek; and this is succeeded by the volcanic-tuff bed, which has here no great thickness. This is followed conformably by the lower limestone. These beds strike north-west, and dip to the north-east at high angles.

The pronounced effect of volcanic action on the continuity of the limestone beds is seen clearly where this limestone crosses the creek near the old sheepyards, for there it ends abruptly and the bed passes on as a calcareous tuff with the same stratification. The junction has all the appearance of a fault, but no sign of dislocation can be seen in the overlying well-stratified beds.

On the western side of the basin these beds are not seen, though they probably underlie the isolated blocks of limestone which occur there, the surface being masked by later deposits of Tertiary age and river-gravels and talus from the mountains lying immediately west. In the upper part of Broken River basin, especially in Waterfall Creek, in the main stream, and in Blackball or Murderer's Creek (a tributary coming in from the north), exposures of the beds can be distinctly seen, those in Broken River itself being most instructive.

About a mile above the road-crossing the river runs through a narrow gap of limestone dipping almost vertically, the upper portion being forced over the lower, this being a subsidiary fault to a main one which runs north-east, the beds on the south-east being thrown down; the fault hades with the dip, and in consequence there is a suppression of the outcrops on the surface, the marls, and perhaps the overlying tuff if it really exists, being cut out. The beds in contact with the limestone are white sand with occasional white calcareous bands. These are succeeded by greensands, and then by a hard concretionary calcareous sandstone bed 20 ft. thick, and below this lie again greensands with large calcareous concretions containing fragments of saurian bones. The dip of these beds is downstream—*i.e.*, to the south-east; but the direction immediately changes to one up-stream, and the beds are repeated in reverse order. They have thus been folded up into an anticline with the eastern limb almost vertical or even slightly overturned, and the limestones which originally formed the roof of the anticline have been removed, but the structure is indicated by remnants to the immediate south-west of the locality. The lateral movement of the limestone at the gorge and the slickensided surfaces of the limestone are secondary phenomena resulting from the structural movements which have produced the folding.

These beds dip up-stream above the anticlinal axis till just past the junction with Waterfall Creek, when they take the form of a syncline, and the dip of the western wing of this continues for some distance up-stream—in fact, to the actual base of the series, where clay and occasional beds of lignite and brown coal occur. The banks of Broken River are here very high, but are thickly wooded and in places subject to slip, so that the actual sequence cannot be made out. Up Waterfall Creek, however, there are excellent sections of the beds between the greensands and the limestone. Hutton puts in a fault as necessary to explain the structure here, but this seems to be incorrect. The sequence is perfectly normal and without signs of dislocation.

The following beds occur in descending order (see fig. 2) :—

*Limestone.*

*Marl*, of uncertain thickness.

*White sand*, with occasional layers of greensand 3 ft. to 4 ft. thick, the total thickness of the whole beds being uncertain owing to the cover of bush and gravel, but certainly between 150 ft. and 200 ft. The beds strike north-west and dip south-west 35°.

*Greensands*, dark in colour, over 100 ft. thick; these pass into the greensands seen at the mouth of Waterfall Creek.

A noteworthy feature of this section is the absence of any volcanic tuff below the limestone.

In the upper portions of Waterfall Creek the limestones are most in evidence, and are subject to a series of anticlinal and synclinal folds. Where the anticlines have been denuded greensands are exposed; this especially is the case on the eastern side of the Hog's Back, a high ridge of limestone near the westerly margin of the basin. In Waterfall Creek and immediately south of it the beds are exposed on a well-marked scarp slope facing east, and the following section is visible :—

*Limestone.*

*Limestone* with volcanic-tuff pebbles, 6 ft. thick, passing into

*Tuffs* and *greensand*, 8 ft. thick.

*Greensands.*

*Light-coloured sands.*

These beds exhibit a conformable succession, and dip west at an angle of 55°.

Immediately west of the section just referred to, above the spot where the river breaks through the limestone, there is apparently a reversal of dip, and coal-beds are exposed under the limestone; but the country is here bush-covered and the relations are obscure. In all probability the limestone and the underlying beds have been slightly upturned, perhaps owing to a fault movement which has produced a line of dislocation passing along the base of the Craigieburn Range; but no clear section can be obtained, owing to the covering of bush, soil, and loose debris.

In that part of the area lying to the north of Broken River the sections are not clear, but exposures in various places show that the beds are existent in their normal stratigraphical relations, with the exception of one locality—viz., that in the immediate vicinity of Parapet Rock. The fault which affects the limestone in Broken River continues to the north-east just past this point, when it passes into a fold without any apparent disruption of the beds. At Parapet Rock the limestone is slightly overturned, but it rapidly flattens out and takes a basin-like form as it follows round Flock Hill. At Parapet Rock and where it crosses Murderer's Creek the limestone is underlain by calcareous tuff, but there is no exposure of the marls and white sands, and their outcrops may be suppressed, as they are in Broken River, as a result of a fault following the strike; but these beds appear in their normal position when traced round the eastern side of Flock Hill, and finally junction with those in the Broken River below the limestone gorge.

To the north and east of Flock Hill the greensand beds and associated coal-measures are well developed, especially on the saddle between Murderer's Creek and the creek which runs east of Flock Hill. At the point where these beds cross Murderer's Creek Haast obtained numerous leaf-imprints, which were subsequently identified by von Ettingshausen, and the same beds cover a fair tract of country to the eastward, and finally junction with the coal-measures which were described previously as occurring in Broken River. This completes the reference to occurrences round the whole circuit of the basin.

In this account of the various localities where clear sections of the lower members of the sequence of Tertiaries are given it will be noticed that there is no indication of an erosion surface, and that the conformity is complete. This has been admitted by both Hutton and McKay. This is an important point, as will be further emphasized when the fossil content of the tuff is considered. The presence of the volcanic-ash beds at different horizons has been a matter of considerable difficulty, but in my opinion the following is a fair statement of the conditions :—

1. Volcanic action commenced at the time when the white sandy beds were being laid down—that is, between the deposition of the greensands and the marl.

2. Volcanic activity was more pronounced in the neighbourhood of Coleridge Creek, the ash beds being there much thicker than elsewhere in the area. The earliest signs of volcanic action are also furnished by that locality.

3. Elsewhere in the district the beds are thinner—in fact, they do not appear at all in the sections in Waterfall Creek, where they should be easily seen were they present. This remark applies to higher occurrences of the ash interstratified in the limestone.

4. This interstratification is not indicative of an unconformity, but that the deposit of ash went on contemporaneously with the formation of limestone and other marine beds in the adjacent sea.

### (*b.*) *Occurrences of Limestone with Interstratified Tuff.*

The limestones, which are in places separated by the uppermost layer of the volcanic-tuff beds, were considered by both McKay and Hutton as quite distinct, and belonging to different geological periods. The present author, however, regards them as belonging to the same period, with a difference in character which any limestone might exhibit as the conditions of deposit slightly changed during its deposition, the tuff bed interstratified in the limestone having just the same geological importance as similar beds interstratified in the sands and marls underneath the limestone. Before considering this question in more detail it will be best to give some account of the occurrences that the locality affords.

The most typical section, and one which is free from disturbing elements, is that obtained in the lower part of Home Creek, just above its junction with the Porter River. The creek cuts across the strike directly, and on the high walls of its gorge-like bed the relations can be easily seen. (Plate XXII, fig. 1.) The following is a description of this section :—

*Limestone*, 60 ft. thick, the upper 10 ft. or 12 ft. of white stone, the lower 50 ft. yellowish and weathering greenish-grey where run over by the stream ; the rock is almost entirely composed of coralline fragments.

*Calcareous volcanic tuff* : This grades down from the overlying bed, and the proportion of volcanic matter increases in the lower part ; the approximate thickness is 10 ft.

*Volcanic tuff*, the upper part consisting of volcanic matter occasionally weathering green, and passing down into volcanic tuff weathering dark green, and finally into volcanic ash, the total thickness being about 75 ft.

*Limestone*, the "lower limestone" of Hutton and McKay, a somewhat flaky argillaceous stone, the lower part greenish, with small fragments of volcanic ash; thickness about 80 ft.

All these beds strike N. 15° W., and dip westerly at an angle of 15°. When followed north towards Broken River the ash bed thins out and disappears, the only indication of the presence of volcanic matter being small particles scattered in places through the stone. The relations between the upper and lower layers of the limestone are obscured between the two rivers, but in the gorge of Broken River a clear-cut section shows no decided line of demarcation between them, and they apparently grade into one another insensibly. The spot, however, is somewhat difficult of access except at times when the river is quite low.

From Home Creek the beds continue south across the Porter, but an excellent section of the upper layer of limestone and the subjacent tuff beds is seen just at the mouth of the Thomas River, the junction of the two being quite conformable. Followed south, the limestones form the highest point of the steep escarpments of Prebble Hill, facing east and south, and the strike swings round as described in the section dealing with the lower beds, till the upper limestone gorge of the Porter is reached. (Plate XXI, fig. 2.) Here occurs the following sequence:—

*Limestone*, full of coralline fragments like the upper layer in Home Creek, 7 ft. thick. This bed can be traced round on the slopes of Prebble Hill, so that it is continuous with the upper layer at the mouth of the Thomas, but it has thinned out very much.

*Volcanic tuff:* Just as in Home Creek, the overlying limestone grades down into this bed, but its lower portions are a true volcanic tuff; the total thickness is about 60 ft.

*Limestone:* The rock is flaky in its lower portion, but in the upper parts it loses this character and takes on the nature of the so-called upper limestone. Hutton says (*loc. cit.*, p. 397), "On the south side of Prebble Hill the limestone is divided into two parts, the lower of which is composed of comminuted fragments of Bryozoa, Hydrocorallinae, &c., forming what is called a coralline limestone, thus differing altogether from its normal character, and resembling the upper limestone presently to be described." This statement is quoted as showing that lithological character will not distinguish the two limestones, and that they are probably one member of the series, and that they grade into one another.

At this point the beds strike almost due east, with a northerly dip of 50°.

From this locality the beds apparently run west, but they are hid by the gravels of the plain till the north-east corner of Castle Hill is reached. Hutton puts in a fault at this place with a downthrow to the north, whereas McKay explains the arrangement by the presence of a fold.

The mass of Castle Hill which dominates the interior of the basin, and whose picturesquely eroded rocks are responsible for the popular name for the locality (Plate XXI, fig. 1), presents a well-defined escarpment to the east, but unfortunately it furnishes no clear-cut sections showing relations of the two limestones (Plate XXI, fig. 2). The exposure along the eastern face of the hill shows that the beds have been folded into an anticline and syncline on going from north to south, the anticline having been eroded at the north-eastern corner of the hill (fig. 4). On a line about 300 yards to the west of this and parallel with it the hill has a dome structure, and the syncline to the south apparently flattens out. In a section from east to west passing through the highest point of the hill it again exhibits an anticlinal structure, flanked on the east by a syncline (fig. 5), which probably passes into a fault in a north-and-south direction, so that the extreme north-eastern end of the hill is separated somewhat

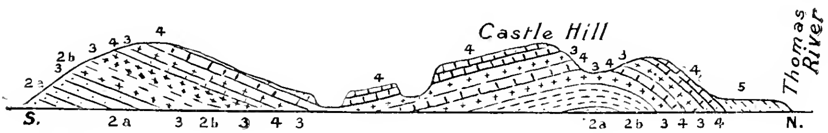


FIG 4.—Section along eastern face of Castle Hill from Whitewater Creek to Thomas River. Distance about 2 miles. Direction, S.–N. 1, greywacke; *2a*, sands, greensands; *2b*, marls, &c.; 3, tuff beds; 4, limestone; 5, sands, sandy clays, shales, and conglomerates—Pareora beds.

from the rocks on the northern flank. This faulting is apparently attended with a thinning-out of the beds, perhaps as a result of folding movements which have resulted in either a pronounced distortion of the limestones as suggested by McKay, or as an actual fault running almost parallel to the line of the Thomas River towards the upper limestone gorge of the Porter as suggested by Hutton. It is probable that both suggestions may be partly correct, the undoubted fold grading into a fault.

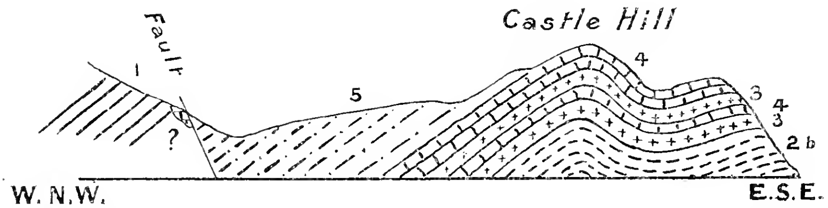


FIG. 5.—Section across Castle Hill. Distance about 1 mile. Direction, W.N.W.–E.S.E. 1, greywacke; *2a*, sands, greensands; *2b*, marls, &c.; 3, tuff beds; 4, limestone; 5, sands, sandy clays, shales, and conglomerate—Pareora beds.

In a small slip about half-way up the north-eastern face there is an exposure of typical lower limestone exactly similar in lithological features to that in the Porter River, and this is succeeded by tuff beds (25 ft.), which pass up into a fossiliferous calcareous tuff with brachiopods, corals, and fragments of molluscs, and overlying this is the upper bed of limestone 150 ft. thick. This is typically developed in the splendid monolithic blocks which crown the hill, and in the fine eastern face. The stone was quarried at one time for building purposes, and was in good repute throughout the whole of Canterbury; in fact, it was looked on as the best building-stone that the province could produce. At the quarry itself it has a free, even-grained texture, nearly white, and admirably suited for general building purposes, its place being now taken by Oamaru and Mount Somers stone, which are inferior in quality; but the remoteness of the locality and the difficulty of transport will always militate against its general use.

On tracing the limestone south to the vicinity of the Whitewater Creek it thins out considerably, so that the total thickness diminishes to about 40 ft. In the bed of the stream there occurs a mass of limestone, but it is difficult to say whether or not this is a slip from solid outcrop in the vicinity. It resembles in character the lower layers of the limestone in position above it, but this is not conclusive proof that it is a slip.

In Whitewater Creek the sequence is as follows, in descending order (fig. 3) :—

*Limestone*, a hard flaky rock, breaking in the upper part into quadrangular blocks ; thickness, 40 ft.

*Calcareous tuff*, composed of limestone and fragments of volcanic rock, exactly similar to that in the analogous position in Home Creek and Broken River ; from 2 ft. to 3 ft. thick ; passing down into

*Volcanic tuff*, 100 ft. thick.

*Limestone*, thickness about 25 ft. : this may be a part of the upper portion of the limestone beds.

These beds strike N. 60° E., and dip in a westerly direction at an angle of 20°.

In Volcanic Creek the beds have the same dip and strike, and are as follows :—

*Limestone*, the lower portion having a definite jointing into quadrangular blocks ; the upper portion like the ordinary upper limestone in general appearance, but corals were absent in the specimens examined. There was a distinct separation into two facies, but no unconformable junction, and no tuff beds between them. Total thickness, 80 ft.

*Calcareous volcanic tuff :* This is well bedded and clearly exposed under the limestone, and similar in lithological character to those beds in the same position elsewhere.

*Volcanic tuff*, of uncertain thickness.

There is no appearance of a lower band of limestone on the banks of this creek, but it may be covered up by surface accumulations ; some indication of its presence should, however, be apparent. This absence increases the probability that the lower band of limestone in Whitewater Creek is only slip from the one bed which is in position, and that there are not two limestones.

Traced towards Coleridge Creek the limestones appear to thin out and lose their distinctive character, especially in the lower part of the creek, where the volcanic tuffs are so well developed. The band of limestone dips to the west, but it is bent round in the form of a syncline and, passing close to the sheepyards, meets the creek again higher up and crosses it to the northern side.

The succession here is as follows :—

*Limestone.*

*Volcanic calcareous tuff*, full of fossils.

*Volcanic tuff.*

*Limestone*, 100 ft. to 150 ft. thick.

These beds are bent round on leaving the creek lower down, but at the upper crossing they have a north-easterly strike and a dip to the north-west at very high angles.

On the western side of the basin there are numerous isolated blocks of limestone, detached from the main mass probably by a fault running north near the base of the Craigieburn Range, which is probably distinct from the main fault movement which bounded the area to the west. These blocks occur in the small creek immediately below the limestone gorge of Coleridge Creek, at a height of 400 ft. above its floor (fig. 6). They occur again higher up the valley-side in the next tributary on the north side of Coleridge Creek; a massive detached block occurs in the upper part of Whitewater Creek, and isolated fragments occur on the slopes of Leith Hill, on the western side of the basin, between the Whitewater and the Thomas Rivers. I have been informed that similar blocks occur in the bush immediately south of the Thomas River, and in the Thomas River itself, though I could not locate them. The occurrences near Coleridge Creek are especially

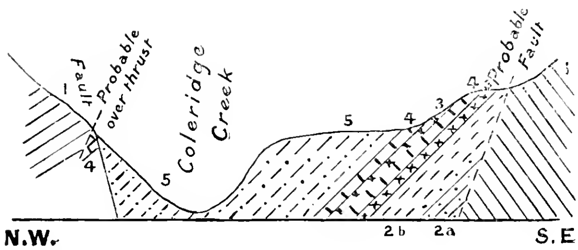


FIG. 6.—Section across Coleridge Creek, just below limestone gorge. Distance, $\frac{1}{2}$ mile. Direction, N.W.–S.E. 1, greywacke; *2a*, sands, greensands; *2b*, marls, &c.; 3, tuff beds; 4, limestone; 5, sands, sandy clays, shales, and conglomerates—Pareora beds.

interesting as they are pinched in between the greywacke and the higher sandy beds of the Tertiary series, and the greywacke has apparently been forced over them along a fault-line. The blocks in Whitewater Creek consist of two beds of limestone, the upper 50 ft. thick; and underlying this white calcareous sands 40 ft.; greensands 10 ft.; and white sands of uncertain thickness. The lower limestone then follows, 40 ft. thick or more (fig. 4). The beds strike N. 60° E., and dip N. 30° W. at an angle of 35°. There is no appearance of overlying beds. The limestones are no doubt a part of the ordinary limestone series, and have been separated from the beds lower down the creek by a fault with a north-and-south direction.

Only the occurrences in the northern portions of the basin are now left to be considered, and these present most interesting structural features. At the lower limestone gorge of the Broken River the following beds occur, all with a N.N.W.–S.S.E. strike and a W.S.W. dip of approximately 20°:—

*Upper limestone,* 150 ft. thick, of the ordinary type but carrying fragments of volcanic tufa throughout, and at times segregated into well-defined layers.

*Calcareous tuff,* 40 ft. to 50 ft. thick, well bedded, and containing a high proportion of calcareous material.

*Lower limestone,* about 200 ft. thick, flaky, and well jointed into quadrangular blocks. Both of these limestones are coralline in origin.

In the neighbourhood of the gorge on the north side of the river there are several small faults with a north-and-south direction and a downthrow to the east. When followed round the eastern face of Flock Hill the strike gradually changes, and the dip becomes southerly at the northern end of the ridge, and farther on, when Murderer's Creek is reached, it is to the south-east. The beds at this point have been subjected to a notable twist, as has been mentioned previously, and the angle of dip rapidly increases from 40° on the eastern side of Murderer's Creek to vertical with a slight overturning at Parapet Rock, and continues so till the bed again crosses Broken River at the upper limestone gorge. From just east of Murderer's Creek to beyond Broken River the limestones are involved in the fault, and some of the underlying members have had their outcrops suppressed (fig. 1).

Throughout this portion of the line of outcrop the rock is of a hard flaky nature, extensively jointed, a result due no doubt to the pressures and dislocations to which it has been subjected. In places it is crystalline, but traces of its coralline origin are visible throughout. It contains particles of volcanic tuff, and at Parapet Rock itself there appears to be a distinct layer of tuff, 4 ft. thick, dividing the stone into two layers, the lower 60 ft. thick and the upper about 80 ft., the latter being less flaky, but breaking into quadrangular blocks. It would therefore appear that there is the division into two layers even in this part of the area, remote from the centres of pronounced volcanic activity.

In the area between Waterfall and Hog's Back Creeks the line of outcrops forms a series of loops, resulting from the erosion of a succession of anticlines and synclines. Continuing from Broken River crossing, it follows the same direction as it has north of the river till it reaches Trout Creek, when it swings round with a change of dip to the west, and forms the mass of Sugarloaf Hill, whose bold escarpment fronts to the north-east. This direction is continued across Waterfall Creek, the limestone itself forming the lip of the fall from which the creek takes its name. After crossing this creek the outcrop extends some distance up the steep slopes on the north and then swings round, forming a syncline, the edges of the bed cropping out on a series of low mounds in the direction of the Hog's Back Creek. When this is reached another reversal occurs and the outcrop follows back to the north, reaching Waterfall Creek once more and just crossing it. At the southern end of this stretch the limestone is almost vertical, and the upper edge of the beds forms a bold cliff along the base of which the Hog's Back Creek flows—in fact, the limestone is probably slightly overturned; but to the north it slowly flattens out, preserving a westerly dip, till in Waterfall Creek it is inclined at an angle of only 55°.

Immediately north of this creek the line of outcrop turns back with a reversal of dip, crosses the creek again, and the bed apparently peters out, or is covered by surface accumulations and cannot be traced more than a few chains south of the creek

A small occurrence of limestone is found on the south side of the Hog's Back Creek, in the vicinity of the greywacke slopes of the Craigieburn Range, on the spur dividing that creek from the Thomas River; but the exposure is so small that it is impossible to determine its relations. It may be a small block separated from the main limestone mass by faulting, or be a part of a fold connected with the Hog's Back Ridge under the creek, and overlain by more recent Tertiary beds.

This limestone is generally hard, and somewhat jointed into flaky quadrangular blocks in its lower portions, but it varies much in character in its various parts In many places the upper layers are distinctly crystalline. Marshall gives the following microscopical description of this rock from a specimen collected by the author: "Polyzoa are again the most frequent organisms in this rock, though echinoderm plates are common. Foraminifera are less common, and only *Cristellaria* could be distinguished. There is some *Lithothamnium.*"* Hutton would discriminate between the two beds by insisting on the coralline nature of the upper as distinct from the non-coralline nature of the lower, but a careful examination shows that the coralline element may occur in both; in fact, Hutton himself has noted the coralline nature of the lower limestone at the upper Porter limestone gorge. Even where, through pressure as a result of intense folding or faulting, the rock has taken on a crystalline facies traces of its coralline origin are apparent. This can be well seen at Parapet Rock and in Coleridge Creek. The lower portions apparently contain a considerable mixture of volcanic-tuff fragments, and are more distinctly bedded in places; especially is this the case in the limestones exposed in the gorge of the Porter. In the upper portions the planes of bedding are less pronounced and the coralline fragments are more distinct, so that a decidedly different appearance is given to the rock. This led Hutton and McKay to class them as two distinct stones, and the absence of the decidedly coralline facies from certain localities led them to attribute its non-existence to erosion. They therefore placed an unconformity between the higher limestone bed and the overlying calcareous sands and shell beds, and the divergence in character between the upper and lower beds led them to place an unconformity between them, thinking also that the volcanic tuff marked an erosion surface. In my opinion they are members of one limestone, for the following reasons: (1.) There is no stratigraphical break; wherever they occur the beds are conformable, and when there is no tuff it is impossible to recognize a distinct break, but one bed passes into another insensibly. (2.) The characters of the two rocks are not invariable. As Hutton pointed out, the lower bed is in places distinctly coralline, and the upper bed, even when there can be no possible doubt as to its identity, may show an entire absence of this feature. (3.) The palaeontological evidence will show that there is no great divergence in fossil-content between the tuff bed under the lower limestone, classified as Cretaceous by Hutton, and the tuff above it, which he assigned to the Oligocene period, the conformity of the upper limestone to the upper tuff being generally admitted.

For these reasons I consider that there is only one limestone; that it is thinnest where volcanic action was most marked—that is, in Coleridge Creek; that in the deep water removed from the volcano sedimentation went on continuously, with a gradual change in the nature and condition of the organisms contributing to the formation of the rock, but that in closer proximity to the volcano interstratification of the limestones and the tuffs took place. Whereas in the lower horizons the limestone had more or less the character of a deep-sea deposit, as time progressed it was laid down in shallower water in preparation for the next suite of calcareous beds, which have the nature of shore material.

### (*c.*) *Pareora Beds.*

The next succeeding suite of beds, called "Pareora" by both McKay and Hutton, is considered by them to rest unconformably on the underlying series, a conclusion based chiefly on the supposition that the upper bed of limestone has been removed by erosion from certain parts of the area. If, however, there is only one limestone, then this argument falls

* P. Marshall, The Younger Limestones of New Zealand, *Trans. N.Z. Inst.*, vol. 48, 1916, p. 92.

to the ground; but before dealing with it more fully it will be best to describe the relations between the various members of the overlying series as it is developed in different parts of the area. I have retained the name "Pareora," since it is convenient to describe a particular facies of Tertiary deposits occurring in numerous places in Canterbury besides the name locality—that is, shore deposits of sandy layers with broken shells, occasionally with concretionary bands, which form the top of the Tertiary fossiliferous beds; but I do not intend to imply that they should be classified as distinct from the Oamaru series as developed in its typical district.

The relations of these beds to the underlying strata are best seen in the neighbourhood of the junctions of the Thomas River and Home Creek with the Porter River. In the former, from the site of the old dipping-yards down-stream, occur the following:—

*Sandy shales;* thickness exposed, 10 ft.
*Lignite,* about 2 ft. thick, dipping S.W. 30°.
*Greenish-grey sands.*
*Yellowish sands,* dipping S.W. 20°.
*Dark greensands.*
*Yellowish sands.*
*Dark greensands,* extending past the junction of the creek on the south.
*Greenish-grey sands.*
*Broken-shell beds,* with sands, 12 ft. thick.
*Greenish-grey sands.*
*Broken-shell beds,* 2 ft.
*Concretionary sands,* with broken-shell bands.
*Broken-shell beds,* 3 ft.
*Sands,* weathering rusty grey, sometimes a light-coloured greenish-grey, 100 ft. thick.
*Calcareous sandstone* with many shells; thickness 15 ft. (?), strike N.N.W., with a dip to the W.S.W. 20°.
*Limestone.*

The relations between the lower bed and the limestone are well seen at the present time owing to a great fall of rock just above the junction of the Thomas with the Porter. (Plate XXII, fig. 2.) Immense blocks lie here with thick layers of shells in excellent state of preservation. These were not available in the time of Hutton or McKay, and the overhang which the rocks no doubt had at that time would prevent their proper examination, the dangerous nature of the locality being remarked by Hutton. In none of the contacts, however, is there any sign of an erosion surface.

In the neighbouring Home Creek the following sequence is exposed:—

*Calcareous concretionary sands* with broken-shell bands, the shell-remains being concentrated into a narrow layer 6 in. to 12 in. thick; total thickness uncertain.
*Sandy beds,* greenish in colour, with broken-shell layers, 15 ft.
*Calcareous concretionary sands,* 2 ft.
*Greenish-grey sands,* 3 ft.
*Sandy beds* with broken shells, very much current-bedded, 5 ft. exposed.
*Broken-shell beds* with sands, sometimes with hard bands, sometimes looser, 20 ft. thick.
*Sands* weathering a rusty brown, with brown concretionary layers and shell-fragments, 80 ft.
*Shelly beds* with loose irregular light-greenish-grey sands, 25 ft. thick.

There is no apparent unconformity here with the underlying limestone.

Between the two limestone gorges of the Porter these beds are bent up into a syncline in sympathy with the underlying limestones. Starting from the fall of rocks and continuing up-stream, we have the following sequence, the first part in ascending order, and when the other limb of the syncline is reached with the beds in descending order:—

*Limestone.*

*Coarse-shell bed*, about 2 ft. thick.

*Finer-shell and sandy bed*, about 5 ft.

*Sands*, rusty brown, inclined at times to grey, 100 ft. thick, striking N.N.W.

*Sands*, with bands of calcareous concretionary sands and shells, 40 ft. thick.

*Sands*, 35 ft.

*Struthiolaria bed*, 4 ft. thick, strike N.N.W., dipping S.S.W. 20°. Other shells are included besides the *Struthiolaria*, but this genus is dominant.

*Yellow ochreous sand*, 80 ft.

*Sandy shale*, 12 ft.

*Lignite*, 2 ft.

*Sandy shale*, 120 ft. thick, bent into a syncline.

*White sand*, 2 ft.

*Sandy shale*, 6 ft.; white sands, 5 ft.

*Sandy shale*, 150 ft.

*Ochreous brown sand*, 20 ft.

*Greenish sand*, 15 ft.

*White sand*, greenish where it weathers, but stained ochreous brown in places, with hard concretionary sandstone band in the middle; total thickness, 25 ft.

*Calcareous sandstone* and concretionary bands with shells (*Struthiolaria* beds ?), 1 ft., striking N.E., dipping N.W. 45°.

*Greenish-grey sands*, 30 ft. (?).

*Broken-shell beds.*

*Sands*, thickness 130 ft. (?). There is some doubt about these beds, owing to the covering of soil.

*Limestone*, 7 ft. thick; strike, E. by N.; dip, N. by W. 55°.

In all this section there is no evidence of unconformity.

The next important section is that occurring in the upper part of Whitewater Creek above the limestone. In a small tributary to the north an excellent show of sections is displayed. Working down this, the following beds are exposed:—

*Sandy shales.*

*Sandy beds.*

*Shell beds* containing *Struthiolaria.*

*Sandy beds* with layers of shells in their lower portions.

*Sandy beds* with concretionary layers containing shell-remains, largely *Macrocallista*, the same as in the Thomas and Broken Rivers at this horizon.

*Sandy shell beds.*

*Limestone.*

These beds have a strike to the north, and dip west at an angle of 20°

In Moth Creek, a tributary of the Thomas coming in on the west side of Castle Hill, there occur sandy shales, blue greensands, and shales with coal. These strike along the creek to the north-east, and dip north-west at high angles—over 60°. In the Thomas River, below the junction with Moth Creek, occur sandy clays and shales with bluish greensands striking almost east and dipping north 65°, practically along the line of the Thomas at that part of its course, the strike of the beds swinging round in conformity with the direction of the limestones on the northern part of Castle Hill. Below the road-crossing the direction is also easterly, with northerly dip; but as the stream is followed down it gradually changes till the exposures near the mouth of the river are reached. Owing to the cover of slip accumulations from the high unstable terraces and river-banks, and the covering of grasses and soil, the exact sequence cannot be determined.

In the upper part of the Thomas River, close to the roadman's cottage, the higher members of this series are developed. They consist of shales, sandy clays, greensands, sulphur sands with occasional beds of impure coal in the lower part but with occasional interstratified layers of conglomerate in the higher portions, and thin bands of lignite. They dip up-stream—that is, to the west—at angles varying from 20° to 30°; some of the variation may, however, be due to slip, and their total thickness must exceed 500 ft. It is important to note the occurrence of the pebble beds at this stage, as they are found not only in other parts of the Castle Hill Basin but widely distributed throughout North Canterbury towards the close of the Tertiary series, and in perfect conformity with the underlying fossiliferous beds. They are specially well seen at the mouth of the Waipara, in the Mount Grey and Mairaki Downs, and up the Okuku River, and indicate the presence of land of considerable extent in close proximity to this region at the close of the Tertiary era.

In the Hog's Back Creek itself the higher members of this series of beds are exposed. At the mouth green sandy shales occur, and above them white sand; but the country is much slipped, and no good sections are exposed for some distance up the creek, where the directions of the beds are involved with the folds which have affected the limestones to the north in the vicinity of Waterfall Creek. However, they seem to conform to their direction.

In a small tributary on the south side of the Hog's Back Creek the beds strike north, and dip to the west at an angle of 35°; but at the mouth of this small creek they apparently have a strike which runs west of north: this may, however, be the result of slip. Half-way up the main creek there is exposed an impure lignitic sandy shale with a N. 70° E. strike and a dip of 30° to the south; this overlies a blue sand weathering brown. Farther up still, the beds strike east by north and dip south at 60° approximately, the beds consisting of white sand and sandy clays, the creek following along the strike. These beds are succeeded again by conglomerates with pebbles of greywacke, representing the highest beds exposed in the series.

At the point where the creek flows past the end of the Hog's Back it is impossible with the limited exposures to make out the relations, but in all probability the beds are pinched in, taking the form of a completely closed syncline, with the small outcrop of limestone noted previously as the western limb of the fold. On the other hand, they may be faulted down. On the west of the Hog's Back Ridge the fragmentary shell beds occur resting quite conformably against the limestone where it dips at high angles, but there is no exposure of the higher beds. In Waterfall Creek, too, there is a small exposure of the greenish sands in the syncline which terminates the limestone ridge.

In the northern part of the area the beds are best exposed in the main stream of Broken River above the gorge, and in its tributary, Murderer's Creek. In Broken River itself the beds are involved in a syncline, its axis being about half-way between the mouth of Trout Creek and the upper limestone gorge of the river (fig. 2). From this point the sequence of beds following down-stream consists of green sandy beds with shell fragments, greenish sands opposite the mouth of Trout Stream, sandy clays at the mouth of the Hog's Back Creek, succeeded by light-coloured sands and sandy clays, till the road-crossing is reached, where a bed of lignite 2 ft. thick crosses the road. Lower still, greenish-grey sands with broken-shell beds in its lower parts, then 50 ft. of sand and irregular broken-shell beds, followed by 140 ft. of sands, about 80 ft. of sands and shell beds, and 25 ft. of shelly bands more or less concretionary, the last-named lying over the limestone without any sign of physical break. The beds here strike N.N.W.-S.S.E. and have a westerly dip of about 20°, but farther up the stream the dip is flatter and the strike more east and west. Between the axis of the syncline and the upper limestone gorge the following sequence occurs: greenish sands, sandy shales with lignite, greenish sands; the angle of dip rising from about 15° to nearly vertical as the fault is approached and the beds abut against the faulted limestone.

A similar sequence of beds is seen in Murderer's Creek to the east, between the Natural Tunnel and Parapet Rock; but the creek runs for most of its length on or near the line of strike, so that few good sections are seen. The coal bed which crosses Broken River and appears in the Thomas, and between the two gorges of the Porter, is present, and forms a part of the bank of the stream for some distance. At the two ends of this section the beds are bent round so that they cross the stream nearly at right angles, and at the upper crossing numbers of fragments of *Struthiolaria tuberculata* were found, showing that this particular bed persists to the north end of the basin.

Beds of this horizon also occur in Coleridge Creek near its limestone gorge. In a small tributary creek just below the gorge the following sequence in descending order is found (fig. 5):—

*Limestone*, entirely out of place, as it resembles in lithological character the lower bed of stone in Coleridge Creek—that is, it is a fine-grained somewhat crystalline polyzoal stone. It is apparently overlain by greywacke, and owes its position to being pushed up from below along a fault-plane, so that it now overlies the beds which are really higher in the sequence, and is itself apparently overlain by Trias-Jura rocks.

*Greensands* and *dark sandy shales* interstratified, the beds being repeated, and followed by sands, which pass down into sands with concretionary bands and layers of shells, mostly in a fragmentary condition. These are succeeded in descending order by brownish sands with shells, and bluish-green sands with shell layers, lying on the upper layer of limestone conformably.

These beds are about 300 ft. thick; they strike north-east and south-west, and dip north-west 60°. The lower members of the sequence are repeated in reverse order on going down Coleridge Creek, and the strike and dip gradually change till the strike is approximately north-and-south and the dip to the west at an angle of 30°. These beds lie conformably on limestone.

Both McKay and Hutton have insisted on the existence of an unconformity above the lower limestone, but the evidence appears to me to be unsatisfactory. The former nowhere states definitely the reason why he considers an unconformity necessary, but his sections, notably those on pages 64 and 65 of his report, leave no doubt as to his position. His representation of the block of limestone in the upper part of Whitewater Creek as lying across the denuded edges of the tuffs and greensand beds is decidedly open to question, and is not borne out by my observations. I could find no exposures which warrant the arrangement of beds as indicated, and the position of the limestone block is easily and more satisfactorily explained by the occurrence of a fault, of which there is undoubtedly other good evidence, bounding the western side of the basin. In his section, too, on page 61 the representation of the beds does not appear to be altogether satisfactory; however, he shows a perfectly conformable sequence near the gorge of the Porter; but his interpretation of the section up the Whitewater has no doubt influenced his ideas of the country to the west of Castle Hill.

On page 406 of his article Hutton emphasizes the existence of the unconformity. His main line of evidence is that in the Coleridge Creek area the lower limestone does not now exist, but has been removed by denudation before the upper limestone was deposited. The absence of the lower limestone in this area can be explained satisfactorily on other grounds—viz., that it was never laid down, owing to the interference with deposition of calcareous beds by volcanic action. In the upper part of Coleridge Creek, more removed from the centre of activity, both beds of limestone, with their intervening tuffs, are quite normally developed and are conformable throughout, the whole sequence being represented. If, therefore, my interpretation of the structure is satisfactory, there is no reason for the unconformity. This opinion is further strengthened by the fact that in those places where the ash beds are not interstratified the lower limestone passes up without a break into the upper stone, and explains why it is that the lower stone does undoubtedly in general have the characteristic coralline character of the upper. They are in fact normally the same bed, and the ash beds do not indicate the presence of a break.

The unconformity which is placed higher in the sequence—that is, over the upper limestone—has also, in my opinion, no foundation palaeontologically or stratigraphically. As far as the last is concerned, the main evidence of Hutton rests upon the disagreement in the strike of the beds in the tributary of Whitewater Creek. After a careful examination of the locality I can see no evidence of this; any change in dip or strike is perfectly gradual, and entirely explicable on the grounds that the beds of the area have been subjected to gradual deformation. The fact that the Pareora beds rest in the northern portion of the basin on the Waipara series is not entirely correct, even assuming that the lower limestone is of Waipara age. In the lower part of Broken River, below the road and near the gorge, the sequence is perfectly conformable and normal; the same is entirely true near the limestone gorge in the Thomas and Porter Rivers. The only apparent discrepancy occurs near the fault which crosses the Broken River, and then it is perfectly possible that outcrops may be suppressed, as so frequently occurs in connection with strike faults. I do not think that this affects the case as far as the contact of the Pareora beds and the limestone is concerned, since to the west of the Hog's Back the Pareora beds lie perfectly conformably on the limestone, in that part of the area there being no tuff bed interstratified with the limestone, although it occurs underneath it. Showers of ashes had evidently not fallen in that area while the limestone was being laid down. It must be noted in this connection that Hutton admits fairly the absolute conformity of the beds exposed between the two limestone gorges of the Porter.

### D. TECTONIC FEATURES.

The main tectonic features are those indicated in my paper on the intermontane basins (p. 341), the conditions of faulting and folding being those which have resulted from the settling of a block of country with a consequent readjustment of the beds to a somewhat smaller area. An arrangement of inward-dipping beds towards the centre of the basin is materially departed from, although a cursory examination of the locality might encourage this belief. The main faults (see map) which are now clearly visible and affect the Tertiary beds are,—

(1.) A fault running north and south to the west of Castle Hill along the base of the Craigieburn Mountains, with a downthrow to the east, as a result of which isolated blocks of limestone are left stranded at the base of the range. It is difficult to arrive at a precise estimate of the amount of throw, but it is certainly some hundreds of feet. The situation of the stranded blocks is somewhat hard to account for, but they may be blocks which were separated from the main mass when the whole of the area was faulted down, their contacts with the adjacent greywackes not being visible, though the occurrence of limestone so close to the latter without any intervening shore-line beds does certainly suggest that this is not the position in which they were laid down. In the section figured in my paper just cited the contact of the limestones with the greywacke to the west of the Hog's Back represents a contact without indication of a fault. At this spot the junction is extremely obscure, and it may be a shore-line or a fault contact—probably the latter, as this would be on the line of the undoubted fault continued north from the west of Castle Hill.

(2.) There is another pronounced fault, running north-east and south-west through Parapet Rock on the main road in the direction of Broken River. This is evidently closely connected with the folding of the beds, and grades at both ends into folds. The downthrow is to the south-east, and there is considerable lateral movement of the blocks of limestone, as is evident from the brecciated and slickensided surfaces.

(3.) Hutton considered that a fault ran from the northern end of Castle Hill eastwards toward the upper limestone gorge of the Porter. This is apparently of the same nature as the last, the folding at the two ends being undoubted; but the middle portion, where faulting should be visible if it really existed, is covered with river-gravels and is completely masked.

(4.) A well-defined line of fault runs parallel to Coleridge Creek in a north-east and south-east direction, as is evident from the stranded blocks of limestone left high and dry on the north-west side of the creek: in fact, the whole valley of this stream appears to be determined by an earth-fracture, the later sedimentaries being dropped down and to some extent pinched in between the walls of greywacke. The folding which the beds exhibit is in all probability due to the folding which attended this dislocation of the strata. This line of fault may be continuous with the fracture which no doubt determined the eastern boundary of the basin, as it will conform thereto with but slight alteration in direction. When this line is continued to the south-east it reaches Coleridge Pass, which forms a slight depression in the lofty ridge of the Craigieburn Range; but there is no positive evidence of its continuance into the basin of the Rakaia on the western side of the range, although its extension in this direction is extremely probable.

## E. VOLCANIC ROCKS.

The volcanic rocks of the area have been described by Hutton. They consist almost entirely of fragmentary matter, which is very thick between Coleridge Creek and Whitewater Creek; in the latter this reaches 1,000 ft. approximately. The beds are also strongly developed near the mouth of the Thomas and in Home Creek. The fragments are usually of small size, pieces over 3 in. in diameter being rare, and are extremely well bedded, indicating submarine deposition, from their association with limestones, and from the marked amount of calcareous material which they frequently show, and from the numerous marine fossil remains which they contain. The fragments are of glassy character, at times with the yellow colour characteristic of palagonite; at others the glass is clouded with iron-ore and with microlites of feldspar, and somewhat frequent crystals of olivine. Deposits of the same character occur just outside the Trelissick Basin near the junction of the Esk River with the Waimakariri, and near the junction of Sloven's Creek with Broken River. In both these cases the beds are well stratified and associated with beds of calcareous material, pointing to a wide extension of the sea over the region in which the volcanoes were situated.

Hutton has noted the occurrence of dykes round the base of Prebble Hill. They do not, however, appear to radiate from any particular point, and are perhaps only remotely connected with the volcanic outbursts. Similar dykes occur on the northern flanks of Mount Torlesse, somewhat distant from the centres of explosive action, the most noteworthy being that on the northern side of the bridge across Broken River, and in Iron Creek, on the western boundary of the Mount Torlesse coal-mining lease.

Other intrusions have not been found in position, but numerous boulders and pebbles of olivine gabbro are found in the bed of the Porter River. In all probability they have been shed from minor intrusions such as are known to occur in the greywackes farther south in the Acheron Valley, from which the large masses found in the gravels of the Rakaia River may probably be traced.

## F. PALAEONTOLOGY.

Although the correlation of the beds in different parts of the area can be determined with reasonable certainty from their stratigraphical relations alone, the palaeontological evidence on which their correlation with beds outside the particular area is based must be considered in detail. The fossil-content of the various beds will be dealt with in order, the authority for the collection of the specimens being given in each case.

The oldest bed in the area which has yielded plant fossils up to the present is the plant-fossil bed in Murderer's Creek, the collection from which was submitted to von Ettingshausen,* of Vienna. There is apparently some doubt about the localities, but these were revised by Hector. In the list given there the following species are recorded :—

*Quercus lonchitoides* Ett.
*Planera australis* Ett.
*Dryandra camptoniaefolia* Ett.
*Cassia pseudophaseolites* Ett.

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* C. VON ETTINGSHAUSEN, Contributions to the Knowledge of the Fossil Flora of New Zealand, *Trans. N.Z. Inst.*, vol. 23, 1891, p. 250.

All these fossil plants are spoken of by the author of the article as having a distinct Tertiary facies, and to be related closely to plants of undoubted Tertiary age from other parts of the world, notably Australia. The characteristic Tertiary character of this flora is very important when the nature of the fauna of the beds immediately overlying is considered. The presumption is that the beds containing it would be undoubtedly admitted as Tertiary were there not beds in another part of the area in a slightly higher position containing animal remains which point distinctly to a Cretaceous age for the containing beds. These occur at the base of the series in Broken River itself, near the eastern margin of the basin, in beds overlying the coal-measures. From this horizon McKay collected *Conchothyra parasitica* Hutt., as well as species of *Perna*, *Cerithium*, and other fossils; and the present author has also collected *Inoceramus* fragments and casts, as well as *Perna*. and *Conchothyra* included among a mass of fragments of black oyster. In beds of approximately the same horizon above the upper limestone gorge of Broken River fragments of saurian bones were also found.

But the lowest horizon from which a representative suite of fossils has been obtained is that of the tuff bed in Coleridge Creek, which is interstratified with the sands and marls above the greensands. From this bed Thomson and the author obtained a number of forms, a list of which has already been published by Thomson.* I have included this list, with additional finds of my own, which will serve to strengthen the position taken by Thomson in his paper as to the age of the beds. The following is the complete list:—

***Admete trailli* (Hutt.).
*Ampullina miocenica* Sut.
*Ampullina suturalis* (Hutt.).
*Ancilla papillata* (Tate).
*Ancilla subgradata* (Tate).
**Callistoma aucklandicum* Smith.
**Cantharidus* sp. very similar *C. pruninus perobtusus* Pils.
*Chione chiloensis truncata* Sut.
*Clio* (*Styliola*) sp. like *Clio tatei* Sut. but larger.
*Cominella intermedia* Sut.
*Coptochetus* sp.
*Crassatellites obesus* (A. Ad.).
*Epitonium marginatum* (Hutt.).
*Epitonium rugulosum lyratum* (Zitt.).
*Epitonium zelebori* Dkr. var.
**Fulgoraria arabica elongata* (Swains).
**Fulgoraria gracilis* (Swains).
*Fusinus bicarinatus* Sut.
*Hemifusus gonoides* Sut.
*Lapparia corrugata* (Hutt.).
*Leucosyrinx alta* (Harris) = *Turris altus* (Harris).
*Limopsis catenata* Sut.
*Marginella harrisi* Cossm.
*Paphia curta* (Hutt.).
*Pecten* sp. ?
*Polinices gibbosus* (Hutt.).
*Polinices huttoni* Iher.
*Polinices ovatus* (Hutt.).
*Seila huttoni* Sut.
*Siphonalia costata* (Hutt.).
**Siphonalia nodosa* (Mart.).
*Siphonalia turrita* Sut.
*Siphonalia* sp. ?
**Siphonium planatum* Sut.
*Surcula seminuda* Sut.
*Terebra costata* Hutt.
*Turritella concava* Hutt.

Of these thirty-seven species, seven (including a doubtful species of *Cantharidus*)—viz., those marked with an asterisk—are Recent, the per-

* J. A. Thomson. The Flint-beds associated with the Amuri Limestone of Marlborough, *Trans. N.Z. Inst.*, vol. 48, 1916, p. 51.

centage being 19—exactly the same figure as Thomson arrived at from a restricted list. This clearly indicated a Lower Tertiary age. It is noteworthy, also, that this bed, one of the lowest in the series, does certainly contain the lowest percentage of Recent forms yielded by beds which are admittedly of Tertiary age.

The next higher fossiliferous horizon in the tuffs is that underneath the lower layer of limestone, the special localities being (1) above the upper limestone gorge of the Porter, and (2) the gorge of the Broken River below the road-crossing.

In the former the following were collected by Thomson :—

*Callistoma aucklandicum* Smith.
*Calyptraea maculata* (Q. & G.).
*Cantharidus tenebrosus* A. Ad.
*Emarginula wannonnensis* Harris.
*Natica australis* (Hutt.).
*Natica zelandica* Q. & G.
*Pecten hutchinsoni* Hutt.
*Pecten yahlensis* T.-Woods.
*Siphonium planatum* Sut.

Of these, all but two species are Recent. In addition to the above McKay collected from this locality in the greensands a species of *Tellina* and also *Ostrea subdentata* (Hutt.), although on the authority of Hutton this specimen really came from the marls. In any case, this Tertiary species comes from beds underlying the tuffs conformably, according to all authorities, and serves to emphasize further the Tertiary age of the beds in this locality at this particular horizon.

In the tuff bed below the limestone in Broken River the following were collected, principally by Thomson :—

*Ampullina suturalis* (Hutt.).
*Ancilla papillata* (Tate).
*Callistoma aucklandicum* Smith.
*Calyptraea maculata* (Q. & G.)
*Cardium spatiosum* Hutt.
*Clio tatei* Sut.
*Crassatellites cordiformis* Sut.
*Crepidula crepidula* (L.).
*Cypraea ovulatella* Tate.
*Diplodonta zelandica* (Gray).
*Emarginula wannonnensis* Harris.
*Flabellum laticostatum* T.-Woods.
*Fulgoraria gracilis* (Swains.).
*Lima huttoni* Sut.
*Modiolaria elongata* (Hutt.).
*Natica zelandica* Q. & G.
*Panopea orbita* Hutt.
*Pecten williamsoni* Zitt.
*Pholadidea concentrica* Sut.
*Phos cingulatus* (Hutt.).
*Psammobia lineolata* Gray.
*Siphonalia mandarina* (Duclos).
*Siphonium planatum* Sut.
*Tellina eugonia* Sut.
*Trochus nodosus* Hutt.

Of these, eleven are Recent species, five of the seven from the upper gorge of the Porter being identical.

From this tuff bed McKay also records (*loc. cit.*, p. 74) numerous specimens of brachiopods of the genera *Terebratula*, *Waldheimia*, *Terebratella*, and *Rhynchonella*. McKay also records the occurrence of spines and plates of *Cidaris*, and specimens of *Echinus enysi* Hutt., as well as *Turbinolia* and various other corals.

The upper tuff bed at the junction of the Thomas River and the Porter is perhaps the most prolific locality in the whole district. The following is the list of fossils collected from there, the name of the collector being indicated by initials: E. = Enys; M. = McKay; T. & S. = Thomson and Speight, 1914; and S. = Speight, 1915.

**Ancilla australis* (Sow.) E.
**Ancilla bicolor* (Gray). M.
**Ancilla mucronata* (Sow.). T. & S.
*Ancilla pseudaustralis* (Tate). E.
*Callistoma acutangulum* Sut. T. & S.
*Callistoma filiferum* Sut. E.
*Callistoma oryctum* Sut. T. & S., E.
**Calyptraea maculata inflata* (Hutt.). E., T. & S., S.
**Calyptraea scutum* Less. T. & S.
**Capulus australis* (Lamk.). M.
*Cardium spatiosum* Hutt. S.
*Cardium waitakiense* Sut. T. & S.
*Chione subroborata* Tate. E.
**Chione yatei* (Gray).
*Corbula humerosa* Hutt. S.
**Corbula zelandica* Q. & G. E., M., T. & S.
*Crepidula striata* (Hutt.). E.
*Cucullaea ponderosa* Hutt. S.
*Cylichnella enysi* (Hutt.). M., E.
*Cypraea ovulatella* Tate. E., T. & S.
*Daphnella neozelanica* Sut. M.
*Dentalium solidum* Hutt. M.
**Diplodonta striata* Hutt. E.
**Diplodonta zelandica* (Gray). T. & S.
**Divaricella cumingi* (Ad. & Ang.). M. & E.
**Dosinia caerulea* (Reeve).
*Epitonium cylindrellum* Sut. E.
**Euthria striata* (Hutt.). E.
**Fulgoraria arabica elongata* (Swains.) E.
*Glycymeris cordata* Hutt. S.
*Glycymeris globosa* (Hutt.). M.
**Lima angulata* Sow. M., S.
**Lima bullata* (Born). S.
*Lima colorata* Hutt. T. & S.
**Lima lima* (L.). M., E.
**Limopsis aurita* (Brocchi). S.
*Limopsis catenata* Sut. T. & S., S.
*Limopsis zittelli* Iher. E.
**Loripes concinna* Hutt. M.
*Macrocallista assimilis* (Hutt.). S.
**Macrocallista multistriata* (Sow.). T. & S.
*Mactra attenuata* Hutt. S.
**Mactra elongata* Q. & G. M., E.
*Marginella dubia* Hutt. S.
*Modiolaria elongata* (Hutt.). T. & S., E., S.
**Modiolus australis* (Gray). T. & S., M., S.
*Modiolus dolichus* Sut. M.
*Monilea praetextilus* Sut. M.
*Monilea sulcatina* Sut. M.
*Mya* n. sp. S.
**Myodora subrostrata* Smith. M.
**Mytilus canaliculus* Mart. S.
*Olivella neozelanica* (Hutt.). S.
*Panopea orbita* Hutt. T. & S.
*Panopea worthingtoni* Hutt. M.
**Panopea zelandica* Q. & G. T. & S.
*Paphia curta* (Hutt.). S.
**Paphia intermedia* (Q. & G.). M.
*Pecten athleta* Zitt. S.
*Pecten beethami* Hutt. M.
*Pecten chathamensis* Hutt. T. & S., S.
**Pecten convexus* (Q. & G.) M.
*Pecten delicatulus* Hutt. E., S.
*Pecten hutchinsoni* Hutt. S.
*Pecten palmipes* Tate. E.
*Pecten triphooki* Zitt. M.
*Pecten williamsoni* Zitt. E.
*Pecten yahlensis* T.-Woods. S.
**Pholadidea tridens* (Gray). M.
*Pholadomya neozelanica* Hutt. S.
*Polinices gibbosus* (Hutt.). M.
*Polinices ovatus* (Hutt.). E.
**Protocardia pulchella* (Gray). E.
*Protocardia sera* Hutt. M.
**Psammobia lineolata* Gray. E.
**Siphonium planatum* Sut. M.
**Tellina glabrella* Desh. S.
*Teredo heaphyi* Zitt. T. & S.
*Trochus avarus* Sut. E.
*Trochus nodosus* Hutt. E.
*Turbo etheridgei* T.-Woods. E.
*Turritella bicincta* Hutt. E.
*Turritella concava* Hutt. M., S.
*Turritella murrayana* (Tate). E., T. & S.
**Venericardia difficilis* (Desh.). T. & S.
*Venericardia difficilis benhami* (Thomson). E.
*Venericardia purpurata* (Desh.) (*australis* Lamk.) S.

It is generally admitted that the tuffs underneath the limestone in the Whitewater Creek section are in the same stratigraphical position as those between the limestones in the Porter. From the former the following were collected :—

**Ancilla australis* (Sow.). M.
**Ancilla depressa* (Sow.). T. & S.
**Callistoma aucklandicum* Smith. T. & S.
**Calyptraea maculata* (Q. & G.). M.
**Cantharidus tenebrosus* A. Ad. M.
**Capulus australis* (Lamk.). M.
*Cardium facetum* Sut. T. & S.
*Cardium patulum* Hutt. M.
**Cochlodesma angasi* (C. & F.) ? M.
*Cymatium minimum* (Hutt.). M.
*Cypraea ovulatella* Tate. M.
*Cypraea trelissickensis* Sut. M.
*Cytherea chariessa* Sut. M.
**Emarginula wannonensis* Harris. M.
*Epitonium cylindrellum* Sut. M.
*Fissuridea annulata* Sut. M.
*Lapparia corrugata* (Hutt.). M.
**Lima bullata* (Born). M., T. & S.
*Lima colorata* Hutt. M.
**Limopsis aurita* (Brocchi). M.
**Mactra elongata* Q. & G. M.
*Marginella dubia* Hutt. M.
*Pecten palmipes* Tate. M.
*Polinices huttoni* Iher. M., T. & S.
*Protocardia sera* Hutt. M.
*Siphonalia orbita* Hutt. T. & S.
**Siphonium planatum* Sut. M.
*Teredo heaphyi* Zitt. M., T. & S.
*Trivia zealandica* T. W. Kirk. M.
*Trochus nodosus* Hutt. M.
*Turritella bicincta* Hutt. M., T. & S.

In addition to the species enumerated, Hutton records the occurrence of the following in the tuffs and greensands, presumably from the upper tuffs, since he does not mention the lower tuffs (*loc. cit.*, p. 405) :—

*Ancilla hebera* (Hutt.).
**Arca decussata* (Sow.).
*Brissus eximius* Zitt.
**Calliostoma spectabile* (A. Ad.).
*Crassatellites attenuatus* (Hutt.).
*Echinus woodsii* Laube.
*Flabellum laticostatum* T.-Woods.
*Flabellum sphenodeum* T.-Woods.
*Fulgoraria attenuata* (Hutt.).
*Leiocidaris australis* Duncan.
*Lima jeffreysiana* Tate.
*Mitra enysi* (Hutt.).
*Mytilus striatus* Hutt.
**Natica australis* (Hutt.).
*Paphia attenuata* Hutt.
*Pecten polymorphoides* Zitt.
*Pericosmus compressus* McCoy.
*Turritella ambulacrum* Sow.
*Venericardia pseutes* Sut.

Hutton remarks that *Flabellum laticostatum* is not found elsewhere, but it certainly occurs in the lower tuff bed at Broken River. He also places the percentage of Recent Mollusca at about 10 per cent. This, however, is much too low in point of fact, and the discrepancy emphasizes the danger of trusting to such percentages for the purposes of determining the age when the number of forms collected is comparatively small.

He also records the occurrence of *Pecten hochstetteri* Zitt. and *Waldheimia triangularis* Hutt. in the overlying limestone.

From the upper tuff beds McKay records obtaining *Echinus enysi* Hutt., *Cidaris* (plates and spines), *Meoma tuberculata* Hutt., *Turbinolia*, and numerous branching and leaf corals which I do not think have been definitely identified.

The following is a list of the fossils collected from the shell bed above the upper limestone at the spot where the great fall of rock into the Porter River has taken place. The greater number occur in a layer which it is evident lies conformably on the limestone in the layer next above, being composed of finely comminuted shells.

*Ancilla papillata* (Tate). S.
*Ancilla pseudaustralis* (Tate). T. & S.
**Anomia walteri* Hect. T. & S., S.
**Arca decussata* (Sow.). T. & S.
*Astraea* (*Cyclocantha*) *bicarinata* Sut. S.
*Astraea transenna* Sut. T. & S.
*Astraea tuberosa* Sut. T. & S.
*Brechites* sp. ? S.
**Calyptraea alta* (Hutt.). S.
**Calyptraea maculata* (Q. & G.).
*Cardium spatiosum* Hutt. T. & S., S.
*Cardium patulum* Hutt. T. & S.
*Cardium subcordatum* Sut. T. & S.
*Cerithium nodosum* Hutt. S.
*Chione speighti* Sut. S.
**Cominella carinata* (Hutt.). S.
*Crassatellites amplus* (Zitt.). S.
*Crassatellites attenuatus* (Hutt.). T. & S., S.
**Crassatellites obesus* (A. Ad.). T. & S., S.
*Crepidula gregaria* Sow. S.
**Crepidula monoxyla* (Less.). S.
*Crepidula striata* (Hutt.). T. & S., S.
*Cucullaea alta* Sow. S.
*Cucullaea alta* var. B Hutt. S.
*Cypraea ovulatella* Tate. S.
*Cytherea enysi* Hutt. S.
*Cytherea sulcata* (Hutt.). S.
**Dosinia greyi* Zitt. S.
**Dosinia magna* Hutt. T. & S., S.
*Dosinia subrosea* (Gray). S.
**Fulgoraria arabica* (Mart.). T. & S., S.
*Glycymeris cordata* (Hutt.). S.
*Glycymeris globosa* (Hutt.). T. & S.
*Hinnites trailli* Hutt. T. & S., S.
**Lima angulata* Sow. S.
**Lima bullata* (Born). T. & S.
*Lima colorata* Hutt. T. & S., S.
*Lima jeffreysiana* Tate. S.
*Macrocallista assimilis* (Hutt.). S.
*Modiolaria elongata* (Hutt.). T. & S.
*Modiolus dolichus* Sut. S.
**Mytilus canaliculus* Mart. T. & S.
*Mytilus huttoni* Cossm. S.
**Mytilus magellanicus* Lamk. S.
*Mytilus striatus* Hutt. T. & S.
*Paphia curta* (Hutt.). S.
**Paphia intermedia* (Q. & G.). T. & S.
*Pecten burnetti* Zitt. S.
*Pecten chathamensis* Hutt. S.
*Pecten hutchinsoni* Hutt. S.
*Polinices gibbosus* (Hutt.). T. & S., S.
**Psammobia stangeri* Gray. S.
*Pecten semiplicatus* Hutt. S.
**Siphonalia dilatata* (Q. & G.). T. & S., S.
**Siphonalia nodosa* (Mart.). S.
*Siphonalia turrita* Sut. T. & S.
**Stephopoma nucleogranosum* Verco. T. & S.
*Struthiolaria cincta* Hutt. S.
*Struthiolaria tuberculata* Hutt. T. & S., S.
*Trochus nodosus* Hutt. S.
*Turbo superbus* Zitt. T. & S.
*Turritella concava* Hutt. T. & S., S.
*Turritella patagonica* Sow. T. & S.
**Venericardia difficilis* (Desh.). S.
*Venericardia pseutes* Sut. (*patagonica* Hutt.). S.
**Zenatia acinaces* (Q. & G.). S.

The locality from which the above list of fossils comes is such a striking one that its absence of record by McKay and Hutton probably indicates that the fall of rock had not taken place in their time. The latter gives a list of fossils obtained from the beds immediately overlying the limestone in the Whitewater Creek and the Thomas River (*loc. cit.*, p. 409), which will correspond closely in stratigraphical position with these beds, and twenty-nine species are recorded as occurring in them. Of these. fourteen species occur in the above list from the "Shell bed," and of the remaining fifteen species five occur in lower beds of the series, while the following are unrecorded :—

*Chione yatei* (Gray).
*Crepidula costata* (Sow.).
*Cucullaea worthingtoni* Hutt.
*Cytherea oblonga* (Hanley).
*Glycymeris laticostata* (Q. & G.).
*Lima crassa* Hutt.
*Serpulorbis sipho* (Lamk.).
*Turritella cavershamensis* Harris.
*Turritella rosea* Q. & G.
*Volutospina* (*Athleta*) *huttoni* Sut. var. *pseudorarispina* (McCoy).

Of these ten species, five are Recent and five extinct forms.

From the upper beds of the Whitewater Creek and the Thomas River Hutton collected the following Mollusca (*loc. cit.*, p. 409) :—

*Ancilla australis* (Sow.).
*Anomia undata* Hutt.
*Bathytoma sulcata* (Hutt.).
*Calyptrea maculata* (Q. & G.).
*Cantharidus tenebrosus* A. Ad.
*Cerithium nodosum* Hutt.
*Chamostrea albida* (Lamk.).
*Cominella carinata* (Hutt.).
*Cominella maculata* (Mart.).
*Crassatellites amplus* (Zitt.).
*Crepidula monoxyla* Less.
*Cytherea enysi* Hutt.
*Dentalium solidum* Hutt.
*Fulgoraria arabica* Mart.
*Fulgoraria gracilis* (Swains).
*Glycymeris laticostata* Q. & G.
*Hemiconus trailli* (Hutt.).
*Macrocallista assimilis* (Hutt.).
*Mactra discors* Gray.
*Mytilus canaliculus* Mart.
*Natica australis* Tate.
*Olivella neozelanica* (Hutt.).
*Perna* sp. ind.
*Polinices gibbosus* (Hutt.).
*Polinices huttoni* Iher.
*Polinices ovatus* (Hutt.).
*Siphonalia mandarina* (Duclos).
*Struthiolaria cingulata* Zitt.
*Struthiolaria obesa* Hutt.
*Struthiolaria tuberculata* var. B Hutt.
*Surcula hamiltoni* (Hutt.).
*Thais succincta* (Mart.).
*Turbo superbus* Zitt.
*Turritella symmetrica* Hutt.
*Venericardia pseutes* Sut.
*Volutospina* (*Athleta*) *huttoni* Sut.

The following is a list of the fossils obtained in the small tributary of Whitewater Creek coming in from the north, in what may be called the *Struthiolaria* bed from the number of remains of this genus occurring. The same bed is met with in a similar stratigraphical position in the Porter River between the gorges and in the Thomas River.

*Ancilla papillata* (Tate).
*Crassatellites obesus* (A. Ad.).
*Crepidula gregaria* Sow.
*Cylichnella enysi* (Hutt.).
*Polinices gibbosus* (Hutt.).
*Psammobia stangeri* Gray.
*Struthiolaria tuberculata* Hutt.

In Murderer's Creek, just below Parapet Rock, from beds which are in the same stratigraphical position as the foregoing, the following were obtained :—

*Crassatellites amplus* (Zitt.).
*Mesodesma australe* (Gmel.).
*Polinices gibbosus* (Hutt.).
*Siphonalia* cf. *nodosa* (Mart.). (An imperfect specimen.)

The salient features brought out by these lists are as follows :—

(1.) The lowest beds contain a Tertiary land flora.

(2.) Over these lie conformably beds containing a Cretaceous marine fauna, a fauna which in other parts of New Zealand, such as at Malvern

Hills, Waipara, and Amuri Bluff, is associated with marine reptiles and belemnites and ammonites—*i.e.*, free-swimming forms.

(3.) All the remaining horizons indicate a Tertiary fauna, the oldest—*i.e.*, the tuffs interstratified in the marls at Coleridge Creek—containing only 19 per cent. of Recent species, while the higher beds contain as follows: The tuff under the limestone at the Porter River, 7 species out of 9; the tuff bed below the limestone in Broken River, 11 out of 24; the tuff bed between the limestones near the mouth of the Thomas River, 33 out of 87, or 38 per cent.: the tuff bed under the limestone at Whitewater Creek contains 11 out of 29 species; the shell bed at the fall of rock yields 21 out of 66—*i.e.*, 32 per cent.: while from the higher beds in the Thomas River and Whitewater Creek, out of 42 species 13, or 31 per cent., are Recent.

The low percentage of Recent forms in the tuffs interstratified in the marls at Coleridge Creek is very significant, as it indicates a lower Tertiary age for these beds—granting that we can rely on percentages of Recent forms as an accurate basis for age-determination—whereas the higher beds contain a percentage that would lead one to think that they were mid-Tertiary. There is, however, no regular increase in percentages as higher beds in the series are considered, a fact perhaps due to the conditions not favouring the entombment of a representative fauna, or, if it has been preserved, it has not been thoroughly examined or collected from. Several well-marked and distinctive forms are, however, persistent right through the series. There is no indication of a distinct faunal break from the tuffs under the limestone up to the highest beds from which fossils have been recorded. There is, on the other hand, this low percentage of Recent forms in the tuffs interstratified in the marls, and a clear faunal break between these beds and those containing a Cretaceous fauna, although the flora associated with this is undoubtedly Tertiary. There is, however, no evidence of the existence of a physical break between these marls and the oyster bed with its Cretaceous fauna, and this opinion has been held by every authority who has examined the section—even Hutton agrees with this; and, further, the last-named authority even agrees that there is no physical break up to the top of the lower limestone: nevertheless the tuffs underneath it undoubtedly contain a Tertiary fauna. This is one of the most important points brought out by a consideration of the locality, and it strongly supports the contention urged by Marshall, Speight, and Cotton, 1910 (*loc. cit.*), and later by Marshall alone, as to the physical conformity of our Cretaceous and Tertiary series.*

The two chief explanations put forward to account for the association of Cretaceous and Tertiary forms in a conformable series are—(1) That the Cretaceous forms survived into the Tertiary era in this region after they had disappeared from other parts of the world, perhaps owing to their having been cut off by land barriers from competition with other forms, just as sea barriers enabled the different archaic forms of land-animals to persist on the land in this part of the world long after they had become extinct elsewhere; (2) that owing to the slow deposition of the marine beds in late Cretaceous

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* P. Marshall, The Younger Rock Series of New Zealand, *Geol. Mag.* (n.s.), dec. v, vol. 9, 1912, p. 314; The "Cretaceo-Tertiary" of New Zealand, *Geol. Mag.* (n.s.), dec. v, vol. 10, 1913, p. 286; New Zealand and Adjacent Islands, *Handbuch der regionalen Geologie*, Band 7, Abt. 1, Heidelberg, 1911, p. 28.

and early Tertiary times a comparatively thin series of deposits represents an enormous period, and that ample space of time was thereby afforded for great changes in the fauna.

The main difficulty in accepting the former explanation is that in other localities in fairly close proximity the molluscan fauna of more or less fixed habitat is associated with free-moving forms and with marine reptiles, both of which are likely to have a wide range in space: and if they peopled other parts of the ocean they must, except under most peculiar circumstances, have penetrated the then New Zealand seas, seeing that it is very unlikely that a portion of the sea surface of the world was completely shut off from the general ocean. It is, of course, possible, but improbable. The other explanation therefore appears to me to be more satisfactory. In the area under consideration the thickness of the beds between those containing the Cretaceous fauna and those with a Tertiary fauna certainly amounts to 1,800 ft.—no mean thickness—and the conditions of deposition were in all probability very slow. In discussing the circumstances of deposition it is important to note that the form of the land surface was entirely different from that now existing,* and that the land in the neighbourhood was probably of low relief and did not furnish any large amount of sediment. The greensands and marls were also laid down in fairly deep water, where deposition would be slow. It seems probable that after the deposition of the coals and estuarine beds at the base of the series the area was depressed, and deposition was slow in the relatively deep water in which the marl was laid down, the unconformity, if any, being due to depression beyond the limit of deposition—that is, a *per saltum* unconformity, and not one due to elevation of the land, erosion, and subsequent depression. That a shallowing of the sea took place towards the close of this period is evident from the presence of the interstratified sands and conglomerates, which become increasingly important towards the top of the series. Numerous instances of slow deposition and small thickness of beds in one area associated with great thickness in an adjoining area can be cited from many parts of the world, but perhaps the most striking one is that afforded by the Silurian beds of Scandinavia, with their compressed though complete sequence, as compared with the beds of the same age in Wales, which are distinguished by their thickness, the former owing their relative thinness to slow deposition in deep water off the shore-line of a continent.

Volcanic activity became manifest in certain parts of the Trelissick area while the marls and sands were being laid down, especially in the neighbourhood of Whitewater and Coleridge Creeks, the eruptions being almost entirely of fragmentary material, and submarine. In close proximity to the centres of volcanic action the limestones thin out and disappear, whereas they are thick in those parts of the area remote from volcanic activity, especially towards the east of the basin. It is probable that while volcanic activity was fairly continuous at one point deposition of limestones was continuous a little distance away, and that in the intermediate localities the limestones and volcanic products are interstratified.

* R. SPEIGHT, The Intermontane Basins of Canterbury, *Trans. N.Z. Inst.*, vol. 47, 1915, p. 345.

## List of Tertiary Mollusca obtained in the Trelissick Basin, arranged for Purposes of Comparison.

The numbers at the heads of the various columns correspond with the following localities:—

1. Tuff beds interstratified with marls, Coleridge Creek.
2. Lower tuff beds, Porter River, just above the limestone gorge.
3. Lower tuff beds, Broken River, just below the limestone gorge.
4. Upper tuff beds, junction of Thomas River with Porter River.
5. Tuff beds, below limestone, Whitewater Creek.
6. Shell bed, at rock fall in Porter River.
7. Sandy beds between the two gorges of the Porter River and in the Thomas River near its junction with the Porter (according to Hutton); also specimens collected by the author in beds of similar position in a tributary on north side of the Whitewater River.

(The suffix *h* indicates that Hutton is responsible for the record of the occurrence of the species in the locality.)

| — | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|
| **Admete trailli* (Hutt.) .. .. | | .. | .. | .. | .. | .. | .. |
| *Ampullina miocenica* Sut. .. | | .. | .. | .. | .. | .. | .. |
| —— *suturalis* (Hutt.) .. .. | | .. | | .. | .. | .. | .. |
| **Ancilla australis* (Sow.) .. .. | .. | .. | .. | | | .. | ×*h* |
| *—— *bicolor* (Gray) .. .. | .. | .. | .. | | .. | .. | .. |
| *—— *depressa* (Sow.) .. .. | .. | .. | .. | .. | | .. | .. |
| —— *hebera* (Hutt.) .. .. | .. | .. | .. | *h* | .. | .. | .. |
| *—— *mucronata* (Sow.) .. .. | .. | .. | .. | | .. | .. | .. |
| —— *papillata* (Tate) .. .. | | .. | | .. | .. | | |
| —— *pseudaustralis* (Tate) .. | .. | .. | .. | | .. | | .. |
| —— *subgradata* (Tate) .. .. | | .. | .. | .. | .. | .. | .. |
| **Anomia undata* Hutt. .. .. | .. | .. | .. | .. | .. | .. | ×*h* |
| *—— *walteri* Hect. .. .. | .. | .. | .. | .. | .. | | .. |
| **Arca decussata* (Sow.) .. .. | .. | .. | .. | *h* | .. | | .. |
| *Astraea bicarinata* Sut. .. .. | .. | .. | .. | .. | .. | | .. |
| —— *transenna* Sut. .. .. | .. | .. | .. | .. | .. | | .. |
| —— *tuberosa* Sut. .. .. | .. | .. | .. | .. | .. | | .. |
| *Bathytoma sulcata* (Hutt.) .. | .. | .. | .. | .. | .. | .. | ×*h* |
| *Brechites* sp. .. .. .. | .. | .. | .. | .. | .. | | .. |
| **Calliostoma acutangulum* Sut. .. | .. | .. | .. | | .. | .. | .. |
| —— *aucklandicum* Sm. .. .. | | | | .. | | .. | .. |
| —— *filiferum* Sut. .. .. | .. | .. | .. | | .. | .. | .. |
| —— *oryctum* Sut. .. .. | .. | .. | .. | | .. | .. | .. |
| *—— *punctulatum* (Mart.) .. | .. | .. | .. | .. | .. | .. | .. |
| *—— *spectabile* (A. Ad.) .. | .. | .. | .. | *h* | .. | .. | .. |
| **Calyptraea alta* (Hutt.) .. .. | .. | .. | .. | .. | .. | | .. |
| *—— *maculata* (Q. & G.) .. | .. | | × | .. | .. | | ×*h* |
| *—— *maculata inflata* (Hutt.) .. | .. | .. | .. | | | .. | .. |
| *—— *scutum* Less. .. .. | .. | .. | .. | | .. | .. | .. |
| **Cantharidus pruninus perobtusus* Pils. | ? | .. | .. | .. | .. | .. | .. |
| *—— *tenebrosus* A. Ad. .. .. | .. | | .. | .. | | .. | ×*h* |
| **Capulus australis* (Lamk.) .. | .. | .. | .. | | | .. | .. |
| *Cardium facetum* Sut. .. .. | .. | .. | .. | .. | × | .. | .. |
| —— *patulum* Hutt. .. .. | .. | | .. | .. | .. | | .. |
| —— *spatiosum* Hutt. .. .. | .. | .. | | | .. | | .. |
| —— *subcordatum* Sut. .. .. | .. | .. | .. | .. | .. | | .. |
| —— *waitakiense* Sut. .. .. | .. | .. | .. | | .. | .. | .. |
| *Cerithium nodosum* Hutt. .. | .. | .. | .. | .. | .. | | ×*h* |
| **Chamostraea albida* (Lamk.) .. | .. | .. | .. | .. | .. | .. | ×*h* |
| *Chione chiloensis truncata* Sut. .. | | .. | .. | .. | .. | .. | .. |

| — | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|
| *Chione speighti* Sut. | .. | .. | .. | .. | .. | × | .. |
| —— *subroborata* Tate | .. | .. | .. | × | .. | .. | .. |
| *—— *yatei* (Gray) | .. | .. | .. | × | .. | × *h* | .. |
| *Clio tatei* Sut. | × ? | .. | × | .. | .. | .. | .. |
| **Cochlodesma angasi* (C. & F.) | .. | .. | .. | .. | .. | .. | .. |
| *Cominella carinata* (Hutt.) | .. | .. | .. | .. | .. | × | × *h* |
| —— *intermedia* Sut. | × | .. | .. | .. | .. | .. | .. |
| * —— *maculata* (Mart.) | .. | .. | .. | .. | .. | .. | × *h* |
| *Coptochetus* sp. ? | | .. | .. | .. | .. | .. | .. |
| *Corbula humerosa* Hutt. | .. | .. | .. | × | .. | .. | .. |
| *—— *zelandica* Q. & G. | .. | .. | .. | × | .. | .. | .. |
| *Crassatellites amplus* (Zitt.) | .. | .. | .. | .. | .. | × | × *h* |
| —— *attenuatus* (Hutt.) | .. | .. | .. | .. | × *h* | × | .. |
| —— *cordiformis* Sut. | .. | .. | × | .. | .. | .. | .. |
| *—— *obesus* (A. Ad.) | | .. | .. | .. | .. | × | × |
| **Crepidula costata* (Sow.) | .. | .. | .. | .. | .. | × *h* | .. |
| *—— *crepidula* (L.) | .. | .. | × | .. | .. | .. | .. |
| —— *gregaria* Sow. | .. | .. | .. | .. | .. | × | .. |
| —— *monoxyla* Less. | .. | .. | .. | .. | .. | × | .. |
| —— *striata* (Hutt.) | .. | .. | .. | × | .. | × | .. |
| *Cucullaea alta* Sow. | .. | .. | .. | .. | .. | × | .. |
| —— *alta* var. B Hutt. | .. | .. | .. | .. | .. | × | .. |
| —— *ponderosa* Hutt. | .. | .. | .. | × | .. | .. | .. |
| —— *worthingtoni* Hutt. | .. | .. | .. | .. | .. | × *h* | .. |
| *Cylichnella enysi* (Hutt.) | .. | .. | .. | × | .. | .. | × |
| *—— *striata* (Hutt.) | .. | .. | .. | .. | .. | .. | .. |
| *Cymatium minimum* (Hutt.) | .. | .. | .. | .. | × | .. | .. |
| *Cypraea ovulatella* Tate | .. | .. | × | × | × | × | .. |
| —— *trelissickensis* Sut. | .. | .. | .. | .. | × | .. | .. |
| *Cytherea chariessa* Sut. | .. | .. | .. | .. | × | .. | .. |
| —— *enysi* Hutt. | .. | .. | .. | .. | .. | × | × *h* |
| *—— *oblonga* (Hanley) | .. | .. | .. | .. | .. | × *h* | .. |
| *Daphnella neozelanica* Sut. | .. | .. | .. | × | .. | .. | .. |
| *Dentalium solidum* Hutt. | .. | .. | .. | × | .. | .. | × *h* |
| **Diplodonta striata* Hutt. | .. | .. | .. | × | .. | .. | .. |
| *—— *zelandica* (Gray) | .. | .. | × | .. | .. | .. | .. |
| **Divaricella cumingi* (Ad. & Ang.) | .. | .. | .. | × | .. | .. | .. |
| **Dosinia caerulea* (Reeve) | .. | .. | .. | × | .. | .. | .. |
| *—— *greyi* Zitt. | .. | .. | .. | .. | .. | × | .. |
| —— *magna* Hutt. | .. | .. | .. | .. | .. | × | .. |
| *—— *subrosea* (Gray) | .. | .. | .. | .. | .. | × | .. |
| **Emarginula striatula* Q. & G. | .. | .. | .. | .. | .. | .. | .. |
| *—— *wannonensis* Harris | .. | .. | × | .. | × | .. | .. |
| *Epitonium cylindrellum* Sut. | .. | .. | .. | × | × | .. | .. |
| —— *marginatum* (Hutt.) | × | .. | .. | .. | .. | .. | .. |
| —— *rugulosum lyratum* (Zitt.) | × | .. | .. | .. | .. | .. | .. |
| —— *zelebori* (Dkr.) var. | × | .. | .. | .. | .. | .. | .. |
| **Euthria striata* (Hutt.) | .. | .. | .. | × | .. | .. | .. |
| *Fissuridea annulata* Sut. | .. | .. | .. | .. | × | .. | .. |
| **Fulgoraria arabica* (Mart.) | .. | .. | .. | .. | .. | × | × *h* |
| *—— *arabica elongata* (Swains.) | × | .. | .. | × | .. | .. | .. |
| —— *attenuata* Hutt. | .. | .. | .. | .. | × *h* | .. | .. |
| *—— *gracilis* (Swains.) | × | .. | × | .. | .. | .. | × *h* |
| *Fusinus bicarinatus* Sut | × | .. | .. | .. | .. | .. | .. |
| *Glycymeris cordata* (Hutt.) | .. | .. | .. | × | .. | × | .. |
| —— *globosa* (Hutt.) | .. | .. | .. | × | .. | × | .. |
| *—— *laticostata* (Q. & G.) | .. | .. | .. | .. | .. | × *h* | × *h* |
| *Hemiconus trailli* (Hutt.) | .. | .. | .. | .. | .. | .. | × *h* |
| **Hemifusus gonoides* Sut. | × | .. | .. | .. | .. | .. | .. |
| *Hinnites trailli* Hutt. | .. | .. | .. | .. | .. | × | .. |
| *Lapparia corrugata* (Hutt.) | × | .. | .. | .. | × | .. | .. |
| *Leucosyrinx alta* (Harris) | × | .. | .. | .. | .. | .. | .. |

| — | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|
| **Lima angulata* Sow. | .. | .. | .. | | .. | × | .. |
| *—— *bullata* (Born.) | .. | .. | .. | × | × | × | .. |
| —— *colorata* Hutt. | .. | .. | .. | × | × | × | .. |
| —— *crassa* Hutt. | .. | .. | .. | .. | .. | × *h* | .. |
| —— *huttoni* Sut. | × | .. | .. | .. | .. | .. | .. |
| —— *jeffreysiana* Tate | .. | .. | .. | .. | × *h* | × | .. |
| *—— *lima* (L.) | .. | .. | .. | × | .. | .. | .. |
| **Limopsis aurita* (Brocchi) | .. | .. | .. | × | × | .. | .. |
| —— *catenata* Sut. | × | .. | .. | × | .. | .. | .. |
| —— *zitteli* Iher. | .. | .. | .. | × | .. | .. | .. |
| **Loripes concinna* Hutt. | .. | .. | .. | × | .. | .. | .. |
| *Macrocallista assimilis* (Hutt.) | .. | .. | .. | × | .. | × | .. |
| *—— *multistriata* (Sow.) | .. | .. | .. | × | .. | .. | .. |
| *Mactra attenuata* Hutt. | .. | .. | .. | × | .. | .. | .. |
| *—— *discors* Gray | .. | .. | .. | .. | .. | .. | × *h* |
| *—— *elongata* Q. & G. | .. | .. | .. | × | × | .. | .. |
| *Marginella dubia* Hutt. | .. | .. | .. | × | × | .. | .. |
| —— *harrisi* Cossm. | × | .. | .. | .. | .. | .. | .. |
| *Mesodesma australe* (Gmel.) | .. | .. | .. | .. | × *h* | .. | .. |
| *Mitra enysi* (Hutt.) | .. | .. | .. | .. | .. | .. | × |
| *Modiolaria elongata* (Hutt.) | .. | .. | × | × | .. | × | .. |
| **Modiolus australis* (Gray) | .. | .. | .. | × | .. | .. | .. |
| —— *dolichus* Sut. | .. | .. | .. | × | .. | .. | .. |
| *Monilea praetextilus* Sut. | .. | .. | .. | × | .. | .. | .. |
| —— *sulcatina* Sut. | .. | .. | .. | × | .. | .. | .. |
| **Myodora subrostrata* Smith | .. | .. | .. | × | .. | .. | .. |
| *Mytilus canaliculus* Mart. | .. | .. | .. | .. | .. | × | × *h* |
| —— *huttoni* Cossm. | .. | .. | .. | .. | .. | × | .. |
| —— *magellanicus* Lamk. | .. | .. | .. | .. | .. | × | .. |
| —— *striatus* Hutt. | .. | .. | .. | .. | × *h* | × | .. |
| **Natica australis* (Hutt.) | .. | × | .. | .. | × *h* | .. | *h* |
| *—— *zelandica* Q. & G. | .. | × | × | .. | .. | .. | .. |
| *Olivella neozelanica* (Hutt.) | .. | .. | × | × | .. | .. | × *h* |
| *Panopea orbita* Hutt. | .. | .. | × | × | .. | .. | .. |
| —— *worthingtoni* Hutt. | .. | .. | .. | × | .. | .. | .. |
| *—— *zelandica* Q. & G. | .. | .. | .. | × | .. | .. | .. |
| *Paphia attenuata* Hutt. | .. | .. | .. | .. | × *h* | .. | .. |
| —— *curta* (Hutt.) | × | .. | .. | × | .. | × | .. |
| *—— *intermedia* (Q. & G.) | .. | .. | .. | × | .. | × | .. |
| *Pecten athleta* Zitt. | .. | .. | .. | × | .. | .. | .. |
| —— *beethami* Hutt. | .. | .. | .. | × | .. | .. | .. |
| —— *burnetti* Zitt. | .. | .. | .. | .. | .. | × | .. |
| —— *chathamensis* Hutt. | .. | .. | .. | × | .. | × | .. |
| *—— *convexus* Q. & G. | .. | .. | .. | × | .. | .. | .. |
| —— *delicatulus* Hutt. | .. | .. | .. | × | .. | .. | .. |
| —— *hutchinsoni* Hutt. | .. | × | .. | × | .. | × | .. |
| —— *palmipes* Tate | .. | .. | .. | × | × | .. | .. |
| —— *polymorphoides* Zitt. | .. | .. | .. | .. | × *h* | .. | .. |
| —— *semiplicatus* Hutt. | .. | .. | .. | .. | .. | × | .. |
| —— *triphooki* Zitt. | .. | .. | .. | × | .. | .. | .. |
| —— *williamsoni* Zitt. | .. | .. | × | × | .. | .. | .. |
| —— *yahlensis* T.-Woods | .. | × | .. | × | .. | .. | .. |
| —— sp. ? | × | .. | .. | .. | .. | .. | .. |
| *Pholadidea concentrica* Sut. | .. | .. | × | .. | .. | .. | .. |
| *—— *tridens* (Gray) | .. | .. | .. | × | .. | .. | .. |
| *Pholadomya neozelanica* Hutt. | .. | .. | .. | × | .. | .. | .. |
| *Phos cingulatus* (Hutt.) | .. | .. | × | .. | .. | .. | .. |
| *Polinices gibbosus* (Hutt.) | × | .. | .. | × | .. | × | × *h* |
| —— *huttoni* Iher. | × | .. | .. | .. | × | .. | × *h* |
| —— *ovatus* (Hutt.) | × | .. | .. | × | .. | .. | × *h* |
| **Protocardia pulchella* (Gray) | .. | .. | .. | × | .. | .. | .. |
| —— *sera* Hutt. | .. | .. | .. | × | × | .. | .. |

| — | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|
| **Psammobia lineolata* Gray | .. | .. | | | .. | .. | .. |
| *—— *stangeri* Gray | .. | .. | .. | .. | .. | ✓ | × |
| *Seila huttoni* Sut. | | .. | .. | .. | .. | .. | .. |
| **Serpulorbis sipho* (Lamk.) | .. | .. | .. | .. | .. | h | .. |
| *Siphonalia costata* (Hutt.) | | .. | .. | .. | .. | .. | .. |
| *—— *dilatata* Q. & G. | .. | .. | .. | .. | .. | | .. |
| *—— *mandarina* (Duclos) | .. | .. | | .. | .. | .. | h |
| *—— *nodosa* (Mart.) | | .. | .. | .. | .. | | |
| —— *orbita* Hutt. | .. | .. | .. | .. | | .. | .. |
| —— *turrita* Sut. | | .. | | .. | .. | ✓ | .. |
| —— sp. | | .. | .. | .. | .. | .. | .. |
| **Siphonium planatum* Sut. | | ✓ | | | | .. | .. |
| **Stephopoma nucleogranosum* Verco | .. | .. | .. | .. | .. | ✓ | .. |
| *Struthiolaria cincta* Hutt. | .. | .. | .. | .. | .. | | .. |
| —— *cingulata* Zitt. | .. | .. | .. | .. | .. | .. | h |
| —— *obesa* Hutt. | .. | .. | .. | .. | .. | .. | ✓ h |
| —— *spinosa* Hect. | .. | .. | .. | .. | .. | .. | ✓ h |
| —— *tuberculata* Hutt. | .. | .. | .. | .. | .. | .. | × |
| *Surcula antegypsata* Sut. | .. | .. | .. | ? | .. | .. | .. |
| —— *hamiltoni* (Hutt.) | .. | .. | .. | .. | .. | .. | × h |
| —— *seminuda* Sut. | | .. | .. | .. | .. | .. | .. |
| **Tellina eugonia* Sut. | .. | .. | ✓ | .. | .. | .. | .. |
| *—— *glabrella* Desh. | .. | .. | .. | | .. | .. | .. |
| *Terebra costata* Hutt. | | .. | .. | .. | .. | .. | .. |
| *Teredo heaphyi* Zitt. | .. | .. | .. | | | .. | .. |
| **Thais succincta* (Mart.) | .. | .. | .. | .. | .. | .. | × h |
| *Trivia zealandica* T. W. Kirk | .. | .. | .. | .. | | .. | .. |
| *Trochus avarus* Sut. | .. | .. | .. | | .. | .. | .. |
| —— *circinatus* Hutt. | .. | .. | .. | ? | .. | .. | .. |
| —— *nodosus* Hutt. | .. | .. | ✓ | | ✓ | ✓ | .. |
| *—— *tiaratus* Q. & G. | .. | .. | .. | .. | .. | .. | .. |
| *Turbo etheridgei* T.-Woods | .. | .. | .. | | .. | .. | .. |
| —— *granosus* (Mart.) | .. | .. | .. | .. | .. | .. | .. |
| —— *superbus* Zitt. | .. | .. | .. | .. | .. | | h |
| *Turritella ambulacrum* Sow. | .. | .. | .. | .. | h | .. | .. |
| —— *bicincta* Hutt. | .. | .. | .. | × | | .. | .. |
| —— *cavershamensis* Harris | .. | .. | .. | .. | .. | h | .. |
| —— *concava* Hutt. | × | .. | .. | ✓ | .. | | .. |
| —— *murrayana* (Tate) | .. | .. | .. | ✓ | .. | .. | .. |
| —— *patagonica* Sow. | .. | .. | .. | .. | .. | | .. |
| *—— *rosea* Q. & G. | .. | .. | .. | .. | .. | h | .. |
| *—— *symmetrica* (Hutt.) | .. | .. | .. | .. | .. | .. | h |
| **Venericardia difficilis* (Desh.) | .. | .. | .. | ✓ | .. | | .. |
| —— *difficilis benhami* (Thomson) | .. | .. | .. | .. | .. | .. | .. |
| —— *pseutes* Sut. | .. | .. | .. | .. | × h | | h |
| —— *purpurata* (Desh.) | .. | .. | .. | .. | × | .. | .. |
| *Volutospina huttoni pseudorarispina* Sut. | .. | .. | .. | .. | .. | h | .. |
| **Zenatia acinaces* (Q. & G.) | .. | .. | .. | .. | .. | ✓ | .. |

I have compared this list with that published by Marshall in connection with the Target Gully beds, near Oamaru,† and find that there is a general similarity in fossil-content to the beds in the Trelissick Basin; but, of course, some forms are missing from each list. This discrepancy may be due to insufficient collecting, or to absence of the fossils, or to a difference in time allowing for some forms to become extinct. The

† P. MARSHALL, Cainozoic Fossils from Oamaru, *Trans. N.Z. Inst.*, vol. 47, 1915, p. 378.

Oamaru locality is rich in small species, which perhaps points to insufficient collecting in the Canterbury locality; but certain larger forms present in one list are wanting in the other. For example, we do not find, in the former, species of *Astraea, Calliostoma, Cardium, Cucullaea, Lima, Mactra, Mytilus, Pecten, Struthiolaria, Trochus,* and *Turbo,* or find them comparatively rarely; while the latter are relatively poor in species of *Bathytoma, Dentalium, Drillia, Latirus, Mangilia,* and *Turris.* By the kindness of Mr. Morgan, Under-Secretary for Mines, I have been allowed to see the lists of fossils to be published in the forthcoming bulletin on the Oamaru District, by Professor Park, and I find that this discrepancy is not sensibly removed even with longer lists. There does seem, however, to be a slight preponderance of extinct forms in the species predominant at Castle Hill over those common at Target Gully, which indicates a rather older set of beds at the former place.

On comparing the list of fossils with that obtained by the author at the Lower Waipara Gorge* it is found that the resemblance is closer, the only marked difference being the presence of the numerous oysters of various species at Waipara, whereas they are practically absent from the mid-Canterbury district. There is a remarkable similarity in the percentage of Recent forms from both these localities, which suggests an approximately identical age. I have not been able to compare these lists with those from the beds in similar position in the Weka Pass section, as they have not been published up to the present date: and in face of the fact that these, and others of equal value for the purpose of correlation of our Tertiary series, are likely to appear at an early date, it seems unwise to comment further, or to attempt to draw conclusions which may be entirely upset after a consideration of fuller evidence.

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## Art. XXIV.—*An Unrecorded Tertiary Outlier in the Basin of the Rakaia.*

By R. Speight, M.Sc., F.G.S., Curator of Canterbury Museum.

[*Read before the Philosophical Institute of Canterbury, 6th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th October, 1917.*]

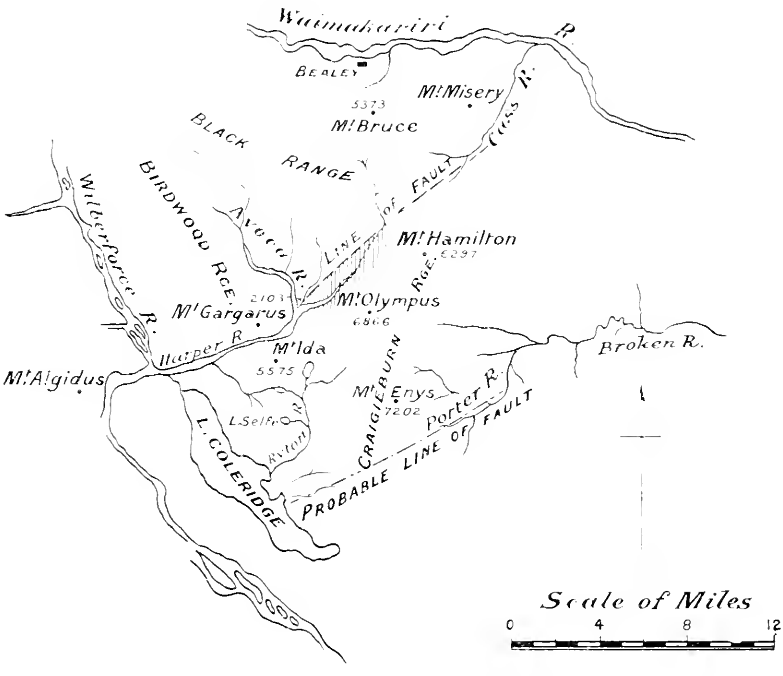
The following is a brief note on some of the features of a hitherto unrecorded occurrence of Tertiary sedimentary beds at the head of the Harper River, a tributary of the Wilberforce, one of the main feeders of the Rakaia. This river rises in a saddle between the northern end of the Craigieburn Range and Mount Misery, and flows in a straight narrow valley in a south-west direction for some fifteen miles till it joins the Wilberforce. It receives its principal supply of water from two tributaries—first of all, an unnamed stream which joins it about three miles from its source, rising at the eastern

* R. Speight, A Preliminary Account of the Lower Waipara Gorge. *Trans. N.Z. Inst.*, vol. 44, 1912, p. 231.

end of the Black Range and flowing south in a glacial trough; and, secondly, the Avoca River, which rises in glaciers on Mount Greenlaw and joins the Harper about six miles below the tributary just mentioned. Although the main stream is called the Harper, the amount of water properly belonging to it is small as compared with the amount from its two main tributaries. It also receives the overflow from Lake Coleridge just before it reaches the Wilberforce.

The only account of the district is that given by Haast,* who traversed the whole length of the Avoca in the year 1866, but was prevented by bad weather from ascending the Harper to its source.

It is in the stretch of the river-valley between the junctions of the Avoca and the unnamed tributary with the Harper that it presents its most interesting geological features. In this locality there is developed a series of




SKETCH-MAP OF HARPER RIVER DISTRICT.

Shaded portion indicates Tertiary beds; dotted lines, probable lines of fault.

Tertiary beds consisting of sandy clays with impure lignite, greensands, concretionary sands, and layers of concretionary shell-beds. It was not found possible under the weather conditions to detach specimens from the hard layers in the time at the author's disposal, but frequent specimens of

* J. HAAST. *Report on the Headwaters of the River Rakaia*, 1866: a report published by the Provincial Government of Canterbury, and reproduced substantially in the same author's *Geology of Canterbury and Westland*, 1879.

*Polinices*, *Turritella*, &c., which could be identified *in situ*, indicated that the beds were probably of mid-Tertiary age. One isolated boulder found in the bed of the stream was full of the black oyster-shell which occurs in beds at the base of the Tertiary series in the Trelissick Basin and elsewhere in Canterbury; indeed, the former area is in comparative proximity, since it is on the other side of the Craigieburn Range, which flanks the valley on the south, so that it is very probable that the lower members of the Tertiary series are also represented in the valley of the Harper.

The beds are best developed on the south-eastern side of the valley, but they also occur on the north-west side as well. They are, however, forest-clad in many parts, covered with moving debris from the neighbouring greywacke hills in others, and in all places subject to slumping movements, so that their relations to one another are difficult to make out. The strike of the beds is in a north-east and south-west direction, with a dip to the south-east, the strike being approximately coincident with the direction of the valley. Near the mouth of the Avoca there is the most remarkable case of weathering into pinnacle forms that I have ever seen.

The only satisfactory solution for the occurrence and position of these Tertiary beds is that they have been faulted down from a higher level and thus escaped the erosive action of frost and ice, which has in all probability removed the connecting masses from higher levels, the beds forming originally a part of the great covering of Tertiary sediments which masked the old peneplained surface of the mountain region at the close of the Tertiary era. It is noteworthy also that this occurrence marks the farthest extension of these beds to the axis of the main range in the northern part of Canterbury; and, as undoubted marine beds are in evidence, it clearly shows the transgression of the sea far inland during late Tertiary times.

If a fault origin for the occurrence is admitted, then it is easy to explain the straight alignment of the valley-walls, and, further, the extension of that alignment into the valley of the Cass over the saddle—a feature to which I have previously drawn attention, and suggested for it a structural origin.* The Cass Valley and the Harper are thus located on an old fault-line running north-east and south-west, and parallel to those occurring in the Esk River Valley, and in the valley of the Upper Porter River, and, in a wider sense, to the system of fractures oriented in the same direction which affect a large part of the north-eastern region of the South Island, as pointed out by McKay† and Cotton,‡ and called by the latter the Kaikoura system of fractures.

The general arrangement of the beds in the Harper Valley, and its characteristic form, are strongly reminiscent of valleys of similar origin in the north-east part of the province, such as the Greta and Waikari Valleys, and, on a small scale, of the great structural valleys of the Kaikoura region. The relative movement of the rocks has resulted in an apparent downthrow of the beds to the north-west, and the same is true in the case of the Harper, so that this movement has extended far inland into

* R. Speight, The Physiography of the Cass District, *Trans. N.Z. Inst.*, vol. 48, 1916, p. 148.

† A. McKay, On the Geology of Marlborough and South-east Nelson, *Rep. Geol. Explor. dur. 1890–91*, 1892, pp. 1–28.

‡ C. A. Cotton, The Structure and Later Geological History of New Zealand, *Geol. Mag.*, 1916, p. 248 *et seq.*

the mountain region of the Southern Alps. It is therefore evident that the relative height of the central portions of that range compared with the parts to the east was at one time greater than it is now, unless there are faults of whose existence nothing is known at present which worked in the other direction.

This is not the only instance that the locality furnishes of a valley determined in all probability by structural movements, for some five miles to the south-east there is an exactly analogous valley in the Upper Porter leading to Coleridge Pass, a low saddle in the Craigieburn Range; and on the Lake Coleridge side of the pass there is a marked break in the parallel ridges which are such characteristic features of that part of the Rakaia region. I have been informed that pieces of coal have been found in this locality, but have never been able to come across any myself, though it is not at all improbable that it exists, and that another small outlier of the Tertiary series exists in that part of the lake-basin. If this is really so it would explain, just as the Harper fault explains, the existence of the isolated blocks into which these parallel ridges are cut. However, many glaciated regions show the presence of such isolated remnants of ridges, and it is hardly safe to explain the Rakaia phenomena in this way without further evidence. It may be noted that Gregory in his book, *The Nature and Origin of Fiords*, notes in numerous places the frequent occurrence of isolated mountain blocks in glaciated regions, and explains them as the result of cross-fractures and not as a product of glacier erosion.

The question of the age of the Harper River fault is a matter of some interest. In its initial stages it is certainly of pre-glacial origin, since the valley has been glaciated. An overflow from the Waimakariri basin came in from the neighbourhood of the Bealey, and came down the unnamed tributary referred to previously, and left traces all down the valley to the junction with the Avoca, where it merged into the great ice-streams which have so profoundly modified the landscape of this region. The result of glacial action on a valley of fault origin will, of course, be considerably different from that in a normal stream-eroded valley. In the former there will be no overlapping spurs, and therefore there will be, after glaciation, no truncated or semi-truncated ends, no beehive forms, but the valley-walls will exhibit complete alignment, a feature well exemplified in the Harper and Cass Valleys. Unless the formation of the valley has antedated the glaciation by a long period there will be little sign of the development of tributaries, so that hanging valleys will be absent. Further, if the sides have all irregularities removed, the flat faces left when the glacier retreats will be stable under the action of erosion agents, and will be preserved much longer than those valley-sides on which the stream-valleys are already organized.

The Cass Valley exhibits a well-developed system of overlapping spurs on its floor, but these are no doubt due to the overdeepening of the flat floor of the glaciated trough by stream erosion after the retreat of the ice; and the same remark applies to the Upper Harper, but to a more limited extent.

Although the fault formation of the valley must be pre-glacial, there is evidence of disturbance of drainage in the case of Lake Coleridge which may be attributable to recent movements along the same line of fracture. The circumstances are as follows: Round Lake Coleridge there is a well-developed old shore-line about 60 ft. above the present level of the lake.

This is to be seen very clearly in the neighbourhood of the intake for the tunnel in connection with the power-station, but clearest of all in the sheltered bays on what is called " the Peninsula," about half-way along the eastern side of the lake. These show clearly that the water within comparatively recent times was 60 ft. higher. The lake now drains out at its northern end towards the Harper and Wilberforce Rivers, but there is a clearly defined old river-channel, with terraces and everything complete, leading from near Messrs. Murchison's station buildings towards the Acheron at the other end of the lake, the road following the bed of this old stream for about a mile. The highest point of this outflow channel above the lake is about 60 ft., so that if the lake were filled up to the level of its old shoreline it would discharge in the opposite direction to what it does at present. The cause of this reversal is attributable to a lowering of the barrier at the northern end. What this barrier was is not clear; it may have been the front of the retreating glacier of the Wilberforce, for if that acted as a ponding agent it would be effective as long as its terminal was below the upper end of the lake, but when the ice retreated farther it would allow the outflow of water in the direction of the Wilberforce. This would no doubt account for the phenomenon, especially as the change in direction of drainage appears to have taken place suddenly, and not by the slow removal of a rock barrier by water erosion.

The other explanation suggested is that the movements on the line of fault had not ceased when the lake discharged normally from its southern end, but that a sudden lowering of the country north-west of the line of the Harper River allowed of escape of water in a northern direction. The slumped character of the sides of the Upper Harper Valley suggest recent earth-movements. Further, if the line of the Upper Harper be continued to the south-west it will pass close to two other Tertiary outliers, one near Glenthorne, at the mouth of the Harper,* and the other near the Mount Algidus Station, across the Wilberforce; and it is possible that their preservation may be associated in some way with the same set of circumstances that have accounted for the occurrence of a Tertiary remnant in the Upper Harper Valley. By suggesting this continuation of the fracture-line across the Wilberforce it is not intended to endorse McKay's extended system of fault-lines as indicated in his map. Although this writer did great service towards the proper interpretation of the structural features of the mountain area of Canterbury, he probably erred in carrying his hypothesis too far. There is no evidence that I am aware of pointing to the extension of this line of fracture farther to the south-west.

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* J. von Haast, *Geology of Canterbury and Westland*, 1879, geological map facing p. 370.

# ART. XXV.—*An Ancient Buried Forest near Riccarton: its Bearing on the Mode of Formation of the Canterbury Plains.*

By R. SPEIGHT, M.Sc., F.G.S., Curator of Canterbury Museum.

[*Read before the Philosophical Institute of Canterbury, 6th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th October, 1917.*]

Plate XXIII.

As the mode of formation of the Canterbury Plains is a matter of especial scientific interest, I venture to submit the following short note, based on the existence of an ancient buried forest, in support of the idea first advanced by Haast (1, 2), and endorsed by the surveys of Doyne (3, 4) and Dobson, that the plains have been formed almost entirely by the action of aggrading streams, and that the form of their surface is due to the overlapping and coalescence of the fans of glacier-fed rivers. The original hypothesis has received support from most geologists of standing, notably from Professor W. M. Davis, who after an examination of their salient features has expressed to me privately his substantial adherence to Haast's theory. This opinion was, however, strongly opposed by Hutton (5, 6), who regarded the plains as a marine deposit built up from material brought down by rivers, the upper surface being a plain of marine denudation.

In two somewhat recent papers (7, 8) I have urged that after being built up in the way suggested by Haast, or while they were actually in process of formation, they were subjected to a gradual sinking of the land—that is, instead of the chief recent movement being one of elevation, as demanded by Hutton, it has been one of subsidence. This is proved almost conclusively by the records of the bores of the artesian-well sinkers in the Christchurch area. On the margin of the plains, especially just north of Banks Peninsula, there is an intermingling of land and marine beds, the latter with marine shells overlying beds of terrestrial origin. There has been a struggle between the agents responsible for building up the land and those causing depression, in all probability the latter getting the better of it; but the effect of this struggle is not clearly manifest on the inland part of the plains owing to the enormous depth of the gravel deposit and the absence of sections showing the whole sequence. The records of the bore being put down at Chertsey for the purpose of prospecting the plains for petroleum show up to the present a thickness of 1,250 ft. of shingle and clay deposit, with no clear sign of a change in its character from that occurring near the surface.

When the earliest colonists arrived in Canterbury in the early "forties" there were patches of forest growing on the low-lying and swampy areas in the neighbourhood of Riccarton, Papanui, Rangiora, and Temuka; while near Oxford, Alford Forest, Mount Peel, and Geraldine the eastern foothills of the Southern Alps were clad with submontane forest, tongues of which stretched out into the plains for a varying distance, that from Oxford following the line of the River Eyre and almost junctioning with the patch on the plains near Rangiora and Woodend; also from the north-western slopes of the Port Hills a few trees formed a straggling connection with the Riccarton Bush. In addition to this standing timber, fallen logs, mostly of totara (*Podocarpus totara*), lay commonly among the tussocks till they were gradually destroyed by grass-fires, thus indicating a former wider extension of these forests. In the swampy areas round Lake Ellesmere and on the low-lying eastern fringe of the plain there existed a great amount of timber, chiefly white pine, or kahikatea (*Podocarpus dacrydiodes*), and manuka (*Leptospermum scoparium*), some of which lay prone in the bogs, while some formed the stumps of trees in position. Since kahikatea is a timber which soon perishes on exposure to the weather, it is evident that the destruction of these forests occurred somewhat recently. This was attributed by the early settlers to the action of fire, but it is difficult to understand how a water-logged swamp could have been thoroughly burnt out, and it is extremely probable that this part of the forest of the plains disappeared largely owing to the killing of the trees by water-logging due either to depression of the land or to the flooding of land owing to the changing course of rivers, itself perhaps partly due to depression, of which there is entirely independent evidence. This is supported by the statement of Mr. Dudley Dobson, Christchurch City Engineer, in connection with the sinking of the sump for the Christchurch water-supply pumping-station at the foot of the Cashmere Hills. While making this excavation he came across, at a depth of 25 ft. beneath the surface, a fine specimen of a totara log, 5 ft. in diameter. In close proximity to this was the stump of the tree with its roots in proper position, extending 16 ft. across, and penetrating a layer of clay, evidently the old land surface on which the trees grew. The level of the roots was almost exactly that of high-tide mark, thus affording a clear indication of the depression of the land. My attention has been drawn by Mr. W. Wilson, of Auckland University College, to stumps in a similar position near Pareora, south of Timaru, thus undoubtedly confirming the existence of a downward movement of the land in the area immediately south of the plains. Also, during heavy storms, pieces of submerged trees are frequently washed out of the beds on shore just north of Timaru; but whether these are from drift material or from trees which are in position it is impossible to say. This evidence of depression is supported as far as this locality is concerned by the form of the shallow valleys cut in the dolerite capping of the Timaru Downs, with their lower reaches occupied by lagoons of brackish water ponded behind shingle bars, which were built up by the pronounced northerly drift of shore material along the coast. The drowned valleys of Banks Peninsula are evidence that a similar downward movement of the land went on farther north.

The instance cited on the authority of Mr. Dudley Dobson serves to emphasize the existence of buried forests of large trees on the former surface of the plains. The occurrence of timber, either drift or in position, at great depth beneath the surface is widespread in this area. Not only is it found in the artesian bores at all depths up to 450 ft., but it is met with in making excavations for foundations in Christchurch itself, and also in the gravel-pits opened on the plains both within and just without the artesian area. In a pit at Hornby, about six miles west of Christchurch and 90 ft. above sea-level, numerous pieces of the stems and roots of trees are found 40 ft. beneath the surface—that is, to the depth of the excavation. These are evidently of drift material, but they show that the totara-trees from which they were derived flourished at higher levels on the plains when the bottom of the pit formed the surface of the ground. Throughout the whole depth of this pit river-gravels and occasional irregular sandy layers form the material of the beds, and there is an absence of the stratification which would be evident were the beds of marine origin. Further, they appear beyond the limit of the area where there is the interstratification of pervious and impervious beds necessary for artesian conditions at shallow depths, although this undoubtedly occurs at lower levels in the same locality, as is indicated by the records of the wells at Islington (8). There are similar occurrences of timber in an excavation for gravel close to the Heathcote River, in Spreydon, at the foot of the Port Hills, as well as in gravel-pits near the Harewood Road.

A more interesting pit, however, is found in the Riccarton district, at Sockburn, close to the Paparua County Council's office. This is about a mile and a half nearer Christchurch than the Hornby pit. It is about 63 ft. above the sea, and has been excavated to a depth of about 12 ft., at which level a bed of sandy clay forms an impervious layer on which water lies except in summer and autumn. The pit has an area of over an acre, and all over this the stumps of trees, mostly of totara, are in position. (See Plate XXIII, fig. 1.) Fully thirty large trees are thus represented, some up to 5 ft. in diameter. At my first visit a large tree, 40 ft. in length and over 4 ft. in diameter, lay exposed on the floor of the excavation, having apparently broken off from one of the stumps: this was subsequently cut up for timber. During a recent visit to the spot in company with Dr. Cockayne I noticed another large tree, fully 5 ft. in thickness, which was uncovered for 20 ft. or more. There is no doubt that we have exposed here an old forest which was growing on the floor of the pit when that formed the land surface, and which has been subsequently buried by the pouring-in of sediment from adjacent rivers. It is clear that the standing trees were broken off from their stumps before they were buried up, otherwise the trunks would not be separated from their roots as they now are. What caused the breaking-off is not apparent, but in all probability the trees were killed while in the standing position and then the stems were snapped off near the ground, or perhaps while the roots were covered up with river-gravels. This process can be seen on many of the shingle fans and river-beds in the mountain region of the province. Living trees of mountain-beech or wild-irishman can be observed standing partly buried in a waste of moving shingle, maintaining a precarious existence, while alongside stand dead and partially buried standing trunks, and farther down-stream the fallen stems lie at all angles and are buried up completely or exposed as the stream washes out a deep channel on the surface of the fan. The occurrence in the gravel-pit at Sockburn is exactly analogous to the second and third of these conditions.

No doubt the growth and destruction of the forests on the plains went on simultaneously in adjacent areas and went on alternately in the same area, the destroying gravel forming the substratum on which the next forest growth was based. Stretches of land with good soil would occur in certain parts, usually low-lying alluvial flats, and on these the forests would establish themselves and maintain their footing for a time; but these parts would be especially susceptible to inroads of gravel, since ultimately the river would use them for a dumping-ground, and the forest would be destroyed or be compelled to remove to an adjacent area. The fact that the forest must have been established *on a land surface* definitely supports Haast's original idea of the formation of the plains, and of itself would negative the idea that they had been formed of waste carried to sea by rivers, spread on a sea-bottom, and levelled finally by the action of the waves, even if there were not strong and independent evidence to the contrary.

The pit under consideration affords no evidence of the downward movement of the land, since the floor on which the trees grew is 50 ft. above the present high-water mark, but there is no evidence which is opposed to that hypothesis.

It is impossible to say definitely how long ago this forest grew, but since its existence at least 12 ft. of gravel has been deposited on the area, and, judging from the present rate of deposit in the Canterbury area, the time since it grew must be considered in hundreds if not in thousands of years. The sound condition of the totara draws attention to the extreme durability of that wood even under conditions which are not altogether favourable for its preservation. On the clay substratum on which it lies it would be exposed to continual alternations of drying and wetting, and the loose texture of the gravel would allow free access of air, so that the present sound condition of the timber is really surprising. (See Plate XXIII, fig. 2.)

The occurrence of the forest serves to draw attention to another point. In an article on the "Post-glacial Climate of Canterbury" (*Trans. N.Z. Inst.*, vol. 43, 1911, p. 408) I put forward the hypothesis that these old forests were established during a pluvial climate, and that their disappearance was not due to fire, but to a gradual desiccation of the region. We have here a forest whose destruction was certainly not due to the former of these agencies, so there were conditions previous to the arrival of man which were inimical to the free growth of these totara forests, and the destruction of the patch which covered the site of the old gravel-pit may have been due to a widespread cause of regional and climatic character, and not due to a local accident destroying a mere fragment of a once much more extended forest formation.

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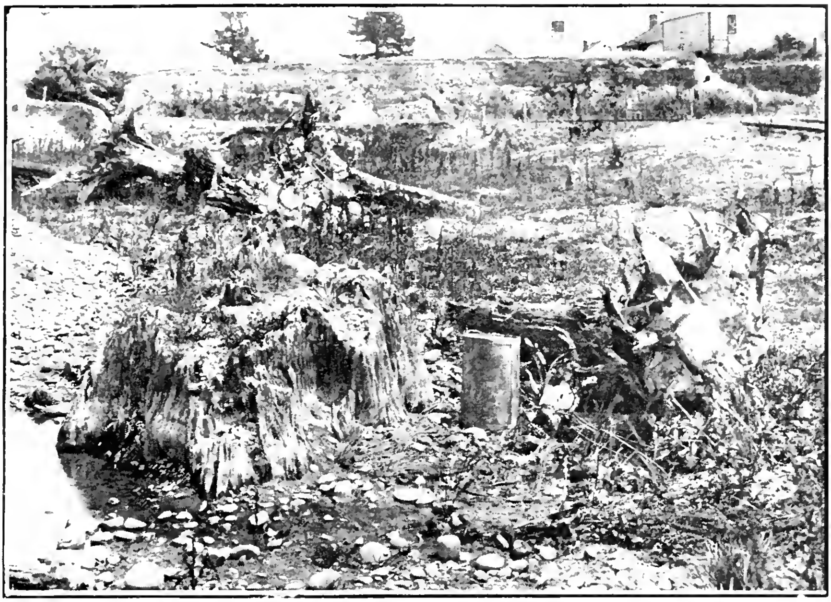


Fig. 1.—Showing bottom of gravel-pit, with stump of tree 5 ft. in diameter in position, as well as drift-wood and remains of other standing trees which have been uncovered.

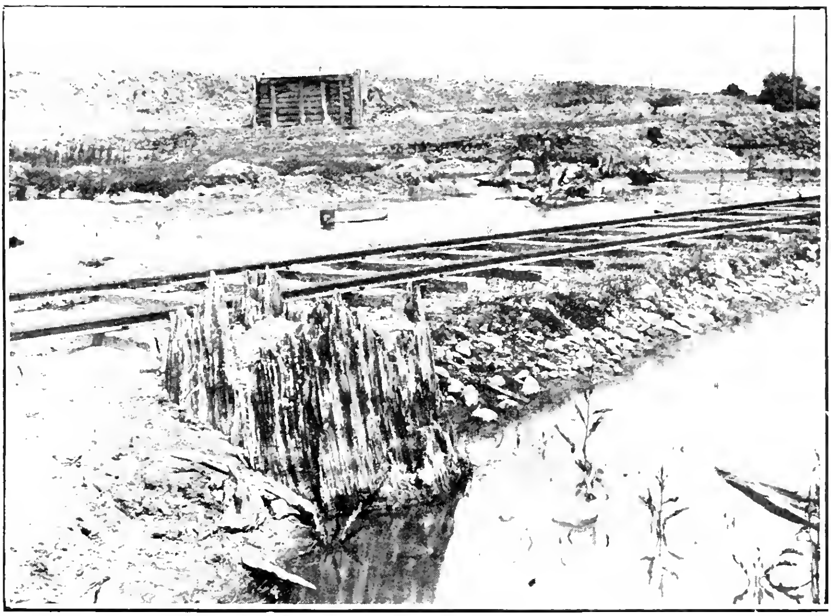


Fig. 2.—Bottom of gravel-pit, showing accumulations of surface water (the picture was taken in the month of November). A large stump is also shown in position, as well as other remains of trees.

# Art. XXVI.—*The Geology of Banks Peninsula.**

By R. Speight, M.Sc., F.G.S., Curator of Canterbury Museum.

[*Read before the Philosophical Institute of Canterbury, 3rd November, 1915; received by Editors, 30th December, 1916; issued separately, 5th November 1917.*]

Plates XXIV–XXVI.

Table of Contents.



## A. INTRODUCTORY.

Banks Peninsula as a geological locality has attracted considerable attention at various times, but no detailed account of its geological features has appeared since Haast published in 1879 his *Geology of Canterbury and Westland*. In this work he summarizes the results of his observations and investigations as Provincial Geologist, reports of which he had furnished to the Provincial Government from time to time, and which were published in its *Gazettes*. A petrological account of the rocks occurring in the Lyttelton Tunnel, based on collections made by Haast while it was being constructed, appeared in Filhol's *Mission de l'île Campbell*, which was issued in Paris in 1885, this containing as well a summary of the geological history of New Zealand. Since then various petrological papers have been published dealing with the rocks of the district, among which may be mentioned "The Microscopical Investigation of some Eruptive Rocks from Banks Peninsula, New Zealand," by B. Kolenko (*Neues Jahrb. f. Min., Geol., Pal.*, 1885, Band 1, p. 1; translation published in *N.Z. Journ. of Science*, vol. 11, 1885, p. 548), and "The Igneous Rocks of New Zealand," by Hutton (*Journ. and Proc. Roy. Soc. N.S.W.*, 1889), containing reference to many rocks from the peninsula; while the following papers have appeared in the *Transactions of the New Zealand Institute*: "The

* This paper is intended to be introductory to one dealing with the petrology of the district, which will be submitted at a later date.

Tridymite-Trachyte of Lyttelton," by P. Marshall (vol. 26, 1894); "An Olivine-andesite of Banks Peninsula" (vol. 25, 1893), "On a Dolerite Dyke from Dyer's Pass" (vol. 26, 1894), and "On a Soda Amphibole Trachyte from Cass's Peak, Banks Peninsula" (vol. 40, 1908), by the present author. There are also a few other papers on general geological subjects connected with the area, such as a "Note on the Silt Deposit at Lyttelton" (vol. 15, 1883), by Captain Hutton; "Note on an Artesian-well System at the Base of the Port Hills" (vol. 33, 1901), by S. Page and E. B. R. Prideaux; and, lastly, a paper "On a Remarkable Dyke on the Hills near Heathcote" (vol. 13, 1881), by A. D. Dobson.

With the exception of several slight references in the writings of others, this is all that has been written on the district; and as no general account of this interesting locality has been issued since 1879, and no comprehensive account of its petrology has yet been published, no excuse need be put forward for this paper.

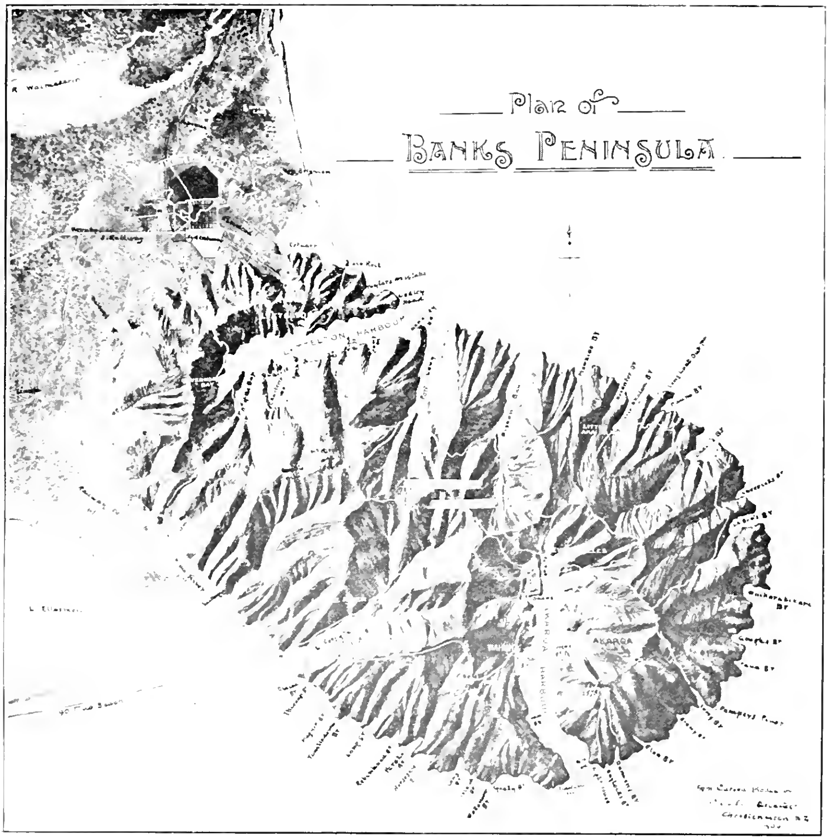
## B. GENERAL TOPOGRAPHY OF THE AREA.

(See fig. 1 and Plate XXIV.)

Banks Peninsula was discovered by James Cook on the 14th February, 1770, while on his first voyage of discovery. He thought it was an island, and named it after the celebrated naturalist who accompanied his first expedition. No landing was made, the nearest approach being about three to four leagues distance. He says with regard to it, "It is of a circular figure, and about twenty-four leagues in compass. It is sufficiently high to be seen from a distance of twelve to fifteen leagues, and the land has a broken, irregular surface, with the appearance of barrenness rather than fertility. Yet it was inhabited, for we saw smoke in one place and a few straggling natives in another." Cook's mistake as regards its being an island can be easily understood when one considers the difficulty of picking up the low-lying land on the south and west from a ship over twenty miles away off shore.

The peninsula lies in latitude 43° 32′ S. and longitude 173° 30′ E., and forms a rough elliptical salient on the central portion of the South Island of New Zealand. Its diameter in a N.W.-S.E. direction is about twenty-five miles, and its breadth at right angles thereto about eighteen miles. It is bounded on the north-east, east, and south by the sea; but on the other side, looking toward the Canterbury Plains, the place of the sea is taken by the estuary of the Avon and Heathcote Rivers on the north-west, by low-lying and swampy land on the west, the latter passing into marsh and shallow lake on the south, where the flat expanse of Lake Ellesmere lies behind a great shingle-spit whose proximal end is attached to the south coast of the peninsula. Near this point another body of brackish water, known as Lake Forsyth, is ponded back in the lower reaches of one of the main valleys stretching south. About forty miles away to the west is the long line of the Southern Alps, and sloping up to their foot lie the Canterbury Plains, formed by the coalescing and overlapping fans of the shingle-charged rivers issuing from the mountain tract.

The most striking features of the peninsula are Lyttelton and Akaroa Harbours, occupying old volcanic craters of the "caldera" type, surrounded by crater-rings, which are broken at one place so as to allow of the entrance of the sea into the depressed floors of the craters. The centres of the two craters occupy, as it were, the two foci of the elliptical area constituting the peninsula. The former lies to the north of the area, and stretches in




Photographic reproduction of relief map of Banks Peninsula, from original in Canterbury Museum by S. C. Farr. This gives a fairly accurate representation of the relief of the region.

an E.N.E.–W.S.W. direction, with its opening to the north-east, while the latter runs south and south-east from near the centre of the peninsula, and forms one of the finest deep-water harbours in New Zealand. The chief summits round the edge of the crater-rings range between 1,800 ft. and 2,500 ft. in altitude, but the highest points in the district are near the centre of the mass on a ridge connecting the rings of the two craters, and formed of territory belonging to some extent to both volcanoes. Immediately to the south-east of Lyttelton is the highest summit, Mount Herbert Peak (3,014 ft.), and five miles south-east from it is Mount Fitzgerald (2,710 ft.), and a mile and a half farther on is Mount Sinclair (2,763 ft.), the last-named lying just outside the Akaroa basin, on the dividing ridge which separates two important valleys—viz., Little River

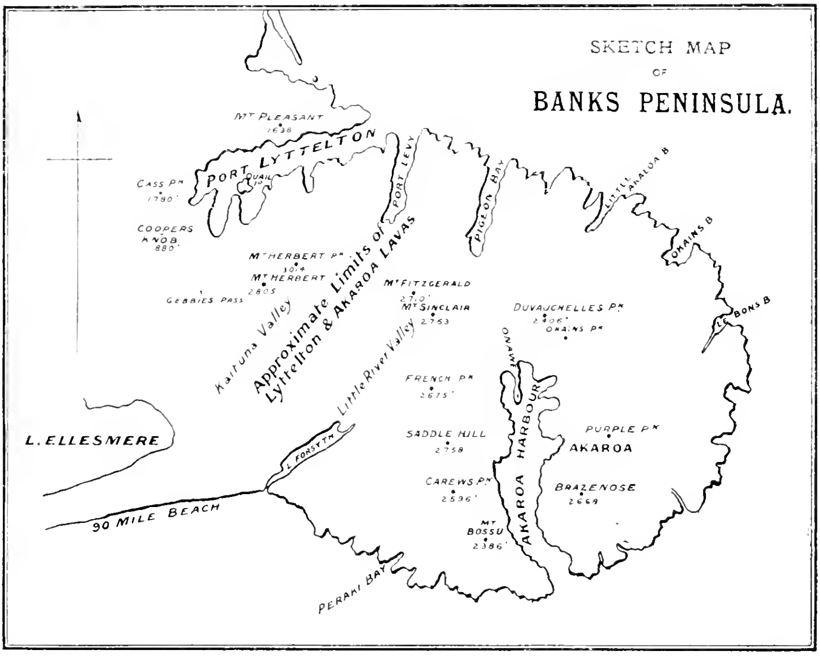



Fig. 1.

and Pigeon Bay—from each other. These two latter peaks are situated almost in the heart of the peninsula, and form its geographical centre, so to speak.

Stretching down from the elevated ridges around the two foci, with rude radial orientation, are numerous valleys whose lower reaches on the eastern side are occupied by the sea and form a series of deep bays, the principal being Port Levy, Pigeon Bay, Little Akaloa, and Okain's Bay, facing north-east; Le Bon's Bay and Long Bay, facing east; and Peraki, which lies to the west of Akaroa entrance, facing south-west; while on the landward side the corresponding indentations are filled with alluvial material, the chief being Gebbie's Valley, leading to the head of Lyttelton Harbour; Kaituna Valley, lying to the south of Mount Herbert and cutting far back into the major axis of the ellipse; and beyond it Little River, whose lower reaches are occupied by Lake Forsyth. All these valleys are short, the longest ten miles in length, and their streams are diminutive torrents which fail altogether or carry but little water in dry weather. In their lower reaches their floors are flat, owing to the aggradation of the streams incompetent to carry their load, and to material which has been swept in by wave and tide and deposited in the sheltered waters at the head of the submerged valleys. This action is well seen in Okain's and Le Bon's Bays, whose streams are tidal for some distance near their mouth; but in these the filling-in has not reached such a mature stage as in the case of Peraki. This effect is more marked on the southern and eastern coasts, which experience to a greater degree the strong northerly drift sweeping up the coast and dropping its load of coarse material on the southern margin of the peninsula, while the fine material is carried farther and contributes markedly to the filling of the lower reaches of the bays, if it be not swept into the deeper water off shore and thus be removed beyond the sphere of influence of waves and shore currents.

When viewed from the sea the land presents, as Cook said, a bold, irregular surface, and the exposed headlands are terminated in high sea-cut cliffs, which reach a height of nearly 800 ft. on the eastern edge of the land. Here they are exposed to the full force of the gales from the south and east, under whose influence the waves have cut back all the headlands which project in that direction, in marked contrast to the spurs which project into the plain, whose terminations are hardly truncated at all, except near the coast, where within comparatively recent times they have been subject to the action of the sea.

When the peninsula was first discovered by Europeans it was almost completely clothed with forest, the only bare patches being the tops of the highest hills and on the extremities of the spurs reaching down to the sea; but this has been cleared off as settlement progressed, so that patches of forest more than a few acres in extent are few and far between. The rainfall amounts to between 30 in. and 40 in. per year, and is well distributed over the entire period, so that under its influence and with the advantage of a rich soil the hills are excellently adapted for pastoral purposes, and are noted for the rich grasses with which they are covered and for the excellent stock they produce.

After this general description I pass on to the more particular account of the principal physical features—viz., Lyttelton and Akaroa Harbours; and, after dealing with them, to the more important minor ones, such as Little River Valley, Kaituna Valley, Port Levy, and Pigeon Bay.

### 1. Lyttelton Harbour. (Plate XXV, figs. 1 and 2.)

Lyttelton Harbour is about eleven miles long by three wide in its widest part, which is opposite the town of Lyttelton, its general width being from one and a half miles to two miles; the entrance is one mile in width. The northern side of the harbour is but slightly indented, and the land rises steeply to the crater-ring, the highest points being Mount Pleasant (1,638 ft.), just behind the town of Lyttelton; the Sugarloaf (1,630 ft.), farther west; Cass Peak (1,780 ft.) and Cooper's Knob (1,880 ft.), towards the western end of the harbour. A little distance beyond this elevation the crater-ring is completely broken down, and the divide between the inside and the outside slopes of the harbour is for a space of about three miles reduced to approximately 400 ft., and in two places, first at the head of Gebbie's Valley and again a little farther east at the head of the parallel McQueen's Valley, the ridge is reduced below that height and forms two passes, which are known from

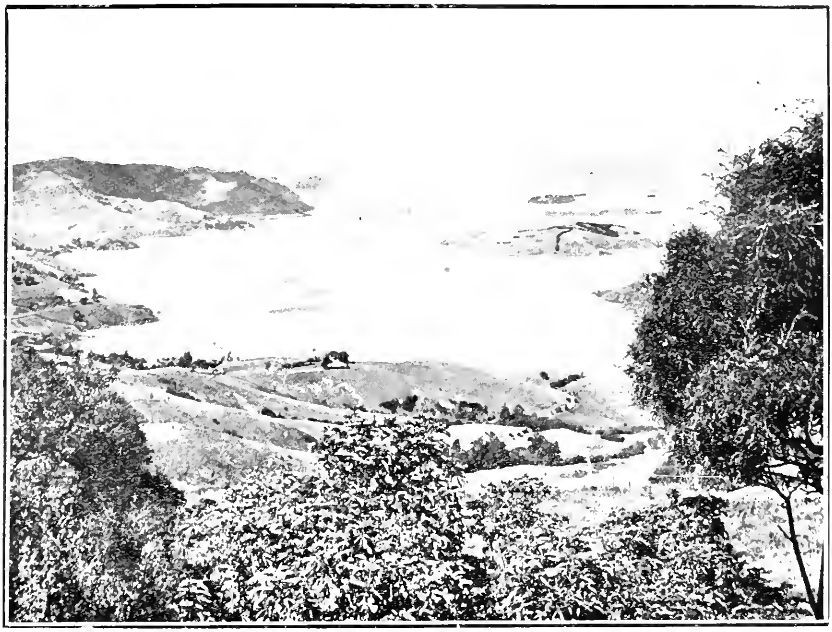


FIG. 1.—Lyttelton Harbour, from near Cass's Peak, showing Quail Island and stream-eroded valleys on the interior of the caldera.

FIG. 2.—Lyttelton Harbour from summit of Mount Herbert, showing drowned-valley topography of upper portion of the harbour and part of the long spur reaching down from Mount Herbert.

Fig. 1.—Akaroa Harbour from summit of Mount Bossu, looking north, showing stream-eroded valleys in interior of the caldera.

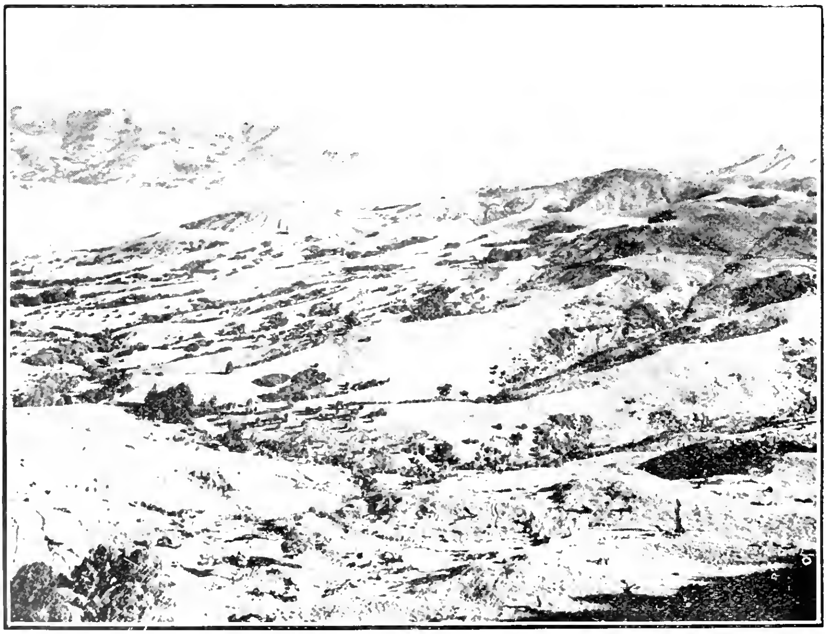


Fig. 2.—Akaroa Harbour from summit of western side of the crater-ring, the stream-eroded slopes of Barry's Bay valley in the foreground, and the entrance to the harbour in the distance.

the names of the valleys which they head. Their heights are as follows: Gebbie's Pass, 360 ft.; and McQueen's Pass, 350 ft.

Immediately to the east of McQueen's Valley the crater-ring rises to 1,843 ft. in Dyke Hill, so called from two prominent dykes on its northern slope, and this is succeeded by Kaituna Pass, on the eastern side of which rises like a bastion the steep slopes of Mount Herbert (2,805 ft.); this passes into Herbert Peak, from whose summit a long gentle slope according with the angle of the lava-streams which form it reaches down to the harbour. This is cut off on the eastern side by the valley which leads down to Purau Harbour, and is then succeeded by the remnants of the crater-ring which lie between it and the southern side of the entrance.

At the head of the harbour there are two well-marked peninsulas which determine the position of three considerable indentations of the shore-line—viz., Governor's Bay, Head of the Bay, and Charteris Bay—the first known as Manson's Peninsula and the second as Potts Point; while on the eastern side of the Mount Herbert slope there lies Purau Bay, another deep indentation. These are all instances of depression topography, and the bays are drowned valleys with their lower reaches prolonged beneath sea-level at the same grade as the exposed floors of the valleys. In the middle of the harbour, in practically the centre of the crater-ring, lies Quail Island, 184 acres in area, seven-eighths of a mile long by half a mile broad, and its highest point 282 ft. above sea-level, with steep cliffs 200 ft. high facing the harbour, but with gentler slope on the other sides. It lies off the end of the peninsula dividing Charteris Bay from the Head of the Bay, and at low tide it is possible by wading to cross the space between the two. About half-way over there is a rise in the connecting ridge which is permanently above sea-level and is known as Little Quail Island.

The harbour is very shallow in its upper parts, and at low water there are extensive mud-flats, the water gradually deepening towards the entrance, where it is about 10 fathoms deep; the floor is almost flat, the deep water continuing right up to the rocky wall-like shores. In one place, just opposite to the entrance to the breakwater, a rocky area rises above high-water mark, and at another place, about a mile nearer the heads, opposite Ripa Island, a solid rock rises to about 10 ft. of the surface. With these two exceptions the floor of the harbour is entirely covered with mud and any irregularities are completely masked.

Lyttelton Harbour was described by Haast as a caldera, the entrance between the heads forming the barranco, and his explanation was adopted by Hutton. Allowing for the modification of the southern wall by the slope reaching down from Mount Herbert Peak, the name, as used in its widest sense, is applicable. It has, however, been considerably modified by stream action: the crater-wall has been broken down completely at Gebbie's Pass, and the majority of the topographic features are due to stream erosion and not to the effects of a paroxysmal explosion. This point will be dealt with more fully when the geological history is considered.

### 2. AKAROA HARBOUR. (Plate XXVI, figs. 1 and 2.)

Akaroa Harbour is of characteristic caldera-like form, with the entrance at the heads forming the barranco. It is fiord-like in some of its features, eleven miles in length and three miles wide in its widest part. The entrance is a mile wide, and flanked by perpendicular cliffs, the southern being 525 ft. in height and the northern about 300 ft. Inside the northern entrance, however, there are cliffs which rise to 500 ft. The summit of the crater-ring is in a remarkable state of preservation, and nowhere does it sink below 1,000 ft. in height, while the prominent peaks rise to just over 2,000 ft. The most important of these are: On the western side—Mount Bossu (2,386 ft.), Carew's Point (2,598 ft.), Saddle Hill (2,758 ft.), French Peak (2,675 ft.), Rocky Peak (2,297 ft.); and on the eastern side—Duvauchelle Peak (2,406 ft.), Okain's Peak (1,880 ft.), Laverick's Peak (2,478 ft.), Brasenose (2,375 ft.), and Flag Peak (2,668 ft.), immediately above the town of Akaroa. The inside of the crater-ring shows well-developed signs of stream erosion, and the valleys so formed are prolonged beneath sea-level. These are best developed near the head of the harbour, where we have the indentations known as French Farm Bay, Barry's Bay, Duvauchelle's Bay, Robinson Bay, and German Bay—all valleys with their lower extremities drowned by the sea, and divided from each other by ridges which are cut back at their extremities to some extent by wave action. Other indentations of the shore which do not show this so markedly are French Bay (near which the town of Akaroa is situated), Wainui and Lucas Bays, two embayments in the western side. The most prominent of all the ridges which stretch into the harbour is the pear-shaped peninsula of Onawe, one mile in length, which rises at its termination into a rounded hill, 348 ft. in height, from which the peninsula stretches back with decreasing height and narrowing cross-section till at the isthmus joining it to one of the ridges which descend from the crater-ring it is almost cut across by the sea.

The general soundings of the harbour as disclosed by charts indicate a gradual deepening from the northern end to the entrance, and suggest that the floor is merely an extension of the gradient of the valleys which are formed at the head. The topographic features thus present a striking analogy to those of Lyttelton Harbour, just referred to; but Akaroa is the more typical caldera of the two.

### 3. Little River Valley, Kaituna Valley, etc.

Little River Valley, the chief one on the southern side of the peninsula, was considered by Haast to be one of the eruptive centres from which its rocks were poured out. In the opinion of the present author its formation can be attributed almost entirely to stream erosion. The main valley is about ten miles in length, the lower portion, six miles in length with a breadth of approximately one mile, being occupied by Lake Forsyth, which is separated from the sea by a narrow bar of shingle. When Europeans first visited the spot it was open to the sea and used as a boat-harbour by the Maoris, but the continual drift of shingle up the coast has now completely cut it off from the sea. The lake is shallow, and the water is brackish. Just above the head of the lake the valley divides, the eastern branch, called the Okute Valley, reaching up to the crater-ring of Akaroa between Saddle Hill and French Farm Peak. It is further divided into the Western Valley, which runs north-west towards the head of Port Levy and is excluded from the slopes which belong to the Akaroa crater-ring. The main valley, however, continues with several small branches, and drains a considerable portion of the north-western slopes of the Akaroa volcano, as well as a large portion of the ridge which stretches west from it and passes through Mount Sinclair and Mount Fitzgerald and divides the Little River Valley from Pigeon Bay and Port Levy on the north. Mount Sinclair is, however, the most striking physical feature at its head. The walls of the valley are steep, and are formed of long ridges whose terminations are between 300 ft. and 400 ft.

in height, but which rise in places to close on 2,500 ft., and it is specially noteworthy that the highest points of these ridges do not occur near their proximal end.

Kaituna Valley is about seven miles in length, and runs in a general south-westerly direction along the south-eastern side of Mount Herbert. Its head reaches back to the main divide of the peninsula which joins Mount Herbert on to the crater-ring of Akaroa. Its walls are steep, since it has followed generally the line of flow of the lavas from Lyttelton—*i.e.*, it has the characteristics of a stream-valley running with the dip of the beds. Its floor is flat and deeply covered with alluvium, but about one-third of the way up from the entrance it contracts somewhat where the valley takes a right-angled turn, and farther up it opens out into a wide amphitheatre-like head which a number of valleys of the region present; it thus reaches to the head of the Little River Valley on the east.

To the north of the main divide lie Port Levy and Pigeon Bay, the former to the east of the Lyttelton crater-ring, but eroded for the most part from the lavas poured out of that vent; but a part of the walls on the eastern side of the valley no doubt belong to Akaroa. Its head is divided up into separate valleys like Little River, and it presents few of the features which would suggest that it was a separate centre of volcanic action. Pigeon Bay has similarly been eroded out of the flanks of the Akaroa volcano, and it closely resembles in form and depth the adjoining bay on the west. It has, however, a broader-headed valley, which has cut into the crater-ring of Akaroa on the eastern side, and farther west reaches to the main divide of the peninsula, where lie the high peaks of Mounts Sinclair and Fitzgerald.

Neither Pigeon Bay nor Port Levy is truly radial in arrangement, and both appear to have been eroded to some extent out of ground where the flows from the two volcanoes mutually interfered with each other and were probably intercalated along the line of junction.

The drainage areas of Little Akaloa, Okain's Bay, and Le Bon's, and also that of Peraki, on the south side of the peninsula, reproduce on a smaller scale the features of Pigeon Bay and Little River, and have steep-walled sides and amphitheatres at their heads.

## C. GEOLOGICAL HISTORY.

### 1. TRIAS-JURA SEDIMENTARY SERIES.

(See fig. 2.)

The oldest rocks exposed on the peninsula consist of a series of slates and greywackes with beds of chert and jasperoid rock occurring to the south of Lyttelton Harbour. They form almost the whole of the spurs which stretch down from the Gebbie's Pass ridge towards the head of the harbour, also the points round the indentation known as the Head of the Bay, and stretch in an easterly direction across the base of Potts Peninsula, extending for half a mile up the valley and on its eastern side, projecting as a narrow fringe under the later volcanics. They form the basement beds under the flat-topped ridge running north from Mount Herbert towards Potts Peninsula, being exposed on both sides under the cap of basalt forming its summit. Greywackes and slates also occur on the western flanks of Mount Herbert across the divide between the harbour and McQueen's Valley, forming the rocks round the heads of the streams running therefrom, and reappearing as inliers on the western side of McQueen's

Valley, and also on the end of the spur dividing that valley from Gold Valley. These rocks are well developed on the western end of the Gebbie's Pass ridge, and form the country round the heads of the streams running therefrom both to the north and the south. The precise limits of this series are at times difficult to determine, since a covering of soil masks the surface and good exposures are rare, except where the rock has been quarried for road-metal or building purposes. These beds are so siliceous in places that many years ago they were prospected for gold, and numerous shafts and

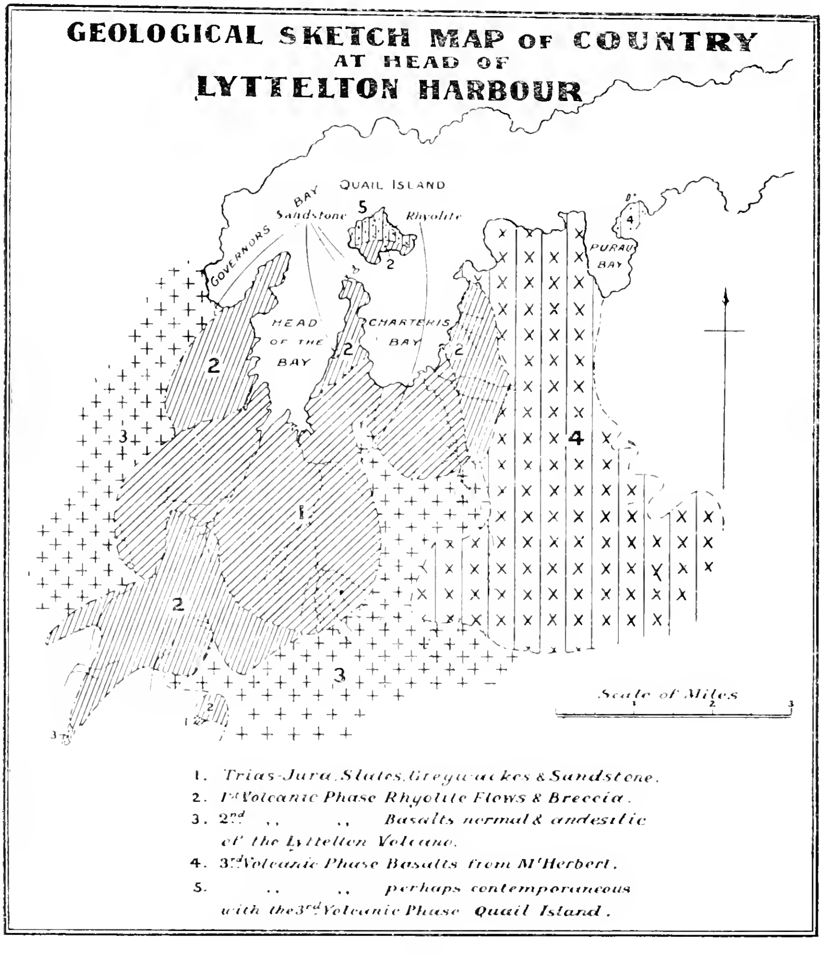



Fig. 2.

drives were made, but without success. The strike of the beds is generally in a north-and-south direction, with variations to the east and west about that mean; a specially heavy band at the western head of Gebbie's Valley shows a north-west orientation.

Up to the present no fossils have been discovered by which their true age may be determined, but judging from their lithological characters merely they are of the same age as those which occur in the mountain region of Canterbury, and have been definitely determined as Jurassic from plant fossils found at Mount Potts, Clent Hills, and Malvern Hills, and therefore should be assigned to the Maitai system of Marshall, which is of Trias-Jura age.

Overlying these submetamorphic rocks is a series of different texture, having more the character of a freestone, which has been classified previously as later than the rhyolite volcanic phase,* but which more detailed examination has convinced me represents a deposit antedating the rhyolite eruptions. These beds are developed at the head of Governor's Bay, where they are at least 30 ft. thick, and may be much more, as the upper and lower boundaries of the occurrence are nowhere visible. The rock is here pinkish in colour, free in the grain, and without well-marked bedding-planes. Under the microscope it is highly quartziferous, with some admixture of feldspar and occasional shreds of mica, and therefore is similar in mineral composition to a greywacke, and may have been derived from the same land-mass as furnished the associated greywackes. This bed has, however, yielded no fossils by which its age and true relations can be determined.

Although the contacts of this occurrence are not clear, exposures of similar rock at Little Quail Island, at the end of Potts Peninsula, and about half-way along its western side show that it undoubtedly underlies the rhyolite; and farther round the head of Charteris Bay near the wharf, and on the peninsula to the west of the bay, this facies of the sandstone also underlies the rhyolite, and overlies directly, without the intervention of volcanic material, the basement slates and greywackes. It is therefore very probable that the Governor's Bay occurrence is in the same stratigraphical position, but whether it rests conformably or unconformably on the greywackes it is impossible to say at present.

This rock has been quarried for building purposes in several places, especially at Governor's Bay, Little Quail Island, and on the eastern and western sides of Charteris Bay. Where any stratification can be observed the beds strike N.E.–S.W., and in places this has been so perfect that large flags suitable for paving and for the making of grindstones were easily obtained. Round the shores of Charteris Bay and at Little Quail Island these sandstones are completely intersected by the trachyte dykes of a later age, which will be referred to hereafter.

## 2. First Volcanic Phase.

The Jurassic rocks were deeply eroded before the first phase in the volcanic history of the district began, and the unconformity is most marked, since the first volcanic beds lie right across the edges of the Jurassic sedimentaries. The matter produced at this stage is exclusively of rhyolite, and is typically developed near the head of Lyttelton Harbour. Rhyolite rocks are visible about half-way along the cliffs of Quail Island facing the town of Lyttelton, extending in one place almost to the summit of the island, and they reappear on the south side, where they form the solid material of the foreshore and the slopes immediately behind it, flows and beds of agglomerate stretching without intermission, except from dykes, from near the wharf at the east end of the island, behind the quarantine buildings, to its extreme south-westerly point. The rhyolites are exposed along the eastern shore of Charteris Bay, above the narrow band of sedimentaries occurring there, and again on the southern shore of this bay,

* J. VON HAAST, *Geology of Canterbury and Westland*, 1879, p. 327.

and after a break they continue west, forming the greater part of the peninsulas stretching into the upper part of the harbour. On the eastern one the rhyolite occurs only on its distal end, the proximal end being of sedimentaries overlain by basic volcanics, but on the western peninsula the rhyolite extends from its extremity right up to the base of the steep slope immediately below the prominent peak of Cooper's Knob, on the Lyttelton crater-ring. After an interval of sedimentaries it appears again in the vicinity of Gebbie's Pass, forming the prominent hills in its immediate vicinity, stretching down on either side of the stream running therefrom, and forming the main mass of the spur between Gebbie's Valley and McQueen's Valley; an isolated block occurs on the eastern side of the latter valley, and a small outcrop also occurs on the east side of the Teddington Valley, to the north-west of Mount Herbert, just opposite Mr. Wilson's house. The only evidence of a wider extension of the rhyolite under the covering of later basics is furnished by a tuff containing rhyolite pebbles on the east side of Onawe Peninsula, Akaroa, this being the only known occurrence on Banks Peninsula outside the Lyttelton area.

In several places, as at Quail Island, near the summit of Gebbie's Pass, and on the shore of Charteris Bay, the lowest beds exposed consist of agglomerate, composed of subangular boulders of all sizes up to 3 ft. in diameter. In McQueen's Valley there is a well-developed breccia with pitchstone fragments. Among the rhyolitic material are occasional foreign elements, such as pebbles of greywacke and fragments of an andesite differing in character from the olivine-bearing andesites or andesitic basalts that were extruded later. Where this came from it is quite uncertain, since no exposure of similar rock in position has been located. The rhyolitic material includes banded rhyolites with irregular wavy bands of microspherulites, garnetiferous rhyolite, mica rhyolite of various shades of colour—green, white, and pink—as well as fragments of pitchstone. The mass has weathered into fantastic forms, with large globular cavities a striking feature.

Wherever these fragmentary deposits occur they are apparently at the base of the series, but in some cases solid rhyolite flows rest directly on greywacke and slate. The rock is typically of white colour, but is occasionally pinkish. In some places it shows dark-coloured phenocrysts of smoky quartz, and in others sanidine crystals 1½ in. in length stand out on weathered surfaces. In many places, however, phenocrysts are not visible to the naked eye. At the back of Quail Island it is markedly spherulitic in places, with spherulites up to 3 in. in diameter, but here, as in other places, it appears to have been markedly silicified after eruption, no doubt by the action of warm waters laden with siliceous material percolating through the mass of rock. The alteration produced by this action is in some instances very pronounced, and as it has involved other rocks as well it is sometimes extremely difficult to determine the relations to the beds with which they are in contact. I have found this specially so on the shores of Charteris Bay.

The rhyolite is penetrated by dykes of trachyte and basalt belonging to a later period, and also by dykes of rhyolite and pitchstone which are apparently contemporaneous with the rhyolite-flows. The most noteworthy of these occur near the crest of the Gebbie's Pass ridge, on the summit of the hill west of the road. The pitchstone dyke strikes east and west and is 50 ft. in width, and close alongside it to the north is a dyke of rhyolite with similar orientation and well-developed columnar structure. Another rhyolite dyke forms the summit of a hill to the north-west of this.

On the southern side of the ridge Haast notes a dyke running north-east across the gully up which the road goes. It appears as a well-defined mass of markedly silicified rhyolite resembling a dyke in its field occurrence, but in all probability is a flow which has been tilted by earth-movements subsequent to its extrusion.

It is difficult to locate the centre from which the rhyolites were erupted. The dykes—excluding from consideration those of later date, which are of no value in this connection—do not show any radiating arrangement (fig. 3), but the flows and ash-beds on Quail Island show a well-defined dip to the north, and those in Governor's Bay, though somewhat irregular, dip to the west and north-west in general, and those in Charteris Bay to the east, so that it seems probable that the centre should be located somewhere near the area now occupied by the Head of the Bay. The present thickness of the deposits, allowing for denudation, does not point to any mass of material having been poured out at all comparable with that from other centres of rhyolitic activity in the province, and as the direction of the flows at the commencement of volcanic activity would in many cases conform to the shape of the land surface on which the volcanic material was poured out a few observations of the inclinations of beds in a case like that under consideration may give a somewhat unsatisfactory result. This is well exemplified on the west side of Potts Peninsula, where the rhyolite-flows overlie immediately the earlier sedimentaries, and exhibit a marked variation in the direction and amount of inclination. The clearest case of bedding is to be observed on the south side of Quail Island on the point between the two groups of buildings, and also on the south side of the point to the south of the Leper Station. In these places the strata dip to the north and north-east at angles of about 20°, so that we can say for certain that the volcanic focus lies to the south or south-west of Quail Island.

An interesting deposit of fossil leaves and stems of dicotyledonous plants is mentioned by Haast* as occurring on the south side of Gebbie's Pass in sandy shales associated with coarse sands and loose conglomerate. These have a strike in an E.N.E.–W.N.W. direction—that is, parallel to the great band of rhyolite thought to be a dyke by Haast. This is distant only a few chains, and its steep inclination accords with that of the leaf-beds, which dip to the S.S.E. at very high angles, approximately 90°. It appears to me, therefore, that the inclination of both the band of rhyolite and the leaf-beds is to be attributed to tilting after deposition as a result of folding or other deformational movement. As far as can be ascertained, the material of which the sands and conglomerate are composed is entirely volcanic in origin, and it is probable that it represents the lowest beds of fragmentary rhyolitic material which occur elsewhere, and that the plants are the remains of the vegetation on the land surface on which the volcano was originally established, and formed in much the same way as the deposits of timber in the pumice to the east of Ruapehu and Tongariro, in the North Island, which is a remnant of the old forest covering of the land in the vicinity of the volcanoes. This idea is supported by the fact that a short distance farther up the valley is a small inlier of Trias-Jura sedimentaries, which can be only a few feet lower in the stratigraphical sequence than the plant-beds, and which no doubt lie close under them at the spot where they occur. No good sections are available, however, and the field relations are obscure.

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* J. von Haast, *loc. cit.*, p. 326.

Outpourings of rock of identical lithological character occur in other localities of the Canterbury Province—*e.g.*, at Malvern Hills, Rakaia Gorge, and Mount Somers—and it is only by reference to them that we can fix the age of the Lyttelton rhyolitic eruptions. The evidence for the period of the former is as follows: In these localities rhyolites lie invariably on an eroded surface of Jurassic strata, while over them lie coal-measures containing the following fossils: bones of *Ichthyosaurus*, shells of *Inoceramus*, *Conchothyra parasitica*, *Trigonia*, belemnites. The fossil-content of these beds fixes them as Cretaceous. At the base of this series lie a conglomerate formed largely of rhyolitic pebbles and beds formed of detrital matter of rhyolitic origin, so that the rhyolites formed a land surface in Cretaceous times. However, at Rakaia Gorge and at Mount Somers coal-seams occur interbedded with rhyolitic tuffs, from which it is evident that eruptions were taking place while the coal was being deposited. It seems certain, therefore, that the rhyolite eruptions took place at the close of the Cretaceous period on the margin of the mountain region of Canterbury; and, although it is not safe to draw inferences as to age based purely on lithological resemblance in the case of volcanic rocks separated by a distance of forty miles, it is the only evidence that we have to rely on at present, and therefore we may say, at least tentatively, that the age of the Lyttelton rhyolite is Cretaceous also.

### 3. Second Volcanic Phase.

#### (*a*.) *Lyttelton.*

The second phase of volcanic activity was marked by the pouring-out of basic lavas which built up the Lyttelton and Akaroa cones. Structurally they are both composite cones of the normal type, as can be seen from the magnificent sections afforded by the sea-cut cliffs. It will be best to consider first of all the case of Lyttelton, as it is more easily examined, not only because roadmaking and excavations are more common near the centres of population, but because the Lyttelton Tunnel has been driven in a radial direction through the wall of the cone, and records of the inclination of the flows and samples of the various rocks encountered were made by Haast,* and a petrological description of these rocks is given by Filhol.† These show that Lyttelton has all the features of a composite cone built up of layers of lava and fragmentary material, the latter being thicker as the interior of the volcano is approached along the line of the tunnel. Judging from the quaquaversal dip of the flows observed on the cliffs and on the sides of the deep-cut valleys, as well as from the records of the tunnel, the centre of the harbour corresponded to the centre of activity, but owing to the occupation of the bottom of the crater by the sea the site of the actual vent cannot be definitely located. It can perhaps be fixed with reasonable certainty as a deduction from the orientation of the dykes which traverse the walls of the crater-ring. Their arrangement is markedly regular, and when they are plotted they are found, with few exceptions, to radiate from a small area just south of Quail Island, which may therefore be regarded as the actual centre of disturbance and the precise locality of the vent.

The exposed limits of the rocks of this series to the north and west of Lyttelton Harbour are easily determined, seeing that they continue down to

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* J. von Haast, *loc. cit.*, p. 355.

† H. Filhol, *Mission de l'île Campbell*, Géologie, 1885, p. 66.

the level of the plains; but in places artesian bores have struck them some distance out from the foot of the hills, so that their actual extension in that direction is quite uncertain. To the east of Gebbie's Pass they form the ridges between Gebbie's Valley and Kaituna Valley, and extend therefrom to the north along the western flanks of Mount Herbert, and probably continue round the western heads of the streams discharging into Charteris Bay. After a considerable gap, where they are covered with later rocks, they appear again at the head of the Purau Valley and form all the mass of hills lying between Purau Bay and Port Levy. They may reach as far eastward as the ridge between Port Levy and Pigeon Bay, since the flows exposed on the eastern shore of the former have a distinct inclination to the east; but as it is apparently impossible to separate in that locality the flows coming from the direction of Akaroa and those from Lyttelton the boundaries in that part of the periphery of the volcano are uncertain. No doubt at one time they extended right across the entrance to the harbour, and across the gap at Gebbie's and McQueen's Passes, but have been removed by erosion in those sectors. Remnants of these covering beds are to be seen on the ridge between Gebbie's Valley and McQueen's Valley. Rabbit Island, or Motukarara, is an isolated fragment lying about half a mile off the western bounding ridge of Gebbie's Valley, surrounded on all sides by lake sediments, and proving by its position a former wider extension of the limits of the volcano in that direction. This remnant owes its preservation to the resistant character of the rock of which the low hill is composed.

With one exception, there are no apparent difficulties in interpreting the structure of the locality as far as these rocks are concerned. On the south side of McQueen's Pass and extending across McQueen's Valley from its western side to the east side of Gold Valley is an occurrence of basic rock associated with the rhyolite whose position is difficult to account for except on the supposition that it is older than the rhyolite. These basic rocks rest on cherts, and are apparently overlain by the acid variety. The appearance may, however, be deceptive, but it should be noted. If it represents an old volcanic flow subsequent to the rhyolite, then the surface contours must have been extraordinarily steep when the extruded material flowed over them.

At the only places where contacts of the rocks of the Lyttelton series of volcanics with underlying beds are visible they rest either on greywackes, slates, and sandstones of the Trias-Jura series, or on rhyolites, their relations to each of these being well seen on the east and west sides of the Gebbie's–McQueen's Valley depression, where the original covering beds have been removed by erosion and the basement series exposed.

The lava-flows and ash-beds of which the cone is constructed are exclusively basic in character; they vary from fine-grained basalts to those in which feldspar phenocrysts form a considerable bulk of the rock. On account of this feature and their consequent high percentage of silica (up to 55 per cent.) they have been classified as andesites, but they contain normally a considerable amount of olivine, so they should more properly be called basalts of andesitic habit. Haast records the presence of trachyte-flows in the Lyttelton Tunnel, but this is probably incorrect, as in my experience trachytes occur only in the form of intrusions, and the occurrence in the tunnel may be merely an overflow from a dyke or a sill. The general high percentage of feldspar phenocrysts seems to indicate that the lava-flows were fairly viscid, and therefore the inclination of the beds is steeper than would be expected in the case of a normal basalt.

From a consideration of their average inclination, especially in the case of those recorded by Haast from the Lyttelton Tunnel, some estimate may be arrived at as to the former height of the Lyttelton volcano. The average inclination of the flows in the tunnel is almost exactly 15°, and this value corresponds with that obtained from observations of prominent flows exposed on the sides of valleys eroded deeply into the flanks of the volcano. Taking this value as approximately correct, and also the distance of the outer fringe of the hills from the centre of the volcano as approximately six miles, the height of the cone must have approached 8,000 ft.; and if we make due allowance for a probable greater inclination of the flows and an increased thickness near the vent, and also for the depression of the land which has occurred since volcanic activity waned, it is possible that the cone approached, if it did not actually exceed, 10,000 ft. in height.

The present form of the cone is no doubt entirely different from that which it presented at the close of this volcanic phase. Instead of the usual moderate-sized crater at the top there is now a great hollow, and evidence suggests that this form had developed to some extent before the next phase in the volcanic history began. The actual cause of the formation of these vast cavities will be dealt with later, but the following three working hypotheses have been put forward to account for them:—

(i.) They have been formed by explosion or collapse of the cone, the former indicating a revival of volcanic activity.

(ii.) The form is due to peripheral faulting causing subsidence of the original crater.

(iii.) They have been eroded by the action of streams, or by the sea, or more probably, in some cases at all events, by a combination of both processes.

*The Dyke System* (see fig. 3).—A most striking feature in connection with this volcanic cone is the dyke system. The great majority of these intrusions are of trachyte, decidedly alkaline in composition, and frequently containing as a consequence alkaline augites and hornblendes, though common hornblende trachytes also occur, as well as ordinary fine- and coarse-grained basalts and andesitic basalts. Many of the trachyte dykes are very massive, such as those on the Lyttelton–Sumner Road, notably the tridymite trachyte; dykes near the head of Heathcote Valley; the great dyke at Rapaki; those near Kennedy's Bush; and on Dyke Hill, near Kaituna Pass—the last four of which are each approximately 60 ft. in thickness. There are besides many others of smaller size, so that the volume of intrusive trachyte as deduced from exposures at the surface exceeds in volume all other dykes. There does not appear to be any definite grouping of the trachytic and basic dykes into pairs so that one might be assumed to be complementary to the other, therefore any explanation of their different chemical composition on the basis of a divergence from a common magma requires that the differentiation took place at some depth and not near the surface of the volcano. There is, however, a general tendency for groups of trachytic or groups of basic dykes to occur in particular localities. For example, along the Lyttelton–Sumner Road there is a special occurrence of trachytes; the same remark applies to Heathcote Valley, near the Bridle Path; then, again, there are the large trachyte dykes at the head of the Rapaki Valley, and numerous smaller ones near Victoria Park and near Kennedy's Bush. Basaltic dykes occur freely to the west of Dyer's Pass Road, near Cooper's Knob, and in places near McQueen's Pass in greywacke and rhyolite, forming well-defined groups; but, all the same, they are occasionally found sandwiched in between trachytes, so that a definite pronouncement must be taken with considerable reserve.

Dykes of both species appear at the very crest of the crater-ring, but it is remarkable that the trachytes, though apparently soft and non-resistant, stand out freely as massive walls sometimes as much as 70 ft. above the surrounding country. As might be expected, the basic dykes are more common on the outskirts of the volcano, while the massive and more viscid trachytes are as a rule short in length and somewhat lenticular in shape. There are, however, exceptions to this general rule.

On the south side of Quail Island the trachyte dykes are unusually numerous, and they are apparently the only ones occurring. The foreshore from the outer wharf to the extreme south-westerly point of the island is intersected by them, nearly sixty occurring in the space of a mile in length.


Fig. 3.—Map showing the system of radiating and divergent dykes belonging to Lyttelton Harbour.

They vary in size from mere ribbons up to masses 12 ft. across. In some cases injection appears to have taken place twice up the same fissure, or the original dyke appears to have been disrupted and injection taken place up the fissure so formed. Most of the dykes are vertical or nearly so, but occasionally they are flat like sills and are injected along the planes of flow of the rhyolite. Friction breccias are also sometimes in evidence. The orientation of the dykes in this locality varies through a right angle, so that looking south from the shore they lie in the quadrant extending from south-south-east to west-south-west, with one or two having a more east-and-west trend. The great majority, however, are directed between south and south-west. Owing to the variation, they occasionally cross, but there is no regularity in the direction of those crossing later from which a conclusion may be drawn as to the existence of more than one focus of eruption, the variation in all probability being due to proximity to the single centre of disturbance. All these dykes are white in the hand-specimen, except where they are stained by oxide of iron, which has been derived from the scanty amount of ferro-magnesian mineral originally present in them, and they are no doubt connected genetically with those occurring in the later basalts, and are not in any way related to the rhyolites in which they are included.

Round the shores at the head of the harbour the dykes exhibit extreme irregularity in orientation. On the western shore of Governor's Bay they strike S.E.–N.W., but on the point running north from Allandale they not only exhibit the same direction, but others have a more easterly trend, while others again, especially towards the end of the peninsula, lie almost N.–S.; even here, however, large dykes have a S.E.–N.W. orientation. On the east side of this peninsula a large dyke runs parallel with the shore—that is, N.–S.—but it is cut by another running E.N.E.–W.S.W. On following the shore to the south their direction averages about S.E.–N.W., but there are several large ones with a N.–S. direction, with a few running E.–W. In the rhyolite quarry on the beach a large dyke strikes S. 15° W.

In Charteris Bay there is the same variation in orientation. On the road near the wharf the dykes strike generally N.W.–S.E., but close to the wharf a dyke runs N.E.–S.W. On the southern shore of the bay their direction is various, but chiefly in the sector N.W.–N.E. and S.E.–S.W. There are isolated occurrences outside even these wide limits; for example, a dyke exposed on the road over the hill to Teddington has a strike E. 25° S.–W. 25° N.

On Potts Peninsula there is also marked irregularity in direction. At its extremity, opposite Quail Island, they strike N.E.–S.W., N.–S., and also N.W.–S.E., with an occasional one E.–W. On the west side of the peninsula the majority strike E.–W., but numerous others intersect them at all angles, so that they do not appear to radiate from any common centre.

In the Gebbie's Pass locality the only dykes, apart from the rhyolites, that I have been able to locate are of basalt, with one possible exception in McQueen's Valley. These are oriented in the direction of Quail Island—that is, in the normal direction of those on the outskirts of the volcanic cone. In this sector it is evident that the tough and resistant greywackes and slates proved too strong for the more viscid trachytes, although the liquid basalts were able to penetrate them freely.

A specially interesting occurrence is that of the tridymite trachyte on the Lyttelton–Sumner Road, described by Marshall.* The inclination of the mass at an angle of 40° to the vertical, plastered, as it were, against the inner side of the crater, certainly encourages his opinion that it was a flow and not a dyke, but an opportunity of more complete examination afforded by a clearing of the ground has confirmed me in the opinion that it is intrusive in origin. Its lower surface has a dyke contact and not that of a flow, and, further, it is oriented in the proper direction for dykes in that locality. It is cut by two other dykes, both trachytic in character, although one, a hornblende trachyte, is more distinctly basic than the average of this class. Another interesting trachyte dyke occurs at Governor's Bay, where it forms the sea-cliff for several chains, and owing to the action of the weather has developed a most remarkable spheroidal weathering.† Close alongside this is a glassy trachyte dyke of distinctly alkaline character and with a texture analogous to that of pitchstone.

* P. Marshall, Tridymite Trachyte of Lyttelton, *Trans. N.Z. Inst.*, vol. 26, 1894, pp. 368–87.

† J. von Haast, *loc. cit.*, p. 335.

Since nearly all the dykes except those at the head of the harbour, which are almost entirely trachytic, have a radial orientation, and therefore do not intersect, no satisfactory conclusion can be come to as to the relative age of the trachytic and basic varieties—if, indeed, they do belong to different periods of intrusion. The only intersections that I am aware of are those of trachytic dykes, and they do not furnish any sound grounds for differentiating between the earlier and later trachytes on the score of composition.

### (*b.*) *Akaroa.*

*Basic Flows, Trachyte Dykes, and Syenite.*—The general features of the Akaroa volcano are analogous to those of Lyttelton. It has been constructed in the same way of alternating flows of basic rock and fragmentary material, but fine- and coarse-grained basalts of normal habit form the great majority of the flows, basalts of andesitic habit being rare. Some of the flows, too, seem to be specially subject to weathering agents, so that there is a thicker covering of fertile soil than in the case of Lyttelton; but hard resistant basalts are very common, and seem to determine by their presence the marked shelves of flat ground which are evident on the sides of the harbour, and also the summits of the higher peaks, elevations such as Mount Bossu, Saddle Hill, French Peak, and Brasenose being composed of flows of lava showing little signs of decay, their slopes facing the harbour being precipitous and bold, while their external slopes are comparatively gentle and accordant with the angle of the lava-flows. Judging from the present spread of the base and the inclination of the lava-streams, the volume of the Akaroa cone far exceeded that of Lyttelton.

Like this it had also a series of radiating dykes, which are generally trachytic in character, but neither their number nor the volume of the output appears to have approached those of Lyttelton. This may, however, be deceptive, since the maturity of erosion and depth of dissection are not so marked in the case of Akaroa, and therefore dykes have not been so extensively exposed. In the neighbourhood of Onawe they depart from the radiating arrangement and form on the shore platform a criss-cross pattern, with no regular orientation, except perhaps that more run in a N.E.–S.W. direction than in any other; but this conclusion may be erroneous.

A most interesting occurrence in the Akaroa area is a coarse-grained plutonic rock—a hornblende syenite of peculiar type—which forms the rounded hill terminating the pear-shaped peninsula of Onawe. The contacts between this and the surrounding rocks are everywhere obscured by soil and debris even down to low-water mark, so that its field relations cannot be worked out satisfactorily. It apparently represents a volcanic rock which has consolidated at a deeper level and has been exposed owing to erosion, and is no doubt connected genetically with the trachyte dykes of the area, which form an intersecting network at the base of the peninsula referred to previously. But one at least of these dykes on the western side intersects the syenite as well as the later basic volcanics, so that the syenite may be a fragment of an older land-mass, and not directly connected with the later volcanic period. Just where this trachyte dyke intersects it there is a small exposure of an extremely basic facies of the rock containing numerous grains of magnetite, and the sand on the beach close to it is largely composed of this material, as well as hornblende and feldspar. The form of the end of the peninsula is one specially characteristic of granite rocks, and the material in position is deeply weathered.

The remaining portion of this peninsula is composed of basalt penetrated by trachyte dykes, with one small exposure on the eastern side of a well-stratified tuff containing pebbles of rhyolite. The field relations of this occurrence are obscure, but it certainly underlies basalt-flows, and it is further interesting as indicating a probable extension in a south-easterly direction of the Gebbie's Pass rhyolites under the covering of basic rocks.

### (c.) *Little River Valley.*

To this epoch Haast* and also Hutton† would also assign the formation of a caldera in the Little River Valley. Although an explosion may have been responsible for the formation of this valley in its initial stages, there is no actual evidence of its having been an independent centre. There is no appearance of a quaquaversal dip of the lavas issuing from a centre located somewhere within its basin; rather they are all disposed as if they flowed from the direction of Akaroa. The dyke system is that belonging to Akaroa and radiating from the centre of that volcano. There is, besides, no difference in the lithological nature of the lavas from the two localities. Further, its shape, with three long trailing spurs directed in some measure towards the middle of its basin, suggests most strongly the action of water. The fact that in certain parts of the western side cliffs face the valley and simulate to a minor degree the form of the caldera is entirely explained by streams cutting parallel with the strike of the beds, which must of necessity produce at times a form which resembles the steep interior faces of a caldera. The same remarks apply to Pigeon Bay, also regarded by Haast as a caldera, except that it is divided into two subordinate valleys, and not into three as in the case of Little River. I regard both as eroded by streams on the flanks of a volcanic cone.

## 4. Third Volcanic Phase.

### (a.) *Mount Herbert Volcano.*

The third distinct phase in the history of the area was marked by outpourings of lava from the neighbourhood of Mount Herbert, in all probability from a centre in Kaituna Valley or on its north-western boundary. This may perhaps be regarded as a third and subsequent vent, analogous to the two great calderas but on a smaller scale. By these eruptions the highest peak on the peninsula was constructed, the greatest development of the lavas being on Mount Herbert Peak and the ridge which extends in a westerly direction from it and forms the flat-topped mountain known as Mount Herbert. The tops of these elevations are formed of massive flows of lava, lying very level, individual flows being from 80 ft. to 100 ft. in thickness, and exhibiting in places columnar jointing on a large scale. The flows form successive tiers of ramparts round the head of the valley above the Head of the Bay and Charteris Bay, and again on the southern side fronting Kaituna Valley; but between Charteris Bay and Purau they form a long gentle slope with an average inclination of 10°, both the slope of the ground and of the lava-flows being in agreement. The termination of the flows has been cut back into a sea-cliff, about 50 ft. in height, for about a space of a mile on the southern shore of the harbour between Charteris Bay and Purau, and there is an outlying fragment on the eastern side of Purau forming a low ridge behind the Ripa Island fort.

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* J. von Haast, *loc. cit.*, p. 343.

† F. W. Hutton, Sketch of the Geology of New Zealand, *Quart. Journ. Geol. Soc.*, vol. 41, 1885, p. 216.

The flows belonging to this series rest almost entirely on the basic rocks of the previous series all round the heads of the valleys reaching down to Purau, Charteris Bay, and the Head of the Bay on the north side, but on the east side of Charteris Bay they rest on rhyolites; in Port Levy and Kaituna Valley they again rest on the older basic rocks. (See fig. 2.)

Where the underlying rocks of the Lyttelton system are exposed they give the idea that even at that period the cavity resembled to some extent that at present existing and that it was of the caldera form, and this suggests that a long period of time elapsed between the two basic series of flows. This point is also emphasized by the juvenile character of the drainage which has established itself on the long gentle slope running down from the summit of Mount Herbert Peak. The period of these eruptions is therefore in all probability late Tertiary, and may agree with those which took place at Timaru, which are in all probability of Pliocene age, seeing that the lavas lie there on an eroded surface of Upper Miocene rocks and that underneath the flows fossil bones of *Dinornis* have been obtained.

The lava-flows from Mount Herbert are exclusively basalts, most of which are extremely fine-grained in texture, but a few are coarse in character. No system of dykes similar to that associated with Lyttelton or Akaroa occurs in connection with this outburst from Mount Herbert.

### (*b*.) *Mounts Fitzgerald and Sinclair.*

To this stage in the volcanic history the two authorities cited above assign outbursts at Mount Fitzgerald and Mount Sinclair, which lie on the ridge connecting the two great cones, and, indeed, form its highest summits. The lavas of these two peaks are exactly the same as those erupted from Akaroa, and there appears to me to be no justification for calling them separate volcanoes. Their lava-streams show an inclination which leads one to think that they flowed from Akaroa; and, though they appear to lie beyond the limits of the crater-ring, they are no farther from the centre of the caldera than similar heights on the eastern side of the harbour about which there has never been any doubt. They apparently lie far out, but this effect is due to the fact that at the head of Pigeon Bay the external stream erosion has cut far into the edge of the crater-wall—in fact, a portion of the internal drainage of Pigeon Bay Peak and its neighbourhood, which should go towards Akaroa Harbour, flows into Pigeon Bay, whose streams are thus capturing the heads of those on the other side of the ridge. Thus it is that the crest-line of the hills round the harbour takes a remarkable bend in at this point, and the headwaters of Pigeon Bay on its western side have cut in circumferentially along the strike and apparently separated the elevations from the walls of the crater. There appears to me to be no reason why they should be regarded as separate centres of eruption, and after careful examination I must withdraw my former endorsement of Haast's and Hutton's opinion.*

## 5. Fourth Volcanic Phase.

### *Quail Island.*

The final stage in the volcanic history of the peninsula was the formation of Quail Island (Plate XXV), which represents in all probability a secondary cone within the crater-ring of Lyttelton. The basement of the

* R. Speight, On a Soda-amphibole Trachyte from Cass's Peak, Banks Peninsula, *Trans. N.Z. Inst.*, vol. 40, 1908, p. 176.

island consists of rhyolitic material described previously, but the lavas capping this are entirely of basalt. The lowest beds exposed on the north-west corner of the island are of basalt, but at the base of the cliffs facing the harbour is a bed of irregular angular material, 80 ft. thick where it is best developed, which may form the lowest member of the series in this locality. The fragments are of all sizes up to 1 ft. in diameter, chiefly of basalt, rhyolite, and trachyte, but with occasional pieces of greywacke, no doubt torn by explosive action from the underlying substratum in close proximity to the vent. Where exposed on the shore platform at the base of the cliffs the material is especially coarse, but in the cliff itself appear layers of fine-grained ash with well-developed stratification. Since there is an absence of traces of sea action, as well as no evidence of marine fossils, it is reasonable to assume that the stratification is due to sorting by the wind and not to water, a mode of formation of wide-spread occurrence where volcanic cones have been constructed on a land surface.

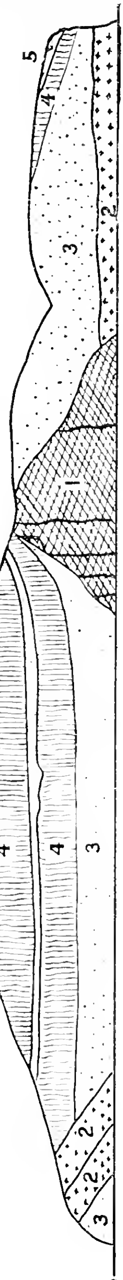


Fig. 4.—Section, north side of Quail Island. Length, 40 chains. 1. Rhyolite with dykes of trachyte. 2. Older basalt, amygdaloidal in parts. 3. Volcanic breccia and tuff. 4. Later basalt, columnar and prismatic. 5. Loess.

At the edge of the shore platform the layer of agglomerate is overlain by solid flows dipping north, an arrangement suggesting that the sea has cut into the heart of the cone and exposed the beds in close proximity to the vent. This is all the more probable since at the extreme north-easterly point of the island the lava-flows dip south—*i.e.*, in the contrary direction. Another fragmentary layer is exposed on the shore at the base of the low cliff just north of the outer wharf, the fragments in this case consisting almost entirely of basalt; and as this lies almost on top of solid rhyolite in position, the junction being in close proximity but obscured, this may represent the oldest bed of the Quail Island series. The massive layer referred to previously probably outcrops on this face of the island as well, but the section is difficult to make out, as would be expected where the extruded material near the vent consists of irregular layers of fragmentary material, as well as small and irregular lava-flows.

Over the thick layer of fragments is a horizontal sheet of rudely prismatic basalt, 50 ft. thick, which is well exposed in the cliff facing Lyttelton. This abuts against the underlying basalt on the east, and against the rhyolite with its trachyte dykes on the west; its continuity is here broken, and it is impossible to say with certainty whether the flows exposed on the cliffs on the north-western point of the island belong to a later flow or not. The upper surface was deeply eroded before the succeeding layer of fragmentary matter was deposited. This layer is similar in character to the layer underlying the prismatic jointed flow, and it may be connected with the layer interposed between the two basaltic flows to the north-west of the island.

The last basaltic outburst has formed another markedly horizontal sheet, which in all probability caps the greater part of the top of the island, and extends down to sea-level on its western side. It shows almost perfect columnar structure in its lower parts, especially where exposed on the cliffs, but the upper layer is rudely prismatic, the line of junction between the two parts being quite distinct, although there is apparently no actual break in the flow. The columns are vertical, and in places the upper part of the flow overhangs and large pieces of rock have broken away and have fallen at the base of the cliff near sea-level. On the southern shore of the island boulders from this flow form a considerable portion of the loose material of the shore-line, though the flow does not appear to have reached the sea-level. Professor J. P. Iddings and Dr. P. Marshall have drawn my attention to the fact that some of these boulders are probably of alkaline type.

Haast considered that a hollow at the top of the island might have formed the crater ;* but both the eastern and western extremities of the two uppermost flows as exposed in the cliff abut against older volcanic material, either solid or fragmentary, and the inclination of the flows on the shore platform is generally to the north, so that the two distinct horizontal sheets occupy the actual floor of the crater. It is extremely probable that the northern side of the cone was breached either by the outflow of lava or by inroads of the sea, or perhaps by a combination of both processes, the reef which lies between the island and Lyttelton being perhaps the remains of a flow which extended in that direction. There is at present no evidence as to the date of these eruptions, but they probably date from the latter part of the Tertiary era.

## 6. POST-VOLCANIC HISTORY.

### (*a.*) *Evidence of Greater Elevation.*

The subsequent history relates to the destruction of the volcano by stream dissection, and to the depression of the land which allowed the sea to invade the floor of the caldera. The former action was actively continued when the land was higher, on lines which were in all probability determined when the volcano was in active operation. Besides the evidence for former greater height deduced from the drowned valleys and the sea-invaded calderas, there is proof available from the records of the bores put down in the artesian area which fringes the volcanic mass immediately on the west.† The land in this region was at least 700 ft. higher when these beds were laid down, as is evidenced by the occurrence of layers of peat at various levels down to 700 ft. beneath sea-level. These are found as far down as boring has been continued, and there is no reason why they should not be found lower still. An elevation of the land by even this amount would drain the caldera-floors, convert the drowned valleys both inside and outside the calderas into dry land,

* J. VON HAAST, *loc. cit.*, p. 348.

† R. SPEIGHT, A Preliminary Account of the Geological Features of the Christchurch Artesian Area, *Trans. N.Z. Inst.*, vol. 43, 1911, p. 420.

and would extend the fringe of land a considerable distance beyond the present outer margin of the peninsula.

Another proof of increased height may be obtained from the character of the vegetation of the mountain-tops. If they were once higher we should expect to find survivals of an alpine or at all events a subalpine flora. This is exactly what we do get. R. M. Laing* has shown that certain forms occurring on the summits are closely related to those found on the Alps fifty miles away to the west. This author, however, says in conclusion, "Whether this florula is to be regarded as a collection of waifs and strays or the remnant of a more widespread flora of glacial times I shall not endeavour to discuss here." Dr. Cockayne is of the opinion that the latter explanation is probably the more correct one of the two.

There is no doubt, however, of the greater height, and this corresponded with the time of the severe glaciation which this country experienced in Pleistocene times and later. It is generally agreed, however, that increased height of the land, and not a marked refrigeration of the climate, was the cause of the extension of the ice; but there is no evidence that the peninsula had a covering of ice or even nourished glaciers in its higher valleys. Their form gives no suggestion that this was the case, and there are no accumulations of angular boulders which might be called morainic in character. The only evidence of the neighbourhood of glaciers is afforded by the covering of loess which is found widely distributed at all levels and in various positions in the area. It is found on the extremities of the ridges dividing the bays on the north and east, on the southern slopes which reach down towards Lake Ellesmere, and on the western slopes above the Canterbury Plains, and it is found very thick in places within the calderas. It is found at all levels up to 2,000 ft., but it is specially thick on the ridges, and, above all, on those within the Lyttelton caldera, which lie at the back of Quail Island, where the capping is in places 25 ft. thick. This is well seen on the ridge between Governor's Bay and the Head of the Bay, in a road cutting. Captain Hutton† considered this a marine deposit, and if so it would imply a depression of the land at least 2,000 ft. below its present level. The general absence of marine fossils, the presence of remains of *Dinornis* and other land-birds, as well as its peculiar distribution, is against a marine origin being assigned to it. It is in all probability a rock-flour formed by glacier erosion, transported out on to the plains by glacial torrents, and distributed by winds during a time of drier and more steppe-like climate. On the slopes of the hills it would receive an admixture of clay derived from the weathering of the silicates contained in the volcanic rocks, so that it should not be regarded as a typical loess such as exists in Europe and America, but as a "pseudo-loess," as it has been called by Heim.‡

Although the later major movements of the land have been in a downward direction, there is evidence of a recent rise of from 2 ft. to 3 ft. at least. In some of the sheltered bays there are beaches with Recent marine shells some distance above high-water mark. The best illustration of this is found on the south side of Quail Island, where a well-

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* R. M. Laing, On a Subalpine Element in the Flora of Banks Peninsula, *Trans. N.Z. Inst.*, vol. 46, 1914, p. 57.

† F. W. Hutton, Note on the Silt Deposit at Lyttelton, *Trans. N.Z. Inst.*, vol. 15, 1883, p. 411.

‡ A. Heim, *Neujahrsblatt*, 107, Zürich, 1905, p. 38.

developed beach with shells occurs at the foot of a wave-cut cliff, now over a chain from the sea at its maximum distance. This evidence is supported by that obtained from the neighbourhood of Sumner, where the marine cliffs are now removed a considerable distance from the present shore-line. A part of this effect may be attributed to the progression of the shore by the deposit of sand, which has developed in places a dune system; but this is hardly sufficient of itself to account for all the phenomena. With this movement is connected in all probability the system of low terraces which fringe the Avon and Heathcote Rivers, immediately north of the peninsula. These streams have reached a second base-level below an original one, which was disturbed by this slight elevation of the land. Pronounced elevatory movements are in evidence on the coast-line from thirty miles farther north, near Amberley, Motunau, Amuri Bluff, and Kaikoura, and it may be that the peninsula is on the outskirts of the area affected, since the upward movement in its neighbourhood is very slight.

### (*b.*) *Results of Erosion and the Formation of Calderas.*

A consideration of the form of the harbours strongly supports the contention that stream erosion combined with wave action in cutting back the cliffs is responsible for their principal landscape features. The importance of stream erosion is very evident when we consider the depth to which valleys have been eroded on the outer slopes of the volcano. In numerous instances they have cut back till a very narrow ridge separates the inner and the outer slopes. This is well exemplified at Heathcote Valley in the dividing ridge above the tunnel, and at the head of the valley leading to Dyer's Pass; and in two places—viz., at the entrance and at Gebbie's Pass—the wall has been completely broken down. It has been mentioned previously that the heads of the valleys generally lead to the lowest parts of the crater-ring, and that this suggests that a former stream system has had the upper parts of the valley removed either by explosion or by collapse. It is possible, however, that it merely means the approach of the heads of two valleys from opposite sides of a ridge, and that the combined attack on the crest has resulted in its being lowered at that spot; and, further, the form of the valleys is a modern development, whereas the formation of the caldera by explosion belongs to some date in Tertiary geological time, and therefore such a feature is not likely to exhibit such a perfect arrangement now. The extent of denudation and its marked effect on the form of the mountains, reducing their height, is emphasized by the facts that the radiating ridges are frequently higher some distance away from the crater-walls, and that these higher portions are frequently capped by rock of more resistant nature, and that when its slope is prolonged craterwards it reaches a much higher level than even the highest parts of the crater-ring in the vicinity. This is markedly true of the Akaroa volcano, for there we have eminences reaching well over 2,000 ft. on the spurs which divide adjacent radial valleys. Instances of this are Pigeon Bay Peak and View Hill, on the northern flanks, and there are as well numerous unnamed elevations on the ridges to the south.

While a volcano is in process of construction streams will establish themselves on its outer slopes, with radial orientation, their heads cutting farther and farther back towards the crater, so that the valleys will be more bunched together towards the centre of the cone than on its margins, and a struggle for existence will occur among them, those reaching farther back robbing the less extended valleys of the supply of water at their heads and cutting in behind them. The result of this will be that the spurs which stretch down from the summit will broaden out as they reach lower levels, and the valleys established on their peripheral portions will in many cases be short. This feature is well displayed in the spurs which reach out in a northerly and westerly direction into the plains, where wave action has exerted but little effect; but on the outer rim of the volcano, where sea action has been intense, the broader terminal portions have been removed, and the effect is not so pronounced, since the lower portions of the short streams have been cut away, and the water either enters the sea by short steep ravines or by falls.

As these valleys run in the direction of the dip of the beds and at right angles to the strike, they exhibit the special features of transverse valleys—that is, they are trench-like in character, with steep sides; there is always a tendency to cut subsequent valleys at right angles, especially in their higher portions, but owing to the variation in the direction of dip and the discontinuity of particular layers these do not exhibit the regularity usually displayed by valleys cut in sedimentary strata. This may explain the amphitheatre-like form which characterizes the heads of many of the valleys, and where this does not occur it explains the branching heads of the valleys. This peculiarity has been noted by J. D. Dana with regard to the volcanic island of Tahiti,* where he states that the valleys of that dissected island are frequently narrow in their lower portions but open out into distinct amphitheatres at their heads. This gives an appearance resembling a crater or caldera, and it is this which probably influenced Haast so strongly in suggesting that the Little River and Pigeon Bay Valleys were really calderas, and the sites of independent volcanic vents.

Owing to the dominant valleys enlarging the upper part of their basins into an amphitheatre-like form, the heads of the adjacent smaller valleys are robbed of their proper supply of water—that is, the amount rightly belonging to the whole of the sector of the volcano which they should drain, and not the outer portion of that sector only. Although the smaller valleys may initially have been truly radial in orientation, in process of time they depart slightly from that direction and their heads point towards the high bounding ridge of the adjacent large valley. Further, owing to the more pronounced erosion in the dominant valley, the walls tend to encroach on the higher reaches of the smaller valley and to capture some portion of its higher reaches, which were primarily eroded by the water which discharged by means of the smaller valley. It thus exhibits what may be called a recessive character. As a result the smaller valleys are often headed by distinct saddles. This is well seen to the east of the Little River Valley. In the former direction, towards Peraki, all the valleys reaching down to the small indentations of the coast rise not from the crater-ring of Akaroa, but from the high eastern wall of the Little River Valley; while to the west, between this valley and the large Kaituna Valley, we have first Price's Valley and then Birdling's Valley reaching back successively to the valley-wall of Little River, the second valley as it touches the crest farther up being far the longer of the two (see Plate XXIV). In both these cases the subordinate valleys are headed by depressions in the dominant ridge, not deeply incised, it is true, but the effect is still visible, and in

* J. D. Dana, *Characteristics of Volcanoes*, 1890, p. 376.

process of time, as the dissection becomes more advanced, it will result in the division of the ridge into a series of isolated blocks and thus aid in the destruction of the cone.

The more energetic attack on the heart of the volcano owing to the bunching-together of the heads of the streams accounts for the form of the remnants of dissected cones, which consist usually of a central resistant plug forming the neck, and then some distance away isolated remnants of the lava-flows in their proper positions.

While the streams flowing on the outside surface of the cone are usually consequent in character, with a tendency to subsequent tributaries, those on the inside of the crater will have the character of obsequent streams with steep grade, obstructed by falls and rapids when they flow over ledges of harder rock. In a normal crater the erosion of obsequent streams will not be important while volcanic action is going on; but if the crater is enlarged by explosion or by breaching this erosion may achieve important results, and specially so if there is any concentration of the drainage of the internal slopes in the early stages. This will naturally arise in the case of a cone not subjected to explosion if it has been breached by a lava-flow from the summit. Thus a well-organized direction of drainage will be promoted from the beginning, and it is very probable that a number of calderas may owe their initial development to this circumstance.

The direction of drainage from the enlarged crater will generally follow the line of one of the consequent streams of the outer slope if it be not breached, since a low place in the wall of the crater-ring will usually head a valley. This is well exemplified at the present time by Ruapehu, for the low part of the crater-ring faces the eastern side, and the drainage from the basin on the top of the mountain will naturally concentrate towards that point. In this case the depression in the height of the wall may be due to the accidents of explosion, or to the attack of the wall from the outer slope, or to both causes. When this direction is once firmly established erosion will tend to enlarge the interior of the crater by sapping back the walls, the form of the crater being to a large extent preserved, the steep scarp slopes of the interior being maintained in just the same way as the scarps of tilted sedimentary strata are preserved. Thus the form of the crater will be kept till it reaches the dimensions of a normal caldera, and the barranco will be the valley due to the erosion of the concentrated drainage. Should any modification of the structure occur from any cause, or should denudation expose material of different character from that of a normal cone or with different stratigraphical arrangement, then a departure from this form will ensue, an instance being seen at the head of Lyttelton Harbour, where the sedimentary strata and rhyolite beds of different arrangement from the remainder of the volcano have caused modifications in the form of the resulting cavity. Should the crater-wall be broken in more places than one by the explosion or by normal volcanic action, or should several streams cut back their heads till they have invaded the crater, then similar features will be produced along other lines and more than one barranco may drain the caldera.

If we take the conditions obtaining now in the case of Lyttelton, we observe that all along the northern side of the harbour the valleys have the features of obsequent streams, and as they cut back their heads and diminish their average grades they will retain this character, but with diminishing characterization, as the grade becomes less pronounced. The spurs in this portion of the harbour are usually terminated in steep cliffs owing to the erosive action of the sea: this, too, tends to maintain the appearance of the interior walls of the crater as having been caused by explosion. The steep-graded valleys carry their grades down below water-level till they merge into the floor of the harbour, emphasizing the unity of origin of the subaerial and submarine portions. In the western part of the basin the interior slopes are occupied by long tongue-like peninsulas, nearly two miles in length from the point where they are joined on to the walls of the crater-ring. The valley-floors between them are very flat and grade insensibly in the floor of the harbour, and they show the form they should possess were the harbour a river-valley and its head enlarged by water action with just that amount of modification effected by the in-filling of sediment into the submerged portion. The sources of the streams which drain inwards are distributed along the inner crest of the crater-walls, but the streams join the main valley at points in close proximity to each other. Where the valleys are cut in the lava-flows dipping outwards the valleys have just the same features as those on the northern side of the harbour.

This locality also illustrates the breaking-down of the wall of the crater by the combined action of streams attacking it from the inside and the outside slopes. The streams responsible for the formation of Gebbie's and McQueen's Valleys, as well as those occupying the valley within the harbour area where Teddington lies, have completely removed the andesites, deeply dissected the rhyolites, and exposed the underlying greywackes over a considerable extent of country. The forms of the two external valleys are so strongly reminiscent of the lower reaches of Lyttelton Harbour that they are probably due to a common cause.

On following the harbour round beyond this gap past a remnant of the old crater-ring the interior slopes are modified from the true caldera form by the gentle slopes reaching up to Mount Herbert accordant with the flow of the lava-streams from that more recent centre of eruption; but even here, where small exposures of the underlying beds can be seen, they suggest a land surface analogous to that on the northern side of the harbour. To the east of these flows, and eroded along their margin, lies another drowned valley, called Purau Bay; but from this on to the southern head the characters are those which we should expect from the erosion of a stream flowing across the strike of gently inclined beds dipping uniformly in one direction. This portion of the harbour thus has a trench-like cross-section, a feature made more pronounced by the attacks of the sea on lava-flows where the jointing is almost vertical. The same feature is seen in the lower portions of Gebbie's and McQueen's Valleys, except that the influence of the sea in forming a wave-cut cliff is not so prominent.

A feature to be considered in arriving at a conclusion as to the origin of the cavity is that the valley-heads almost entirely occupy lower parts of the crater-ring and do not lead up to the highest peaks. Although this suggests that the valleys have had a portion of their upper courses beheaded by explosion or by collapse of the cone, such as happened in the case of Mount Mazama,* in the United States, it is quite possible to explain the phenomenon as an effect of normal stream erosion on a cone which has not suffered such a catastrophe. The approximation of valley-heads on the

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* J. S. Dillon and H. B. Patton. Geology and Petrography of the Crater Lake, National Park, *U.S. Geol. Surv. Prof. Paper No. 3.* 1902.

inside and outside of a cone would probably arise as erosion proceeded without the intervention of explosion or collapse of the interior.

The general features of the Lyttelton crater are reproduced in Akaroa Harbour. The steep interior slopes towards the entrance, the peninsulas at the head with their drowned valleys lying between them, the gradually deepening of the harbour and its tributary bays towards the entrance, the accordance of the grade of the floors of the valleys with that of the harbour, the wave-cut cliffs gradually getting higher as the outlet is approached, and the perpendicular walls which guard the entrance agree exactly in both cases. Akaroa has, however, a more perfect crater-ring: it is only broken where the sea enters, and its regularity is not destroyed by subsequent eruptions breaking out on the edge of the crater, as has happened in the case of Lyttelton. If we make due allowance for the special features which exist in the case of Lyttelton and are absent in Akaroa, we cannot but conclude that the same causes have contributed in each case to establish the caldera-like form, and the dominating one is the effect of stream action on a crater which has been enlarged by a paroxysmal explosion of moderate intensity or by breaching, but not one which has produced the great cavities which now form the harbours as they are.

The stream-erosion theory of the formation of calderas has been advanced by Gagel in connection with the Palmas Caldera, and I believe that he did not regard explosion as a contributing agency. I have not been able to obtain his paper, but have only the reference to it in Professor R. A. Daly's *Igneous Rocks and their Origins*. Haast and Hutton, on the other hand, regarded the cavity as having been produced by explosion alone. If, however, explosion were entirely responsible for the formation of the cavity there should be accumulations of fragmentary matter round the vent approximately equal in volume to that of the cavity. The amount of material thrown out to make a space five miles across and at least 2,000 ft. deep should certainly have left traces in the surrounding country, even after allowing for denudation. There is no such accumulation under the subsequent lava-flows from Mount Herbert, where it would be protected from denuding agents. It is not intended to deny that in the early stages moderate explosions did exert some effect. When the small size of the necks of old volcanoes is considered (see Sir A. Geikie's *Ancient Volcanoes of Britain*), the largest recorded in Fife being a mile in diameter, and the average far below this, we must conclude that unless the original crater is enlarged in some way water erosion by itself would in all probability be unable to produce a cavity of the shape usually arrived at.

Subsidence of the floor due to faulting has been suggested by Dutton* as a prime cause of the formation of calderas, especially those of the Hawaiian group. When, however, we examine the line of junction of the Lyttelton lavas with the underlying greywackes at the head of the harbour and the Gebbie's Pass ridge, there is no sign of dislocation following the base of the crater-ring; the long tongues of rhyolite stretching down therefrom into the upper part of the harbour and almost reaching the actual centre show no sign of a break, such as should occur were the line of fault to follow the bounding walls of the depression. If such a line did occur it should certainly be found cutting across the direction of flow of the rhyolite lava-streams in close proximity to their junction

*C. E. DUTTON, Hawaiian Volcanoes, *4th Ann. Rep. U.S. Geol. Surv.*, 1884, p. 105.

with the greywacke. There is also no sign of dislocation in the discordance of the grades of the streams which would cross such a line: perhaps this point is of no great importance. I am therefore of the opinion that the determining cause of the formation of such great hollows as Lyttelton and Akaroa Harbours is prolonged water erosion and not paroxysmal explosions, although an explosion of moderate intensity or the breaching of the cone by a lava-flow may have initially determined the directions of the streams which established themselves on the surface of the volcano.

The landscape features of these two harbours are reproduced almost exactly in the case of Carnley Harbour, in the Auckland Islands, the comparison with Akaroa being especially striking,* except that Carnley is on a much larger scale, and instead of having one peninsula it has three large peninsulas forming long trailing spurs directed towards its interior. The agreement as to nature of the lavas, arrangement of the flows, height of the encircling hills, form of the internal and external slopes, and the shape of the great cavity suggest a similar origin and a similar geological history. No doubt the hollow was formed primarily by a moderate explosion or by breaching of the cone, and was enlarged subsequently by stream erosion and a glaciation of moderate intensity—the latter absent in the case of Akaroa—at a time when the land was higher. The enlargement of the cavity by erosive agents and the removal of the periphery of the mountain by the action of the sea have resulted in the partial break of the walls at one place on the western side and in their complete breakdown in another, and through the gap fierce tides and heavy waves pour into the western portion of the basin. The proper entrance is placed at the east, being exactly similar in form and cross-section to that of Akaroa and Lyttelton, with a distinctly fiord-like character, a result perhaps due partly to glacier action, but certainly attributable in great part to the action of water as described previously.

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## Art. XXVII.—*The Relationship of the Upper Cretaceous and Lower Cainozoic Formations of New Zealand.*

By Professor James Park, F.G.S., Otago University, Dunedin.

[*Read before the Otago Institute, 5th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

In vol. 48 (1915) of the *Transactions of the New Zealand Institute* there appear papers by Mr. P. G. Morgan, Dr. J. Allan Thomson, and Dr. Marshall dealing mainly with the relationship of the Lower Cainozoic marine strata of New Zealand to the Upper Cretaceous. In each of these papers my own views as to the so-called Cretaceo-Tertiary succession, and those of other New Zealand geologists, are discussed at considerable length. Of an admittedly complex problem, rendered all the more puzzling to outside geologists by the great diversity of opinion expressed at various times by many writers, Morgan's paper† embodies, to my mind, the most lucid and comprehensive exposition that has so far been placed on record. He recognizes the Miocene age of the uppermost beds at Waipara and Weka Pass,

* R. Speight, Physiography and Geology of the Auckland, Bounty, and Antipodes Islands, *Subantarctic Islands of New Zealand*, 1909, p. 708.

† P. G. Morgan, Records of Unconformities from Late Cretaceous to Early Miocene in New Zealand, *Trans. N.Z. Inst.*, vol. 48, pp. 1–18, 1916.

the Upper Cretaceous age of the lowermost beds, and the *apparent* stratigraphical conformity of the strata from the Miocene to the Cretaceous, but finds himself, after a judicial summary of all the available evidence, unable to support the Cretaceo-Tertiary theory of the old Geological Survey. He describes the uneven corroded surface of the Amuri limestone where overlain by the Weka Pass stone in North Canterbury, and, while not placing undue stress on the magnitude of the discordance at this contact, he seems to think that the break between the Cainozoic and Cretaceous may occur at this horizon. In this he agrees with the view all along held by Hutton, and in 1912 adopted by myself* after the discovery (or rediscovery) of Cainozoic molluscs in the Weka Pass stone at Waipara by Thomson and Cotton.

In his paper† on the "Flint-beds associated with the Amuri Limestone" Thomson records the occurrence of Tertiary (Oamaruian) molluscan fauna in a bed of tuff intercalated in the Amuri limestone in the Trelissick Basin. This discovery, made by Thomson and Speight in 1915, seems destined to furnish the solution of many of the perplexities that have in the past obscured the unravelling of the relationship of the Lower Cainozoic and Cretaceous of New Zealand. The bed of tuff is overlain by 10 ft. of Amuri Limestone and underlain by 350 ft. of Amuri limestone. Of the molluscs enumerated by Thomson, 19 per cent. are Recent, and the remainder are all well-known Tertiary species, mostly Oamaruian (Miocene). Save foraminifera (mostly *Globigerina*), some radiolarians, and sponge spicules, the Amuri limestone itself is unfossiliferous, or, at any rate, devoid of molluscan remains; and, while recognizing the Oamaruian age of the tuffs and overlying portion of Amuri limestone, Thomson expresses the view that the portion of the Amuri limestone below the tuffs fills the hiatus between the Senonian and Oamaruian.

Marshall‡ in his paper on the "Relations between Cretaceous and Tertiary Rocks" discusses at considerable length the views of different New Zealand geologists as to the Waipara succession, and furnishes much useful information as to the relationship between the Cretaceous and Tertiary rocks in other parts of the globe. He reaffirms his belief in a Cretaceo-Tertiary succession.

I do not think that any useful object would be served by a further discussion of the various points of disagreement between myself and Dr. Marshall. The settlement of the Cretaceo-Tertiary can only be achieved by a detailed geological survey of the Middle Waipara and Weka Pass districts. The groups of beds recognized there, and their order of superposition as agreed by all geologists, are—

| | |
|---|---|
| 1. Greta beds | Oamaruian (Miocene). |
| 2. Mount Brown beds | |
| 3. Grey marls | |
| 4. Weka Pass stone | |
| 5. Amuri limestone | |
| 6. Glauconitic greensands | .. Doubtful. |
| 7. Saurian beds | Senonian. |
| 8. Oyster-bed | |
| 9. Quartz sands with brown coal | |

* J. PARK. Tertiary Fossils in the Weka Pass Stone, New Zealand, *Geol. Mag.*, July, 1912, p. 336.

† J. A. THOMSON, *Trans. N.Z. Inst.*, vol. 48, 1916, pp. 48–58.

‡ *Loc. cit.*, pp. 100–19.

The Saurian beds contain *Plesiosaurus* and other reptilian remains of a Cretaceous facies, and are probably of Senonian age. According to Haast,* the glauconitic greensands contain *Waldheimia lenticularis* (which he says is also common in the Mount Brown beds), a *Pecten*, and a large smooth *Inoceramus* which he says resembles *Inoceramus planus* of Europe. When *Lima laevigata* was first reported† in the Cobden limestone it was called *Inoceramus*. The presence of the brachiopods and pectens inclines me to suspect that the large smooth *Inoceramus* of Haast may be, after all, nothing more than *Lima laevigata* Hutton.

The upper five members of the succession—or, at any rate, the upper four members and the uppermost portion of the fifth (Amuri limestone)—are acknowledged by all to be Tertiary. The age of the glauconitic greensands has been considered Cretaceous by all who have written on this subject, but in view of the recent discovery of an assemblage of Oamaruian molluscs in tuffs intercalated in the Amuri limestone, and the doubt as to the correctness of Haast's identification of *Inoceramus*, I am inclined to think that this view may have to be revised.

The opponents of the Cretaceo-Tertiary hypothesis place the unconformity between the Cretaceous and Tertiary at the close of the Amuri limestone. The discovery of Tertiary molluscs in the tuffs intercalated in the Amuri limestone leads me to conclude that the unconformity must be looked for under the Amuri limestone. Later investigation may even show that the unconformity occurs between the Saurian beds and the glauconitic greensands.

The unconformities that have been recognized between the Mount Brown and Greta beds, and between the Amuri limestone and Weka Pass stone, may prove to be local and of no palaeontological significance.

A glauconitic sandstone containing a Tertiary molluscous fauna has been reported by McKay as lying below the hydraulic limestone at Kawakawa, and a rich assemblage of molluscs was discovered by myself‡ as far back as 1885 in glauconitic greensands underlying the hydraulic limestone at Pahi, in the Kaipara district. The Pahi molluscs are undoubtedly Oamaruian. The presence of this Tertiary fauna below the hydraulic limestone has always presented one of the perplexing problems of the geology of North Auckland. The correlation of the Amuri limestone with the hydraulic limestone receives powerful support from the discovery of a Tertiary fauna in the Amuri limestone at the Trelissick Basin. The placing of the Amuri limestone in the Tertiary succession removes the most perplexing difficulty that has confronted geologists in the interpretation of the geology of the North Auckland district. What now remains to be done is to determine the relationship of the glauconitic greensands in the Middle Waipara to the overlying Amuri limestone and the underlying Saurian beds.

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* J. Haast, Notes on the Geology of the Central Portion of the Alps, including Mount Cook, *Reports of Geological Explorations during 1870–71*, 1871, pp. 11, 12.

† A. McKay, Reports relative to Collections of Fossils made on the West Coast District, South Island, *Reports of Geological Explorations during 1873–74*, 1877, pp. 80, 101; and *during 1874–76*, 1877, p. 38.

‡ J. Park, On the Kaipara District, *Reports of Geological Explorations during 1885*, 1886, pp. 164–70.

## ART. XXVIII.—*The Rate of Erosion of Hooker and Mueller Glaciers, New Zealand.*

By Professor JAMES PARK, F.G.S., Otago University, Dunedin.

[*Read before the Otago Institute, 5th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

IN a paper on the rate of erosion of the Hooker and Mueller Glaciers, presented to the Otago Institute in August, 1912, Dr. Marshall* records the results of thirteen determinations of the amount of suspended matter carried by the Hooker River, which drains the Hooker and Mueller Glaciers. The first sample was taken on the 17th November, 1911, and the last on the 25th March, 1912. The lowest result gave 1 part of suspended matter in 885 parts of water, and the highest 1 in 39,141. He concluded that the whole of the suspended material was the product of glacier erosion due to the slow movement of the ice over the rocky bed. From his meagre data he calculated that the rock bed over the whole *névé* and glacier area of the Hooker and Mueller Glaciers was being removed at the rate of $\frac{1}{63}$ in. annually, equal to 1 ft. in 756 years.

In the discussion which followed the reading of the paper I pointed out that both the Hooker and Mueller Glaciers were heavily dirt-laden, and that in all probability a large proportion of the suspended matter ascribed by Dr. Marshall to glacial erosion was in reality released from the melting *névé*.

Since that date I have again examined the Mueller and Hooker Glaciers. The Mueller Glacier, especially in its lower portion, is covered with an extraordinary quantity of transported material, ranging from large angular flaggy slabs of argillite and greywacke to small angular grit mixed with fine particles of fresh unoxidized rock. Ten pannings of the finer material, taken at different points near the terminal end of the *névé*, contained from 0·08 to 3·60 per cent. of material sufficiently fine to form suspended matter when placed in water moving at the rate of 3 ft. per second.

The Hooker Glacier also carries a large load of frost-shattered rocky material, and in many places is interstratified with thousands of thin bands of fine material that alternate with thin bands of almost clear *névé*. These dirt bands descend through the body of the *névé* to an unknown depth. When the *névé* melts they discharge their load into the river draining the glacier.

Experimental tests of the material forming the dirt bands showed the presence of from 0·16 to 2·34 per cent. of material sufficiently fine to form suspended matter in slowly moving water. The lowest observed velocity of the water at the Hooker bridge was 5·6 ft. per second.

The *névé* is constantly melting at the terminal face and on the walls and roof of the ice-tunnel under the glacier. Moreover, the glacier river flows in the ice-tunnel with a great velocity, as may be seen at various places where the sides have collapsed. The wear-and-tear and pounding of the larger fragments of argillite when they fall into this turbulent stream, in the two miles between the terminal face and Hooker bridge, must be

* P. MARSHALL, Note on the Rate of Erosion of the Hooker and Mueller Glaciers, *Trans. N.Z. Inst.*, vol. 45, 1913, pp. 242–43.

considerable—probably sufficient to form a certain amount of fine suspended matter.

How much of the suspended matter in the Hooker River is liberated from the melting *névé*, or how much originates from the attrition of the fragments that are carried along by the fast-flowing stream, or from ice-erosion of the glacier rocky bed, is indeterminate. At any rate, Dr. Marshall has neglected to take into account some obvious sources of suspended matter, other than ice-erosion. For that reason I am unable to regard his tests as a trustworthy basis for the computation of the rate of ice-erosion of the Hooker and Mueller Glaciers.

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## Art. XXIX.—*On a New Species of Coral from the Lower Oamaruian Tuffs near Deborah, Oamaru.*

By Professor James Park, F.G.S., Otago University, Dunedin.

[*Read before the Otago Institute, 5th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

Plate XXVII.

### Family OCULINIDAE Milne-Edwards and Haime.

### Genus Oculina Lamarck.

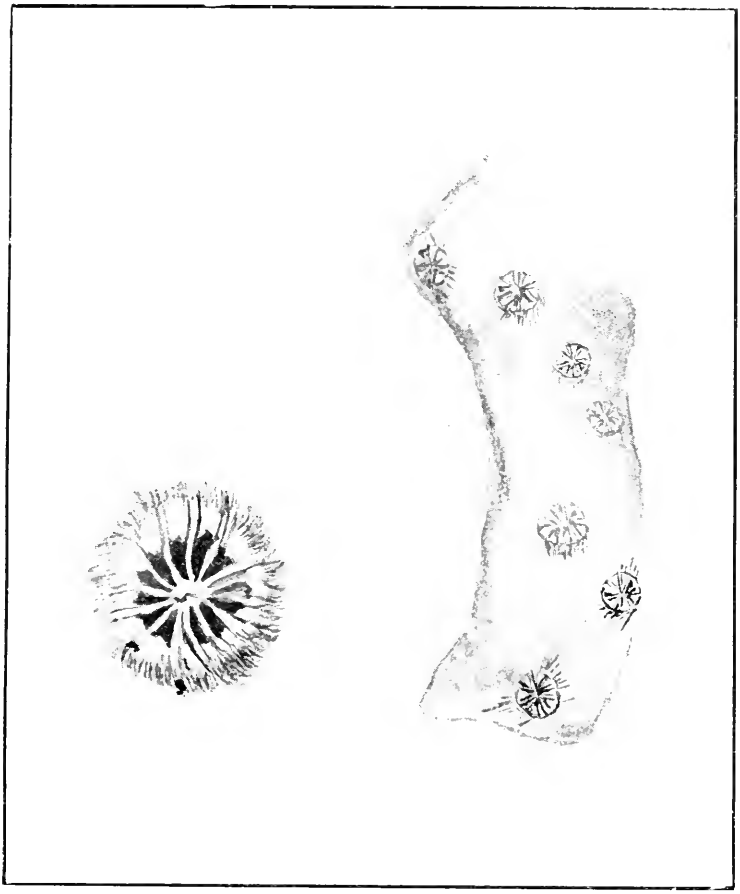
### Oculina oamaruensis sp. nov.

Corallum dendroid, branches cylindrical or subcylindrical, from 1 cm. to 3 cm. in thickness; calices circular; diameter of calices from 3 mm. to 5 mm.; calices usually from two to three diameters apart, but in a few cases less than one diameter on young branches; in axial direction calices show a tendency to be disposed in regular spirals. The margins of the calices are slightly raised; in some cases they may project as much as 2 mm. The cavity of the calice is shallow. Only casts were available for examination, and as the material forming the casts is somewhat coarse in texture the septa are not well preserved, and hence cannot be numbered. For the same reason the pali teeth are obscure. The columella appears to be well developed.

*Locality.*—From bed of calcareous tuff overlying pillow-form basaltic lava at old quarry on north bank of Awamoa Creek, half a mile north of Deborah railway-siding.

*Geological Horizon.*—The calcareous tuff lies about 45 ft. below the Oamaru stone. It therefore belongs to the Waiarekan stage of the Oamaruian.

*Age.*—Probably Lower Miocene or Oligocene. This is the first recorded occurrence of the genus *Oculina* in New Zealand. The Oamaruian species appears to be almost identical with *O. mississippiensis* (Conrad), 1900, from the Vicksburgian Oligocene of the Lower Mississippi. It may be noted that *Oculina mississippiensis* (Conrad), 1900 = *Madrepora mississippiensis* Conrad, 1847; *Oculina americana* Milne-Edwards and Haime, 1857; and *Dendrophyllia mississippiensis* Conrad, 1866.



[J. G. del

*Oculina oamaruensis* Park.

Face p. 396.]

# ART. XXX.—*Diastrophic and other Considerations in Classification and Correlation, and the Existence of Minor Diastrophic Districts in the Notocene.*

By J. ALLAN THOMSON, M.A., D.Sc., F.G.S., Director of the Dominion Museum, Wellington, New Zealand.

[*Received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

CONTENTS.



## I. DIASTROPHIC CONSIDERATIONS IN CORRELATION, AND THE EXISTENCE OF MINOR DIASTROPHIC DISTRICTS IN NEW ZEALAND DURING LATE CRETACEOUS AND EARLY TERTIARY TIMES.

CORRELATION by lithology implicitly involves diastrophic considerations, but the first explicit use of these in the classification and correlation of the younger rocks of New Zealand occurred in a paper by Marshall, Speight, and Cotton (1911). The thesis put forward by these writers after an examination of several critical localities was that no unconformity exists within these younger rocks, which were deposited in a single cycle of depression and re-elevation. In different localities the basal beds of the series vary in age from Cretaceous to Miocene, owing to overlap during depression on a surface of high relief; but the middle member, the limestone, was deposited at the period of maximum depression, apparently "early Oligocene," and is therefore contemporaneous throughout the country.* In support of this principle of correlation a paper by T. C. Chamberlin (1909), entitled "Diastrophism the Ultimate Basis of Correlation," was cited in a footnote. The authors mentioned their intention to state fully the palaeontological side of the question in future papers, thereby admitting to some extent that the palaeontological evidence was not adequately known, but would be expected to fall into line with the diastrophic considerations.

Diastrophism is defined by Chamberlin and Salisbury (1909) as including all crustal movements, whether slow or rapid, gentle or violent, slight or extensive. In claiming that these movements form the ultimate basis of correlation, Chamberlin (1909) gives reasons for accepting the periodicity of the great world-warping deformations, while admitting the adjustment of minor stresses at other times, producing intercurrent departures from the strict tenor of the great systematic movements. The base-levelling

* The contradiction implied in this statement is presumably only a slip on the part of the authors. The highest basal beds should not be later than Oligocene on their theory. Marshall now classes the limestone as Miocene.

of the land which follows the great deformations means a contemporaneous filling of the sea-basins by transferred matter, and hence a slowly advancing sea-edge, which is thus brought into active function as a base-levelling agent. "The water-movement is essentially contemporaneous the world over, and is thus a basis for correlation. The base-levelling process involves a homologous series of deposits." It is further pointed out that diastrophism lies back of both stratigraphy and palaeontology, and furnishes the conditions on which they depend. The relationship is not reciprocal in any radical sense. The life does not in any appreciable way affect diastrophism, nor does deposition control diastrophism except by exercising a localizing influence. "Diastrophism therefore seems to be the ultimate basis of correlation. The criteria of this correlation include at once its own specific criteria, the criteria of stratigraphy as dependent on diastrophism, and the criteria of palaeontology as modified by the direct and indirect effects of diastrophism."

Chamberlin recognizes four stages produced by diastrophism—"(1) the stages of climacteric base-levelling and sea-transgression; (2) the stages of retreat which are the first stages of diastrophic movement after the quiescent period; (3) the stages of climacteric diastrophism and of greatest sea-retreat: and (4) the stages of early quiescence, progressive degradation, and sea-advance." For stratigraphical purposes it appears useful to introduce a grouping of them, and to recognize in a diastrophic cycle two main periods—one of climacteric deformational activity, and one of relative inactivity, including the stages of sea-retreat which are the first stages of a new deformation, and the stage of early quiescence. During the period of climacteric activity the land is greatly extended and its surface diversified, and inequalities of climate and such extremes as aridity and glaciation are liable to occur. The deposits of such a period include clastic deposits in land basins and on low slopes, wind deposits such as loess, glacial deposits, and clastic deposits on the sea-margins. The terrestrial deposits of this period are largely destroyed during the subsequent base-levelling, while the marine deposits lying on the outside of the continental slopes are seldom likely to be raised above sea-level. The deposits of the period of relative deformational inactivity are dominantly marine, and furnish the main deposits of the stratigraphical record. The cycle of marine sedimentation as opposed to the diastrophic cycle includes a series of deposits formed during a period of gradual sea-advance followed by gradual sea-retreat, the land surface which supplies the sediments being at first diversified and later base-levelled, so that the sediments of the later stages of sea-retreat are marked by the increased erosion of the deep soil-mantles accumulated in the base-level period. The succession of sediments given by Marshall as characteristic of the younger rocks of New Zealand is an excellent example of such a sedimentary cycle. The first deposits are gravels and sands, marking the early base-levelling process. Then follow greensands, the formation of the glauconite in which is believed to be conditioned by a scanty supply of sediment to the sea-floor, indicating that base-levelling was well advanced or the coast distant. These are followed by limestones, during the formation of which there was a nearly complete absence of sediment, corresponding to very distant or low-lying (peneplained) coasts. Greensands succeed, and then follow mudstones arising from the erosion of the thick soil-mantles accumulated on the peneplains, and finally sands and gravels, indicating that the surface of the peneplains has been destroyed by erosion due to sea-retreat. Marshall and his colleagues, it should be noticed, did not recognize the physiographic implications of their theory, and supposed that depression was so rapid as to produce marked overlap without allowing for the lowering by erosion of the land surface during deposition which the deposits themselves indicate.

Willis (1910) in discussing the periodicity of diastrophism finds it necessary to make certain qualifications. "The general law should be supplemented by one which recognizes unlike dynamic histories of different oceanic regions. It may be stated thus: The phenomena of diastrophism are grouped according to several distinct dynamic regions. Each region has experienced an individual history of diastrophism, in which the law of periodicity is expressed in cycles of movement and quiescence peculiar to the regions. The cycles of one region have been, however, to some extent parallel, though not conterminous, with the cycles of other regions, and thus major cycles of world-wide conditions are constituted by coincidences of regional conditions."

There is a considerable difference between these points of view so far as the world-wide application of diastrophic criteria are concerned. According to Chamberlin's view, the great deformations are world-warping, and it is the effect of these movements and of subsequent sedimentation through base-levelling on the level of the sea the whole world over which is emphasized as important for correlation. According to Willis's view, the existence of independent dynamic districts means that emergence of land in one district may at any particular time more or less compensate for the filling of the sea-basins by sedimentation in another. The rise and fall of the sea-level, so far as this is effected by displacement simply and not by gravitational attraction, will be the sum of the displacements produced by different great deformations, which are not necessarily in the same phase; and the sedimentary cycles of the different districts may be in different stages, and differently effected by the world-wide changes in sea-level. It is only when the great deformations are approximately in the same phase that the deposits can be homologous the whole world over. This latter view seems better adapted to explain the stratigraphical diversity of different parts of the world, the greater duration of sedimentary cycles in one part than another, and the frequent impossibility of bringing important groups of sediments into fully developed cycles of sedimentation.

When it comes to the discussion of actual problems of correlation the specific criteria of diastrophism may at times appear to conflict with the criteria of palaeontology, and in such a case Ulrich (1911) contends that the palaeontological evidence is the more trustworthy. This, indeed, seems axiomatic. The physical conditions controlling the deposition of beds of a given lithological character may be reproduced by diastrophism; the life accompanying the recurring conditions may be similar, but can never be exactly the same, owing to the fact of organic evolution. The criteria of palaeontology as at present developed are more delicate, and permit a more certain discrimination of apparently similar but really different effects than do the criteria of diastrophism. The latter are affected by the intercurrent departures within the cycles, departures which are only revealed by the criteria of stratigraphy and palaeontology.

In New Zealand about the early Cretaceous* there was a great diastrophic deformation, with wrinkling of the earlier Hokonui and so-called Maitai rocks and the formation of an extended land surface. Base-levelling and

* The ammonite beds of Kawhia lie on the dividing-line between Jurassic and Cretaceous; the belemnite beds and plant beds of Waikato Heads are later, and generally ascribed to the Wealden. The deposition of these beds apparently preceded the close at least of the great post-Hokonui deformation.

sea-advance followed, and it was not until a comparatively late Tertiary period that a new cycle of major diastrophism commenced with the Kaikoura orogenic movements.* Between these maxima of diastrophism were laid down those sediments, ranging from Middle Cretaceous (Utatur) to late Tertiary (Wanganuian), which were called by Marshall and his colleagues the younger rock-series of New Zealand, and named by Marshall the Oamaru system.† Previous classifications had not brought out the close diastrophic relationship of this group of rocks, and in this respect the paper in question marked a great advance.

Cotton (1916) has recently attacked the study of the younger rocks from a physiographical and structural point of view, and his conclusions as to the surface on which the beds were laid down are diametrically opposed to those reached in 1911. After the folding of the middle and lower Mesozoic rocks, he concludes that the surface was reduced practically to a peneplain before the deposition of the covering strata in several districts. The evidence for this is very clear in the case of the Ngaparan rocks of North Otago and South Canterbury, and the still younger rocks of the Aorere Valley and the Gouland Downs. Cotton (1913) originally suggested a similar state of affairs for the Middle Cretaceous covering rocks of the Clarence Valley, but it is not to be expected on theoretical grounds that at this date peneplanation was complete, nor does the very thick series of conglomerates, sandstones, and mudstones of this age support the suggestion. The presence of thick beds of greensand in the Senonian of North Canterbury, however, makes it likely that by this date the land surface had lost its former great diversity. Speight (1915) from an analysis of the nature of the sediments in Canterbury has come to a similar conclusion. If this view is correct, and if the great differences in the age of the basal covering beds in different districts are admitted, a view for which the palaeontological evidence is overwhelming, it follows, as I pointed out in 1914, that the earth and sea movements which permitted the deposition of these beds were not purely regional sea-advance, so far as the New Zealand area is concerned, as is assumed in the simple diastrophic theory, but movements irregular in their effects. Depression below sea-level occurred at an earlier date in some regions than in others. In north-east Marlborough it occurred in the Middle Cretaceous, in North Canterbury in the Upper Cretaceous, at Kaitangata between Senonian and Ngaparan, in South Canterbury and north-east Otago in the Ngaparan, in the Lower Awatere district in the Upper Oamaruian, at Maharahara in the Wanganuian, and so on. A still stronger line of evidence than the period of commencement of depression below sea-level is afforded by a consideration of the periods at which deposition ceased owing to sea-retreat. Even if the different age of the sea-advance in the different districts was due in some measure to differential relief, the irregularities in the surface would have been obliterated by sedimentation, and deposition should have ceased, under uniform regional conditions, approximately contemporaneously in all areas, whatever the date of its commencement. Nevertheless, the youngest marine deposits of the Clarence Valley are Oamaruian (stage uncertain), those of North Otago are Awamoan, those of North Canterbury (the Motunau beds) are probably

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* *Cf.* Cotton, 1916. The Kaikoura movements did not commence everywhere at the same time, and probably the Awatere and Clarence areas were the first to be affected.

† Marshall has not yet included the Middle Cretaceous rocks of the Clarence and Awatere Valleys in his Oamaru system, but it is difficult to see how otherwise he could deal with them.

Waitotaran, those of Wanganui are Castlecliffian. Regional sea-advance and sea-retreat may have been operative all the time, but differential movements of the land surface were certainly also operative in an important measure, and the total effect of the movements of land and sea resulted in the formation of sedimentary series in different districts, each of which resembles a full cycle of sedimentation but does not coincide in point of phase with the series of other districts.

We are thus led to the discrimination of minor diastrophic districts in New Zealand during the general relative inactivity between the great post-Hokonui and Kaikoura deformations. Two such districts were indicated by me (1916, No. 2) in contrasting the Amuri and Ototara limestones, and there are many others. It is the presence of these districts that has given rise to the problems of classification and correlation which have so much impeded geological inquiry in New Zealand, and it will be by a clearer recognition of them that the problems will be elucidated.

Marshall (1916, No. 1) has supplemented his original diastrophic argument for the correlation of all the younger limestones of New Zealand by an argument based on palaeontological grounds. His conclusion as to the equivalence in age of the Ototara and Amuri limestones is directly opposed to the conclusions drawn by me (1916, No. 2), and one or the other must be wrong. As a matter of fact, Marshall has reasoned incorrectly. The Ototara limestone contains *Amphistegina*, and so also do the polyzoal limestones of Whangarei (Horahora and Waro). "The frequent occurrence of *Amphistegina* thus points decisively to a Miocene age for this rock, and this organism may be used to correlate all those limestones in which it occurs, for it appears to be the same species in all of them." In passing, it may be pointed out that the premises do not justify the conclusion. The genus *Amphistegina*, on Marshall's own showing, ranges from Upper Eocene to Recent, and the species in question may, like other species of Foraminifera have a range nearly as large as that of the genus. Having thus correlated the Ototara and Whangarei limestones, Marshall then states that it is the general opinion of geologists that the Whangarei limestone is a lower horizon than the hydraulic limestone in the North of Auckland, or at least that the two limestones belong to the same series. The Amuri limestone, he continues, has always been correlated with the hydraulic limestone, and is therefore of approximately the same age as the Ototara limestone. No palaeontological evidence has been presented for the correlation of the Amuri and the Whangarei hydraulic limestones, and, until it has, the correlation of the Amuri limestone with the Ototara limestone by the intermediary of the Whangarei hydraulic and polyzoal limestones cannot be given any weight.

Marshall supports his arguments by stating that "the Otaio limestone, which is always regarded as an outcrop of the Amuri limestone, and which is a very fine-grained type of rock with an abundance of *Globigerina*, also contains this *Amphistegina*, which is apparently the same species as in other parts of the country." The only reason advanced for regarding the Otaio limestone as an outcrop of the Amuri limestone is its lithological nature. It is not directly underlain, as is the Amuri limestone, by Cretaceous rocks. It lies within the diastrophic district of north-east Otago and South Canterbury, where the sequence commences with Ngaparan coal-beds, and within which no Cretaceous rocks have ever been found. The typical Amuri limestone is always underlain by rocks containing Cretaceous fossils, and has never been found resting on rocks with Tertiary fossils. It is not known south of the Trelissick Basin.

A further argument advanced by Marshall in support of his correlation is the statement that Thomson and Speight have discovered a (Miocene) molluscan fauna in the beds beneath the Amuri limestone in the Trelissick Basin. In this case Professor Marshall seems to have misunderstood a verbal statement. There is a molluscan fauna beneath the Amuri limestone of the Trelissick Basin, the genera represented being *Ostrea* and *Inoceramus.* The fauna intended to be indicated by Marshall is of an Oamaruian type, and lies near the top of the Amuri limestone. There is no reason, however, to regard it as Ototaran rather than Waiarekan.

The substantial palaeontological arguments advanced by Marshall thus have no reference to the typical Amuri limestone of Marlborough and North Canterbury, and apply to rocks of other districts which are correlated on lithological grounds alone with the Amuri limestone. The evidence advanced by myself (1916, No. 2) is drawn from the district within which the typical Amuri limestone occurs, and is the only evidence at present available on which an opinion may be based.

Marshall (1916, No. 2) has himself brought forward new evidence which militates directly his position. From his description of the fossils of the beds at Wangaloa it is clear that this fauna occupies a position intermediate between the Senonian and the Oamaruian.* If the Amuri limestone follows the Senonian conformably, as Marshall believes, and correlates with the Ototaran, then between it and the Senonian beds there should be developed beds which are the equivalent of the Waiarekan, the Ngaparan, and the Wangaloa beds. The section observed by me in the Waipara River between the limestone gorge and the Doctor's Gorge is as follows:—

| | | Feet. |
|---|---|---|
| | Oamaruian Weka Pass stone. | |
| Amuri limestone | Hard white short-fractured limestone including a few marly bands .. .. | 100 |
| | Grey marly limestone.. .. .. | 60 |
| | Grey marly limestone passing gradually down into a dark blue-grey mudstone with plant remains, glauconitic at the base .. .. .. | 150 |
| Senonian | A few well-marked hard bands of greensand with Saurian teeth .. .. | 6 |
| | Black glauconitic mudstone with yellow efflorescence .. .. .. | 80 |
| | Concretionary greensands .. .. | 150 |
| | Purple mudstones (Saurian beds) with yellow efflorescence .. .. | 100 |
| | Sulphur sands passing down into white sands .. .. .. .. | 200 |
| | Poecilitic sandstone; *Ostrea* bed .. .. | 15 |
| | Sandstones and fine conglomerates with coal .. .. .. .. | 40 |

* This discovery is one of the highest importance, and greatly simplifies our problems of classification. It fills the palaeontological gap caused by the unfossiliferous nature of the Amuri limestone, and thus removes one of our greatest stumbling-blocks. Professor Marshall is to be heartily congratulated on his discovery.

The total thickness between the highest bed with Senonian fossils and the base of the Amuri limestone is less than 150 ft. of mudstone. This bed is hardly thick enough to represent the Waiarekan alone, much less that stage in addition to the Wangaloa beds and any immediate beds which may exist. The truth seems to be that the Wangaloa beds are represented in this section by some part (probably the lower part) of the Amuri limestone, and that the latter rock belongs to a much lower horizon than the Ototara limestone. The only alternative to this view is disconformity at the base of the mudstone into which the Amuri limestone passes down.

In the districts within which they are typically developed the Amuri and Ototara limestones each represent the period of maximum depression or sea-advance. These periods are, I contend, not the same, owing to the masking of any general regional sea advance or advances that may have occurred by the provincial warpings of distinct diastrophic districts.

The existence of other districts of this nature is proved, as pointed out above, by a consideration of the periods at which deposition commenced and ceased. In further support of my thesis I now propose to give palaeontological evidence which supports a difference in age between the Ototara and Takaka limestones.

In the Takaka and Aorere Valleys, including the Gouland Downs and Tata Island, there is a limestone which rests almost directly on the older mass of the Aorere series, being separated only by a thin bed of rolled quartz pebbles, bound together in many places by a calcareous cement. The limestone is followed by more or less calcareous mudstones upwards of 100 ft. in thickness. Higher beds are not known. From the limestone the following brachiopods have been identified: *Rhizothyris rhizoida* (Hutton), *Neothyris novara* (von Ihering), and a new species of *Neothyris* peculiar to this district. From the clays in the Brown River, Aorere Valley, I collected *Pachymagas abnormis* n. sp. (see Appendix I). The known ranges of these species are as follows: *Rhizothyris rhizoida* occurs in all Oamaruian stages from the Waiarekan to the Awamoan, but the specimens from the Wairekan are dwarfed, and are perhaps to be distinguished specifically. The species is found most abundantly in the Hutchinsonian. *Neothyris novara* occurs outside Nelson Province only in the Weka Pass district, where it is confined to the uppermost Mount Brown limestone, which I regard on the evidence of its other brachiopod fauna and its stratigraphical relations as Awamoan. *Pachymagas abnormis* occurs in the main or middle Mount Brown limestone of the Weka Pass, which I regard as Hutchinsonian on the evidence of its other brachiopod fauna, in the Awamoan blue clays of All Day Bay, and in mudstones in the Gisborne district.

These facts suggest that the age of the limestone is Upper Oamaruian rather than Ototaran. Excluding the new species distinctive to the district, all three brachiopods are known elsewhere from the Awamoan; one is confined, so far as present knowledge goes, to this horizon; a second ranges down only to the Hutchinsonian; and the third, while rarely found as far down as the Ototaran in its typical form, is most abundant in the Hutchinsonian. Further knowledge of the range of these species may invalidate these conclusions,* and, in any case, they must be considered in connection with the evidence obtainable from other groups of fossils, but until this other evidence has been similarly analysed the Takaka limestone must be regarded as younger than the Ototaran. In this district sea-advance did not commence until after the period of maximum depression at Oamaru.

* My statements as to the range of these brachiopods are based on the determination of well over ten thousand specimens from all parts of New Zealand.

The histories of the individual diastrophic districts thus indicated within the New Zealand area are not in all cases parallel. In some there has been a conformable series of sediments deposited; in others there have been earth-movements of different ages, producing unconformities in the series. There is no single unconformity that has been proved to be common to all districts. Hence any classification that shall be applicable to the whole country cannot be made to depend on the presence or absence of unconformities.

## II. Supplementary Statement of Principles involved in Classification.

It appears at first sight unfortunate that two new sets of local names applicable to the divisions of the Tertiary in New Zealand should be proposed in the same volume of the *Transactions* (Thomson, 1916, No. 1; Marshall, 1916, No. 2). As the principles given for selecting them are, however, fundamentally distinct, the adoption of either of them will doubtless be determined ultimately by the acceptance given to those principles, and I do not desire to insist unduly on the claims of priority which attach to my own proposals It seems desirable, however, to state more fully the principles which are at issue, as until there is agreement concerning these it is hopeless to expect that any system of nomenclature will meet with acceptance The analysis shows that there is no necessary conflict between the two proposals, but that Marshall's procedure is somewhat premature and his nomenclature not satisfactory

A distinction must be drawn in the first place between classification and correlation. Marshall's principle of classification is also made the main principle of correlation. The principles of correlation are numerous and intricate, especially as applied to Tertiary rocks, and they must be used as they are found applicable, and, if necessary, independently of any principles used in classification. The latter are much more simple.

The first point of my paper was that correlation with the divisions of the European classification is a matter of considerable difficulty in New Zealand, and one that has not been at all adequately discussed except for a very few groups of organisms, and then only for fossils from a very limited number of districts. The conclusions reached are contradictory, and none is entitled to outweigh the others. Consequently we begin at the wrong end when we call our rocks Eocene, Miocene, or Pliocene. There is no finality in such a procedure. Marshall's Miocene is not the same as Hector's or Hutton's, and yet all these authors were in practical agreement as to the relative position within the New Zealand succession of the rocks they so termed. The order of superposition of our Tertiary rocks is not in doubt in practically any district where there is a series developed. Let us, then, frame a classification with local names which are non-committal as far as European correlation is concerned. So far Marshall appears to be in agreement: "It would obviously be better to use New Zealand local names for the horizons of the Tertiary rocks of this country."

Geological classification is no longer governed by considerations of conformity or unconformity, but by the succession of faunas. This was first established as an empirical conclusion, and later received a logical basis through diastrophic considerations. Diastrophism is now recognized to be cyclic, and to be a prime cause of the changes of fauna. The interpretation of diastrophic history, however, depends again on palaeontological and stratigraphical studies, and, of the three kinds of criteria available, those of palaeontology are found to be the least open to misinterpretation.

Hitherto the only subdivisions recognized by Marshall within his Oamaru system have been the unit rocks of the series—conglomerates, sandstones, greensands, limestone, greensands, mudstones, sands and gravels; and he has even attempted to correlate beds in different parts of New Zealand by their height above the limestones there developed. He has now proposed a classification of the post-Cretaceous members of his system on the basis of faunas, characterized by their percentage of Recent species. With this method of characterizing faunas I shall deal below. Meanwhile it is satisfactory to note that in adopting the principle of successive faunas, employed by Hutton, he has returned to sound lines. Concerning his Waitaki series, which appears to be the equivalent of the Oamaruian, he states, "The dominant fact emerges that the species are so similar throughout that the beds obviously belong all to one series." If this conclusion is maintained, as I believe it will be, it of course justifies the use of a series name to include them. It is based, however, on small collections from few localities for each stage, except in the case of the Awamoan, and takes into cognizance only the molluscan fauna. In my opinion it is premature to attempt to revise the earlier groupings of the Tertiary rocks into series by their faunas without a much more exhaustive statement of what those faunas are.

My own proposal was for a series of unit or stage names for the smaller well-marked rock divisions, which have been recognized in all earlier classifications, leaving their grouping into series or systems until our palaeontological knowledge is more complete. Such a system of stage names will still have a permanent value after the grouping is possible, unless the divisions prove too large for zonal purposes. It is, of course, also based on the succession of faunas, as Marshall himself has helped to show by his statement of the increase of the percentage of Recent species in successively younger beds of his series; but it neglects intentionally the grouping of the units into series by major faunistic considerations, because this is considered premature. It may be a minor diastrophic accident that the succession at Oamaru commences with the Ngaparan. The fauna of the preceding stage may also be such that it should be grouped in the same faunistic series as the Oamaruian stages.

The two sets of local names for divisions of our Tertiary rocks are not, therefore, necessarily in conflict. One is a set of names for stages, the other a set of names for faunistic series. Both are based on the principle of a succession of faunas independent of considerations of conformity and unconformity. It remains to be considered whether the principles by which the divisions are selected and the names chosen are sound.

The only principle of division adopted by Marshall is that of the percentage of Recent molluscan species in the different beds. In passing, it may be observed that the percentages of Recent species adopted by Lyell included also the Brachiopoda, which are unimportant in the European Tertiary, but assume a much greater importance in New Zealand. To use the percentage of Recent species as a sole principle of division seems to me premature. The lists of fossils published during recent years do not cover one-tenth part of the determinations made by Mr. Suter for the Geological Survey on old and new collections, and for no single bed that I know of has collecting been so thorough that a further visit has not added to the list of species. We do not know accurately the percentage of Recent species for any division of the New Zealand Tertiary. Even if we did, the results could not be used with confidence in the correlation of one bed with another without a further analysis. The percentages may be different for the species which lived above and below the 100-fathom line; they may be different again for the faunules which inhabited sandy, muddy, glauconitic, or calcareous bottoms. Further, it would be an assumption to consider that the successive Tertiary faunas are entirely direct descendants the one of the other, and that the curve obtained by plotting the percentages of Recent species against even divisions of time is necessarily a straight line. If we suppose a large immigration of foreign species at any one stage, and suppose further that the immigrants subsequently became extinct or evolved into new forms in a greater proportion than the endemic forms derived from the previous stage, then it is not beyond the bounds of possibility that the later stage would show a lower percentage of Recent species than the earlier one, although the actual number of the Recent forms could not, of course, be smaller unless they had temporarily emigrated elsewhere. A numerical example worked out in Appendix II to this paper will make this possibility more clear. Although such a reversal of the increase of the percentage of Recent species in successively younger stages is very unlikely in the New Zealand area, still the possible effect of immigration or emigration in making the curve irregular must always be looked for. Until the course of the curve is much better known it seems premature to base divisions of the time scale upon arbitrarily chosen percentages of Recent species.

It is, of course, true that the original classification of the European Tertiary by Lyell was nominally based upon the principle of the percentage of Recent species. There were special circumstances in this case which caused the departure from the more ordinary methods, such as gave rise to the divisions of the Jurassic or Cretaceous in England. Lyell was faced with the problem of devising a classification for widely separate sets of beds, the order of age of which could not be fixed by superposition. In New Zealand we have not this difficulty. Lyell had in his mind, however, and definitely mentioned, certain actual beds which would serve as types for his different divisions—viz., the deposits of the London and Paris Basins for the Eocene, the faluns of Touraine for the Miocene, the Subapennine beds of Italy for the Older Pliocene, and still younger beds in Sicily for the Newer Pliocene. The percentages of Recent species which characterized his different divisions were not chosen or stated arbitrarily, but were directly derived from the known faunas of these "type" beds. When an increase in the knowledge of the fossils of these beds necessitated a change in the value of the percentages, this change was accepted without question by him, even although, as he stated, it rendered the derivations of his names somewhat inaccurate.

Stratigraphical classification resembles biological classification to this extent: that the ultimate court of appeal must be not the idea set up by the systematist in founding his species or division, but the actual and immutable thing or *type* that lies behind it. A classification by percentages of Recent species is based upon an idea liable to modification. A classification by beds is based on things which for human purposes are immutable. Behind any division of geological time based on a succession of faunas there must be the actual beds which contain those faunas, and from which the nature of the faunas can be ascertained. There is no past fauna of which our knowledge is complete, and it is not necessary to wait for a complete knowledge before using the faunas for classification, provided the rocks containing them can be defined. This definition Marshall has neglected to carry out, except so far as the names he suggests imply certain beds.

If the principle of the type in stratigraphical classification is admitted it may be desirable to import into stratigraphy the procedure used in zoological classification—viz., the right of a subsequent author to fix a type when the original author has left it vague. It would hardly be fair at present to go so far until the principle has been recognized, nor is it necessary. For all practical purposes Marshall's Wanganui series is equivalent to Wanganuian, and his Waitaki series to Oamaruian, the types of which are defined. The Wangaloa series is discussed more fully below.

As regards nomenclature, I have given in my former paper an account of the principles which seem to be necessary for attaining finality in this respect. The earliest-used name for a geological division should be retained if possible. In any case, a name once used should not be later taken up in a different sense. The rocks intended to be covered under a given name should be fully developed in the district from which the name is chosen, although it is not necessary that all the rocks developed in the district should be embraced by the name. The last two of these principles are violated by Marshall's use of the term "Oamaru system." This name was previously used in a different sense by Hutton, and is therefore preoccupied. In any case, it is made by Marshall to include large and important series of rocks which are not developed near Oamaru at all. His use of the term is therefore open to very grave objections, and must be rejected. The names suggested by him for his series are not open to such serious objection, but two of them nevertheless violate the principle of priority without any compensating advantage. The "Waitaki series" is a new name not before used in any different sense, but the same beds originally were given the name of "Oamaru series" by Hector in 1864, and if the unity of the series is established this name should be revived. Marshall would no doubt have used it if it had not coincided with the name he had given to the whole system. "Wangaloa series" is a new name, but the same beds have been termed the "Kaitangata series" by Park (1912). "Wanganui series" is presumably equivalent to Hutton's "Wanganui system" and Park's "Wanganuian."

## III. An Age Name for the "Covering Strata" or "Younger Rock-series" of New Zealand.

As stated above, there is a succession of beds in different parts of New Zealand which, apart from the controversial question of their conformity or unconformity, have a certain diastrophic unity in that they were laid down between two epochs of major diastrophism. It is desirable for many purposes in New Zealand geology to have a name which will embrace them all, a name which will replace the earlier name of "marginal rocks" used by Park and myself, and the physiographic and structural term of "covering strata," when an age significance is intended. Marshall's name of "Oamaru system" is undesirable for the reason stated above, and for similar reasons it is impossible to find any local name that is suitable. This is owing to the development of minor diastrophic districts within New Zealand. In the Clarence Valley the rocks in question commence with the Middle Cretaceous and end with some stage of the Oamaruian. In the Waipara district they commence with the Upper Cretaceous and end with the Motunau beds, probably Waitotaran. At Oamaru they are entirely comprehended within the Oamaruian, and at Maharahara within the Wanganuian, and so on. There is no district where the complete sequence is developed. Hence no local name is suitable.

The systems of the stratigraphical record as established in the Old World are now known to correspond approximately to major diastrophic cycles. Had these divisions been first worked out in New Zealand there is no doubt that the break roughly corresponding to that between the Mesozoic and Tertiary in Europe would have been placed between the Hokonui and the younger rocks, and that corresponding roughly to the break between Tertiary and the Quaternary would have been placed between the Wanganuian and the raised-beach deposits.

So far as New Zealand is concerned, the rocks deposited between the post-Hokonui and Kaikoura deformations are the younger rocks. Let us recognize this fact by giving them the descriptive name of *Notocene*.* To avoid all ambiguity, the Notocene embraces all the beds lying with marked unconformity above the Hokonui or so-called Maitai series, including the Middle Cretaceous beds of the Clarence Valley and the Castlecliffian of Wanganui, and all the intermediate beds, but excludes the raised beaches and other superficial deposits which lie unconformably on the Castlecliffian. Should still older or younger beds than those mentioned, deposited in the periods between the Hokonui and Kaikoura deformations, be subsequently discovered, they should also be included in the Notocene. The use of the term implies no necessary assumption that the beds embraced by it are all conformable or separable into unconformable groups, any more than the use of the term "Tertiary" implies that the Eocene and Miocene are necessarily conformable or unconformable. It also is not intended to imply that the post-Hokonui deformations ceased or the Kaikoura deformations commenced in all parts of New Zealand at the same time. Considered as a period of time, the Notocene is continuous, whether or not the present New Zealand area was wholly a land surface during any part of it, and no marine rocks corresponding to that part of it are accessible.

## IV. New Adjectival Names applicable to the Divisions of the Notocene.

The use of local adjectival stage names for the younger or Tertiary divisions of the Notocene was advocated because of the doubt attaching to direct correlation of these divisions with those of the European Tertiary. Although it appears from the exhaustive analysis of the available collections by Wood (1917) that direct correlations with foreign beds are possible for the older or Cretaceous divisions, a little consideration will show the advisability of local names for these also. Thus the beds below the Amuri limestone in the Amuri Bluff, and Waipara districts are placed in the Senonian, but it is exceedingly unlikely in view of the different diastrophic history of Pacific and Atlantic lands that these beds correlate exactly and completely with the European Senonian. Again, the Cretaceous beds of the Clarence Valley are correlated with the Upper Utatur of India, and by this bridge with the Middle Cretaceous of England. To term these beds in New Zealand "Utatur" would be highly inconvenient. Local names may therefore be applied with advantage. Until further study of these lower beds has been made, unit or stage names for the smaller divisions of the lower Notocene are unnecessary, and only names for larger divisions comparable to groups of stages such as Oamarnian and Wanganuian are at present advisable.

The Cretaceous beds of north-east Marlborough below the flint-beds are best developed in the Middle Clarence Valley, and may be termed *Clarentian*. They include coal-beds and marine rocks. The younger Cretaceous beds underlying the Amuri limestone between Kaikoura and Oxford are most fully developed at Amuri Bluff, and there is no previous name which applies to them exactly. Thus Haast's "Amuri Bluff beds" included the Amuri limestone, Hector's "Amuri series" was restricted to the beds below the Black Grit, and Hutton's "Waipara system" included the Amuri limestone. Hutton's name of "Ngarara group" meets the case

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* Greek νοτος, south; καινος, recent (as in Eocene, &c.).

more nearly; but this name was descriptive and not derived from a locality, being founded on *ngarara*, Maori for a reptile.

As the term "Amuri" is indissolubly connected with the Amuri limestone, which must be excluded from the group for which a name is sought, it cannot be used, and a new name becomes necessary. The most appropriate appears to be *Piripauan*, derived from Piripaua, the Maori name for Amuri Bluff. The disadvantage of this introduction of an entirely new name is compensated by the greater definiteness attaching to it. The Piripauan includes the sequence of beds at Amuri Bluff below the *Teredo* limestone, excluding the latter rock. It also excludes the "marlstone," or "cannon-ball sandstone," probably of Lower Cretaceous age, on which the Upper Cretaceous beds rest unconformably. The Piripauan in North Canterbury includes both coal-beds and marine rocks.

As thus defined both Clarentian and Piripauan are group names, embracing each a considerable thickness of rocks, but as Wood's researches show that each has a faunistic unity they may be also considered as names of series. The period of the Notocene between these two divisions is not at present known to be represented by fossiliferous rocks in the New Zealand area.

Marshall's Wangaloa series is apparently based collectively on the beds of Wangaloa, Brighton, and Hampden, which he correlates with one another. The reasons given for this correlation are not entirely satisfactory, and are practically only that in each of these three localities species with Cretaceous affinities are found. These species are different in each of the three localities, and two of them at least, *Trigonia neozelanica* Suter and *Trigonia* n. sp., are not really proved to have any Cretaceous affinities. The genus *Trigonia* is divided by ornament into several sections, each of which has a restricted stratigraphical range, and *Trigonia neozelanica* is distinctly of a post-Cretaceous type. If the new species mentioned is similar, this will leave only *Avellana tertiaria* Marshall of the Hampden fossils as a Cretaceous survival. This species is not shown to have any near relative in the New Zealand Cretaceous.

Previous collections at Hampden have not disclosed any notable differences from the faunas of the Oamaruian. Hutton (1887), indeed, found no difficulty in placing the Hampden beds in the Pareora system—*i.e.*, Awamoan; but McKay (1884) on stratigraphical grounds considered them the correlatives of those overlying the coal-beds in the district inland of Oamaru—*i.e.*, of the Waiarekan; and Park (1905) came to a similar conclusion. The latter view seems the most reasonable in the present state of our knowledge, as we know now that Hutton's Pareora fauna was composed of a mixture of Awamoan and Waiarekan fossils, and that he placed other Waiarekan beds in the Pareora system. Marshall apparently considers the Waiarekan as Miocene; but although there is some direct evidence in favour of the Miocene age of the Ototaran, contradicted in this case by other evidence, there is none yet adduced, beyond the imperfectly known percentage of Recent species, to prove that the Waiarekan is Miocene. It hardly seems necessary to point out that if the present New Zealand fauna is the direct descendant of the Oamaruian fauna without important immigrations, as Marshall seems to hold, the percentages of Recent species in the Oamaruian is likely to be much greater than in its correlatives in Europe, where successive recessions and transgressions of the sea in the Tertiary caused bodily migrations of the faunas, and the cold of the late Pliocene and the Glacial Epoch forced the greater number of the species surviving the early Pliocene into more southern seas. The percentage of Recent species in the Waiarekan is not inconsistent with an older age than Miocene for this stage, and there seems no reason why a Cretaceous survival should not occur. The presence of *Avellana tertiaria* does not by itself prevent the correlation of the Hampden beds with the Waiarekan. Obviously, then, it would be unsafe at present to base a new stage or group name on the Wangaloa series of Marshall if the Hampden beds are correctly placed in this series.

The beds at Wangaloa, however, are in a different category. They are given a more distinctively Cretaceous aspect than the Hampden beds by the presence of *Pugnellus australis* Marshall, a form nearly allied to *Conchothyra parasitica* Hutton of the Piripauan. Marshall's list of fossils contains twenty-nine new species not hitherto found in the Tertiary, and only twenty-one found in the Oamaruian or higher beds. Although little has been yet published as to the range of the species within the Oamaruian, a large number of species from this division of the Notocene has already been described, and from the very considerable collections examined by Mr. Suter a large number of additional new species have been detected and are now being described. The presence of so many new species at Wangaloa (58 per cent. of the entire collection), coupled with the Cretaceous relationships of some of them, is sufficient ground for considering that this fauna is intermediate between the Oamaruian and the Piripauan. A new adjectival name is therefore desirable, and in choosing it two earlier local names must be taken into consideration—viz., the Kaitangata series (Park, 1912) and the Wangaloa series (Marshall, 1916). On grounds of priority Park's name should be chosen as the basis, a course that has the further advantage that the rocks intended to be included in it are clearly defined, which is not the case with the Wangaloa series. The *Kaitangatan*, then, includes the Kaitangata upper and lower coal-measures as described by Park (1911) and the intermediate marine horizon, but excludes the Oamaruian coal series and overlying Oamaruian marine rocks which rest unconformably, according to Park, on the Kaitangata coal-measures proper. The Kaitangatan, like the Piripauan and the Clarentian, includes both coal-beds and marine rocks, and is a group name, which may be subsequently resolved into stages, for the name of one of which " Wangaloa " may still serve as a basis.

The classification of the Notocene rocks proposed by me is thus as follows :—

| Group Names | Stage Names. |
|---|---|
| Wanganuian .. .. .. | Castlecliffian.<br>Waitotaran.<br>(Other stages possible.) |
| Oamaruian .. .. .. | Awamoan.<br>Hutchinsonian.<br>Ototaran.<br>Waiarekan.<br>Ngaparan (coal-beds).<br>(Other stages possible.) |
| (Other groups or stages possible) .. | Paparoan (coal-beds). |
| Kaitangatan. | |
| (Other groups or stages possible.) | |
| Piripauan. | |
| (Other groups or stages necessary.) | |
| Clarentian. | |

The only possible overlapping of the above names is that the Upper or Lower Kaitangatan coal-measures may correlate with the Paparoan. One is, however, a stage name and the other a group name, and both may still be retained. It is worthy of notice that each of the groups of rocks named above embraces coal-beds in some part of the country.

## V. A NEW NAME FOR THE SO-CALLED QUATERNARY ROCKS OF NEW ZEALAND.

As we have no evidence that the highest Notocene stage, the Castlecliffian, corresponds exactly to the youngest Pliocene rocks of the Old World, it is undesirable to use such a name as "Quaternary" for the superficial rocks such as raised-beach deposits, glacier deposits, alluvial gravels, and loess, of which all we know is that they are post-Castlecliffian, or even only that they are subsequent to the main Kaikoura deformation affecting the area in which they occur. It is still more undesirable to attempt to distinguish between Pleistocene and Recent deposits in New Zealand, where the fossil Mammalia on which these distinctions have been based are not found. New names that do not beg the question of correlation are desirable. It is quite possible that in time the criteria of correlation will be sufficiently developed to permit the recognition of distinct stages to which local names may be given within the period intended to be covered; but as there is nowhere, and from the nature of the case hardly can be, in any one locality an accessible complete succession of rocks covering the period to be embraced, no local name is suitable for the totality of rocks to be included, and a descriptive term is preferable. For this *Notopleistocene** may be suggested. The Notopleistocene period may be defined as commencing where the Notocene, which has already been defined, leaves off, and continuing to the present day.

In general there will be no difficulty in the application of the term, and there are important series of rocks, notably in Taranaki, to which it may usefully be applied. In some cases there may be a difficulty. If the Kaikoura orogenic movements commenced very much earlier in one area than another (and we do not know that they have yet ceased everywhere), it is possible that superficial deposits were accumulating unconformably on Notocene rocks in the former area while ordinary marine Notocene rocks were being deposited in the latter. These superficial deposits would, by the definitions given above, have to be classed as Notocene in age. Thus in the Waipara district there is a series of terrestrial gravels which overlie the Motunau beds unconformably, but nevertheless share to some extent in the general tilt which the marine Notocene rocks of that district have experienced, having in the Kowhai River a dip of 12° to the south-east. These gravels, in addition to the greywackes of which they are mainly composed, contain boulders not only of the Motunau and Mount Brown beds, but also of the Amuri limestone and underlying greensands. The marine Notocene rocks forming the cover to the greywackes must have been tilted, and in places completely removed by denudation, exposing the underlying greywackes, before the gravels were deposited. In other words, the latter are subsequent to the main Kaikoura deformation of the area. They have, however, shared in a later tilting, which is presumably a continuation of the Kaikoura movements, and they are much older than the terrace-gravels of the present Kowhai River. It is an open question whether their age is Notocene or Notopleistocene. McKay has described similar

* Greek νοτος, south; and Pleistocene.

gravels in South Canterbury, which presumably rest unconformably on the Awamoan rocks, and there are other terrestrial rocks in other districts which have been regarded as "Pliocene."

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## VI. Appendix I.—Description of *Pachymagas abnormis* n. sp.

Shell small, suborbicular with a slightly straightened front, nearly as broad as long; valves depressed, the dorsal with a well-marked anterior median sinus, the ventral with a broad median fold and flattened sides; anterior commissure with a broad, fairly deep sinuation. Hinge-line broad, nearly straight. Beak short, sharply keeled, the ridges meeting in an apex; foramen hypothyrid, moderately large, reaching nearly to the hinge-line, deltidial plates strong, united only at their bases. Surface smooth with numerous fine and a few strong growth-lines.

Hinge pattern pachymagoid with a minute pyramidal cardinal process occupying only about one-quarter the length of the hinge-trough.

Dimensions of holotype: Length, 20·5 mm., breadth, 20 mm.; thickness, 9·5 mm.

Type locality: Sand interbedded with main Mount Brown limestone, cuesta overlooking the Weka Pass, Canterbury.

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## VII. Appendix II.—A Hypothetical Case illustrating the Effect of Immigration on the Percentage of Recent Species.

Suppose A to be a stage in which a certain area was isolated, and contained a provincial fauna of 400 species of Mollusca, of which 20 per cent. (80 species) subsequently survived to become Recent. Suppose B to be a later stage in which isolation came to an end and immigration occurred, the climate being different from that of A. Suppose C to be a still later stage in which isolation was restored and the climate reverted to the conditions of A.

Owing to the change of climate and the competition produced by immigration there would be at the beginning of B a severe mortality and probably a considerable evolution in the endemic fauna of A. Suppose of the original 400 species in A, 200 (including necessarily the 80 Recent species) survived into B, 100 became extinct, while 100 evolved into new forms, of which 10 subsequently survived to become Recent species: the endemic element of B would then consist of 300 species, of which 90 were Recent. Suppose the number of the immigrants to be 300, of which, owing to the later change in climate in C, only 20 survived to become Recent species: the total fauna of B would be then 600 species, with 110, or 18 per cent., of Recent species.

A reversal of the percentage of Recent species is thus shown to be within the bounds of possibility.* That it has actually occurred in our area is not very probable. The above figures have been carefully manipulated to create the reversal. If 30 of the immigrants in B survived to become Recent species the percentages in A and B would be the same. On the other hand, if some of the Recent species in A temporarily emigrated from the area during B, returning in C, as would be the case if the north-south extension of the coast were considerable, a reversal might easily occur. In any case, the figures show that migration is a factor complicating the application of the principle of percentage of Recent species in classification.

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* Professor Benson has kindly pointed out that the Sarmatian fauna, with no Recent species, overlies the normal second Mediterranean stage (early Miocene).

Migration in brachiopods is conditional on continuous areas of sea-bottom above the 1,000-fathom line. The deep seas are barriers as effective as land barriers. With molluscs, however, this is not the case. The free-swimming larvae can cross the deep oceans in the surface currents, and distribution is controlled by the direction of the currents. A land connection with Australia or the Antarctic is not, therefore, essential for immigration of molluscs, but only such a change in the distribution of land and sea as would cause new currents to strike these shores.

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# Art. XXXI.—*The Hawera Series, or the So-called "Drift Formation" of Hawera.*

By J. Allan Thomson, M.A., D.Sc., F.G.S., Director of the Dominion Museum, Wellington, New Zealand.

[*Read before the Wellington Philosophical Society, 20th September, 1916; received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

The "drift formation" which is the subject of this paper was so termed by Park in 1887 in his paper "On the Geology of the Western Part of Wellington Provincial District and Part of Taranaki."* Park divides the "Recent and Pleistocene" into—

(*a.*) Blown sands, river-terraces, and superficial pumice deposits.

(*b.*) Drift formation of Taranaki and Wanganui.

Using "Notopleistocene" instead of "Recent and Pleistocene," I am in full accord with Park in this classification. The "drift formation" is very well displayed on the coast-line between Wanganui and Hawera, and lies in age between the Wanganuian beds and the superficial blown sands and river-terrace gravels of the district. The superficial pumice beds to which he refers cluster around Mount Ruapehu, and do not extend into the area under consideration.

Park gives the following description of the "drift formation":—

"This formation is very widely distributed, and extends as a maritime belt from the Ruahine Range to the foot of Mount Egmont; and, on the North Taranaki coast, from New Plymouth to the Mokau. At Kawaiki it occurs at an altitude of 400 ft. above the sea, but at no other place has it been observed at a greater height than this.

"It consists of stratified sands and clays that are usually micaceous, and of a yellow or red colour; and coarse gravels that are often cemented by iron-peroxide into rusty conglomerates. Near the volcanic centre of Taranaki the gravels consist chiefly of igneous rocks, while east of the Rangitikei they are composed of siliceous sandstones and dark slaty shales.

"The drift is well exposed in the cliffs between Wanganui and Patea, and a great many opportunities are presented of closely studying its character. Drift-timber and upright stumps of trees occur in most places at its base. These are covered or mixed with gravels, in which marine shells are sometimes found in small patches or irregular layers. There appears to be no regular order of superposition of the various beds of the drift. For short distances the drift-timber and gravels are absent, or more frequently appear at the top of the series, and the yellow sands and clays lie directly on the Tertiary clays or limestones.

"At most places on the coast between Wanganui and Patea the Tertiary strata are but slightly inclined from a horizontal position, and where immediately succeeded by the stratified sands and clays of the drift there is no apparent unconformity between the Pleistocene and Tertiary formations. But, although at special points it is difficult to determine an unconformity, this is made quite clear by the manner in which the drift is found resting successively on the different members of the Tertiary formation. At Wanganui it lies on the upper sandy beds, and proceeding along the coast, on the rise of the beds, it may be seen resting alternately

* *Rep. Geol. Explor. during 1886–87*, No. 18, 1887, pp. 24–73 (ref. to pp. 57, 59–60).

on the Kai Iwi blue clays, Okehu beds, Waitotara limestone, Whenuakura and Patea clays. On the Taranaki coast also it lies on the younger Tertiaries between the Waiau and the White Cliffs, and on the Cretaceo-Tertiary strata at the Mokau.

"The submerged forest already alluded to as underlying the drift is associated with a bed of lignite of variable thickness, which is well exposed at Languard Bluff, and in many places north of Wanganui.

"It is remarkable that, although the drifts extend inland a great many miles, the evidences of a submerged forest and lignite are never met with more than a mile or two from the present shore-line, and then only in low-lying areas. It would thus appear that this ancient forest flourished in a narrow belt of low, swampy land adjacent to the sea. The occurrence of irregular beds of marine shells at the base of the drift points to the existence of shallow brackish lagoons within the influence of the tide. The shells are all marine and Recent, and include the following forms: *Venus stutchburyi*, *Venus mesodesma*, and *Turritella rosea*."

My own observations of this formation concern only parts of the coast between Wanganui and Hawera, along the whole of which it is well exposed in the sea-cliffs. My visits to this coast were primarily for the purpose of collecting fossils from the Wanganuian beds, and it was only at the sea-cliff at the "Zigzag," near Hawera, that I made any detailed notes of the Noto-pleistocene beds. This cliff is about 200 ft. in height, the lower 50 ft. being composed of mudstone (papa), the exact horizon of which cannot be quite definitely stated at present. It lies in nearly horizontal beds which continue without any appreciable dip along the coast as far as the head west of the Patea River. The Hawera papa is thus probably of about the same age as the Patea blue clays, which are placed by Park below the *Ostrea ingens* bed of Waitotara. It is certainly older than Castlecliffian, and is probably Waitotaran.

The upper 150 ft. of the cliff at Hawera, with the exception of a superficial layer of a few feet, consist of the so-called drift formation, which is here better displayed than at any other point, and which, therefore, I propose to term the *Hawera series*, using that term in a purely local stratigraphical and not a general systematic sense. It is in the main composed of loose sands which are thinly and irregularly bedded, and in places exhibit good current bedding. In the lower half there are several layers of blue clay, each about 1 ft. thick, interbedded with the sands, and formed presumably by a rewash of the papas. There is at least one seam of lignite in the lower half, while at the base there is a gravelly shell-bed resting on a surface of hard papa bored by the molluscs *Barnea* and *Venerupis reflexa*. Owing to the predominance of loose sands the cliff is much obscured by slipped material, and it would be a matter of difficulty to give a detailed account of the order of succession of the various beds; nor is this especially desirable, since the beds vary rapidly in a lateral direction. The sands in the lower half are loose, and are often dark owing to an abundance of green and black ferruginous minerals. Some layers in the lower third contain quite large flakes of both black and white mica. The layers in the upper half are harder, owing to the presence of a ferruginous cement resembling a bog iron-ore. The bedding, except where current bedding occurs, is approximately horizontal.

The wind-blown sand which forms dunes resting above the Hawera series lies unconformably upon it, and is doubtless derived from it. This is important from an economic point of view, as showing the source of the chief ironsand deposits of southern Taranaki. They are not blown up from the present beaches, but are derived nearly *in situ* from the Hawera series, and their elevation is largely due to the movements which brought that series into its present position. Few layers of the Hawera series are themselves sufficiently rich in iron minerals to deserve the title of iron-ore, and it is the second sorting, by wind-action, which has produced the concentration found in the ironsands.

The Hawera series can be traced continuously all the way on the coast-line between Hawera and Wanganui, except where large graded rivers like the Patea and Waitotara enter the sea by wide valleys. The series is seldom so thick elsewhere as at Hawera, but its composition remains much the same, and the presence of the bored papa beneath it may be seen at a number of points, although shell-beds similar to that at Hawera are not extensively developed. West of Waitotara in the basal bed there are occasional boulders of andesite of a much larger size than those near Hawera. At Castlecliff there is a strong bed of lignite developed.

The drowned forest so clearly displayed at low water near the mouth of the Waitotara River cannot belong to the Hawera series unless this has been dropped by faulting some 50 ft. in this area, a supposition for which I found no other evidence. Since its formation the Hawera series has undergone elevation to a fairly uniform level, but this forest, together with a similar one which I am informed exists in the Patea River, points to a recent movement of slight depression on this part of the coast-line. Park observed that, although the "drift formation" extends inland for many miles, the evidences of submerged forests are never met with more than a mile or two from the present shore-line, and then only in low-lying areas. From this he draws the inference that this forest flourished in a narrow belt of low swampy land adjacent to sea; but the facts support a different explanation. The forest apparently flourished in the flood-plains of the Waitotara and Patea Rivers, and is only found submerged and partially buried with estuarine mud near the mouths of these rivers, because these were the only areas, with the exception of the sea-beaches, which were carried below high-tide level by the slight movement of depression. On the other hand, the lignite-beds which Park associates with the drowned forests in mode of occurrence are certainly an integral part of the Hawera series.

The unconformity of the series to the Wanganuian is shown not only by its resting in turn on all the Castlecliffian and Waitotaran beds between Castlecliff and Waitotara, but also by the bored surface existing beneath it, and by the existence of faults which have affected the Waitotara beds prior to their truncation and to the deposition of the Hawera series upon them. A section illustrating this last feature very clearly is exposed on the cliffs west of the mouth of the Waitotara River.

The mode of formation of the Hawera series seems, from the above observations, to have been much as follows: The Wanganuian beds after their deposition were elevated considerably above sea-level, and also slightly tilted, and were attacked by subaerial and marine erosion. An extensive plain of marine denudation, backed no doubt by sea-cliffs, was thus cut across their upturned edges, and upon this the shell-beds were laid down, followed by sands and layers of mud as marine erosion carried the cliffs landwards. The sands were no doubt in part derived from the coarser material washed out of the Wanganuian beds, and a part of their content of dark minerals may also have been derived from this source, for the papas of Hawera contain volcanic minerals; but the boulders of andesite in the Hawera series, and probably a large part of the sands, owe their origin to the material brought down by rivers from Mount Egmont. A cessation of cliff-recession followed, either from elevation or because the supply of waste became sufficient to produce a prograded coast similar to that of Marlborough, and a low-lying coastal strip in which lagoons and ponds could form gave rise to the ferruginous cement in the upper layers of the series. Finally deposition was brought to an end by elevation of considerable amount.

My own observations do not permit me to state how far inland the Hawera series extends from the present coast-line, but between Wanganui and Hawera Park's map does not show it more than six miles inland. From the top of the large sand-dunes seaward of the railway-station at Okehu one sees in a north-east direction two distinct terraces, one with cliffs facing the present beach, the other with cliffs parallel to the former series and facing the lower terrace. These latter cliffs cross the Okehu and Kai Iwi Streams transversely, and thus have no immediate relationship to the present drainage. They must be either fault-scarps or old sea-cliffs, and their general parallelism to the present sea-cliffs makes it probable that the latter explanation is correct, and that they mark the limit of inland extension of the Hawera series. The lower terraces will in that case be typical coastal plains. Farther inland towards the headwaters of the Okehu and the Waitotara there is a still higher terrace, much more dissected, and with wooded tops. It is possible that there are a number of older Notopleistocene series, similar in mode of occurrence and formation to the Hawera series, resting on the inland terraces.

The fossils obtained from the Hawera series at Hawera comprise the following species: *Pecten triphooki* (derived fossil), *Ancilla australis, Anomia walteri, Arca decussata, Calyptraea maculata, Calliostoma punctulatum, Cardita calyculata, Chamostrea albida, Chione crassa, Chione stutchburyi, Corbula zelandica, Crepidula costata, Diplodonta globularis, Dosinia subrosea, Euthria linea, Glycymeris modesta, Glycymeris laticostata, Leptomya lintea, Mactra scalpellum, Mesodesma subtriangulatum, Mesodesma australe, Modiolus australis, Mytilus magellanicus, Natica zelandica, Nucula hartvigiana, Ostrea angasi, Pecten zelandiae, Siphonalia nodosa, Subemarginula intermedia, Trochus chathamensis, Trochus viridis, Trochus tiaratus, Trivia zealandica, Turritella rosea, Venerupis reflexa, Venericardia difficilis, Hemithyris nigricans, Terebratella rubicunda, Terebratella sanguinea, Evechinus chloroticus.* All these fossils, with the exception of the rounded, worn, and obviously derived fragments of *Pecten triphooki*, belong to Recent species. It does not seem probable that the raised beaches of different heights which are known in various parts of New Zealand will ever be correlated or distinguished satisfactorily by their marine faunas, but where vegetable fossils are found in the Notopleistocene rocks it is quite possible that owing to climatic changes a succession of floras may be distinguished on which an age classification may be established.

The study of such Notopleistocene deposits as the Hawera series is exceedingly important from an economic point of view, for most of the richer soils of the Dominion lie on such deposits. The famous dairy-farming land around Hawera is floored by the Hawera series, and not directly by the Wanganuian papas. This paper does not profess to treat of the subject exhaustively, but it is hoped that it will cause this series to receive more attention than it has attracted during the last thirty years.

My thanks are due to Miss M. Mestayer for assistance with the determinations of the fossils.

# Art. XXXII.—*Additional Facts concerning the Distribution of Igneous Rocks in New Zealand.*

By J. A. Bartrum, Auckland University College.

[*Read before the Auckland Institute, 13th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

Plate XXVIII.

The following notes record a few facts which have come under the notice of the writer, and which may be of use to other workers in New Zealand geology. Some of the facts doubtless are known to other New Zealand geologists, but the author believes that the majority have not yet been published. If they have, he pleads the lack of time for full perusal of literature, and the inaccessibility of some of the papers bearing on New Zealand petrography, as his excuse for including them in this paper.

In some cases considerable work, particularly with regard to the chemical characters of the rocks described, is required before the knowledge of them can be regarded as at all satisfactory, and the writer hopes to be able to continue this work later.

## Hypersthene Basalt, Ruatangata, near Whangarei.

In slides made from a flow basalt of Pleistocene or Recent age, which, macroscopically, is similar exactly to the general ophitic basalts of the Whangarei district, the mineral hypersthene has been detected in interesting circumstances.

It is believed that this is the first olivine-hypersthene basalt described from New Zealand, though it must be remarked that some of the hypersthene and other andesites approach closely to basalts. Professor Thomas has pointed out, for example, that some of the andesites of the Tarawera district approximate basalts, some carrying scanty olivine.* The majority, however, are very evidently andesites. Professor Thomas notes also, in connection with lavas from Tongariro, that "Most of them are free from olivine; but others are rich in this mineral, and must be termed basalts."†

In the Auckland University College collection is a light-grey rock, with well-marked fluxion banding, showing numerous phenocrysts (up to 5 mm. in diameter) of olivine, with smaller ones of hypersthene, a few fragments of xenolitic quartz, and somewhat inconspicuous feldspar. It is labelled "Otouku, near Tongariro," and evidently represents one of Professor Thomas's basalts. Small partings between plates parallel with the fluxion bands show very minute crystals of some zeolite, apparently cubic, though in the absence of an exact goniometer this could not be established.

In section, besides the coarse olivine phenocrysts there are numerous smaller ones showing a corrosion border of iron-ore. Many highly corroded coarse plagioclase phenocrysts occur, and idiomorphic hypersthene is abundant. Augite frequently forms a fringe to the hypersthene, and there are one or two small phenocrysts apparently of augite. The groundmass is pilotaxitic, and the feldspar mesh is crowded by hypersthene prisms and a very little iron-ore.

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* A. P. W. Thomas, *Report on the Eruption of Tarawera and Rotomahana, N.Z.*, Wellington, Government Printer, 1888, p. 58.

† *Loc. cit.*, p. 21.

The abundance of olivine and hypersthene appear to justify the classification of the rock as a basalt, though only chemical analysis can establish this.

The Ruatangata rock is similar to the more feldspathic of the Auckland basalts, but besides phenocrysts of olivine, augite, and plentiful coarse labradorite there is also subsidiary hypersthene. The groundmass is pilotaxitic, and plagioclase predominates slightly over pyroxene. Iron-ore is unimportant. There are occasional xenolites of andesitic nature.

In several instances the augite has formed a parallel growth about a central crystal of hypersthene; the latter mineral apparently became unstable during the last stage of consolidation, although sharply idiomorphic unattacked hypersthene is also common. The photomicrograph (Plate XXVIII, fig. 2) illustrates this feature satisfactorily, the hypersthene being extinguished in the centre of the field.

Abundance of feldspar is more marked than in most Auckland basalts, whilst olivine is less noteworthy; but field relations and microscopic characters alike show that the rock is one of the series of the latest extrusives, which, in the Auckland and Whangarei districts, are universally basalts.

### TROCTOLITE, WADE, AUCKLAND.

In hand-specimens this is a blotched dark-green and white coarse gabbroid rock, showing serpentine, some evident fresh plagioclase with albite striations, and much altered feldspathic material.

In section serpentine shows up as almost 50 per cent. of the rock. It presents the usual characters of serpentine derived from olivine, and encloses here and there large kernels of unaltered olivine. A little pale bladed amphibole (tremolite) is associated with the alteration products both of the olivine and of the plagioclase. This latter mineral where unaltered has extinction angles on albite twin lamellae of from 30° up to 44° (approximately), and is therefore labradorite. Its alteration presents difficulties. Often the result of the alteration is a greyish product, with very high refractive index and very low polarization tints, which is apparently a saussurite consisting mainly of some mineral of the epidote group. Again the feldspar is largely converted first into strings and then into larger patches of a densely fibrous transparent mineral with approximately the same index of refraction and the same birefringence as the feldspar itself. This is probably a zeolite.

### GRANODIORITE WITH PRIMARY EPIDOTE, REEFTON.

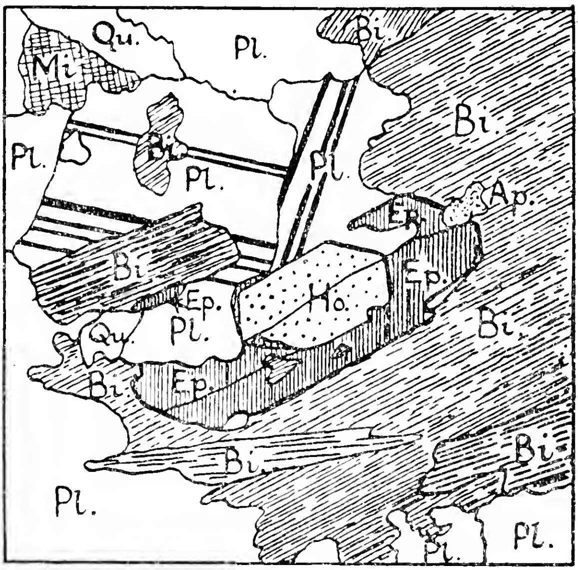
The field relations of this rock are unknown. It is represented by a specimen collected by Professor A. P. W. Thomas (apparently from river-gravels), and now in the collections of the Auckland University College.

Macroscopically it is a moderately coarse light-coloured granitic rock, with abundant biotite (occasionally aggregated in small basic secretions), and showing other pale yellowish-green crystals along with brownish rather resinous ones. The microscope shows that these latter are epidote and sphene respectively.

Microscopically the rock is readily classed as a biotite-rich granodiorite. The feldspars include microcline, orthoclase, microcline perthite, perthite, and plagioclase which is probably acid andesine, though this latter determination is not exact. The lime-soda feldspar predominates slightly over the alkali variety.

Muscovite is present in small amount with the biotite, and epidote is very plentiful and moderately coarse. Sphene is abundant in coarse characteristic wedge-shaped crystals. Magnetite occurs sparingly in coarse crystals, and apatite and zircon are accessories.

The chief interest lies in the epidote. This is a pleochroic pale-yellow to colourless variety, with the usual optical characters. It is very frequently enclosed as sharply euhedral crystals in feldspar; sometimes nests of sharply bordered rounded grains are enclosed pseudo-poecilitically by the feldspar. Very commonly it is enwrapped or enclosed, sometimes as idiomorphic crystals, by the brown biotite. This last mineral is thus important in its relations to the epidote; there can be little doubt that it is primary: all indications point to this conclusion.




Representation of the relations of epidote to hornblende, plagioclase, and biotite in a granodiorite from Reefton. Crossed nicols. × 60 approx. *Qu* = quartz; *Pl* = plagioclase; *Bi* = biotite; *Ep* = epidote; *Ap* = apatite; *Ho* = hornblende; *Mi* = microcline.

An important fact bearing on the question of the primary character of the epidote is that, in no less than seven cases in the two sections cut of the rock under consideration, the mineral surrounds a central crystal of brown hornblende: only one or two hornblende crystals were observed that were not in association with the epidote. In all cases the amphibole is in small crystals.

At first thought the above facts would suggest that the epidote is an alteration product of the amphibole; but against this view it is to be observed that the idiomorphic epidote enclosed in feldspar or biotite does not present the outlines of hornblende crystals. Possibly some of the epidote has been derived thus, but it appears more probable that the epidote, in great part

Fig. 1.

Fig. 2.

Fig. 1.—Photomicrograph of gneissic diorite, Albany, near Auckland. The bent twin lamellae of the plagioclase and the granulation are well shown. Crossed nicols. × 22.

Fig. 2.—Photomicrograph of hypersthene basalt, Ruatangata, showing a central crystal of hypersthene (extinguished in the centre of the field) surrounded by a parallel growth of augite. Crossed nicols. × 22.

Face p. 420.]

at all events, crystallized out during the solidification of the magma, probably largely at the expense of unstable hornblende. It is shown by the figure, which represents one of several similar examples, that, on occasion at all events, the epidote is one of the earlier products of crystallization. A twin crystal of it here surrounds a central twin crystal of idiomorphic hornblende; it encloses a few flakes of biotite, and is itself enwrapped by biotite and plagioclase. A very narrow partial border to the hornblende (exaggerated in the figure) is possibly also epidote.

It seems impossible to escape from the conclusion that the relations of mineral to mineral establish the primary character of at least some of the epidote. Such epidote is not unknown, but it does not seem commonly to have been described.*

### BASALT WITH BIOTITE (VAR. ? ANOMITE), SOUTH OF TOKATOKA SWAMP, WAIROA RIVER.

This is the stone often used in Auckland for monumental work, and called locally the "Kaipara granite." The writer has examined this and several other of the Kaipara extrusive and intrusive rocks and has found them mainly normal basalts, but there are also andesites such as that at Tokatoka, near Dargaville, which carries a deep-green hornblende.

The "Kaipara granite" is a very coarse-grained basalt with abundant coarse olivine, enclosed with plentiful pale-green augite and coarse ilmenite in a coarsely pilotaxitic holocrystalline feldspathic groundmass.

The point of interest about the rock is that it contains a highly pleochroic (rich reddish-brown to pale canary-yellow) biotite in abundant flakes which are often sharply euhedral. In one or two instances these enclose ophitically the feldspar of the groundmass.

The optic axial angle in the few favourable sections obtained varies from zero to a few degrees, the biaxial character being distinct in only one instance. The dispersion for red is greater than that for the blue rays. The pleochroism is Y = Z = rich reddish brown, X = pale canary-yellow or golden.

This mineral is similar to a biotite in basanites near Dunedin which Professor P. Marshall first showed me in 1907, and which he considered anomite. The characters of the biotite in the Kaipara rock, so far as they are determinable, agree with those given by Rosenbusch for anomite.†

Sollas has described a biotite basalt from a Tertiary conglomerate at the Waipaoa River, Poverty Bay,‡ whilst Andrew has discovered anomite in a similar rock near Milburn, Otago.§

### HORNBLENDE BASALT, SUMNER–LYTTELTON ROAD, NEAR SUMNER.

Marshall has mentioned the occurrence of hornblende basalts at Dunedin,|| but, apart from these, few hornblende basalts seem to have been noted from New Zealand.

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* See, for example, H. ROSENBUSCH. *Mikroskopische Physiographie*, 4th ed., i, 2, 1905, p. 284; and E. WEINSCHENK (trans. by R. W. Clark). *Petrographic Methods*, 1912, pp. 264–65.

† H. ROSENBUSCH. *loc. cit.*, pp. 259–60.

‡ W. J. SOLLAS and A. MCKAY. *Rocks of Cape Colville Peninsula*. Wellington Government Printer, vol. 2, 1906, p. 176.

§ A. R. ANDREW. On the Geology of the Clarendon Phosphate-deposits, Otago, New Zealand, *Trans. N.Z. Inst.*, vol. 38, 1906, p. 459.

|| P. MARSHALL. The Geology of Dunedin (New Zealand). *Quart. Journ. Geol. Soc.* vol. 62, 1906, p. 412.

The Sumner rock is known to other geologists, but has not been reported in literature so far as the writer is aware. It contains abundant iron-stained idiomorphic olivine crystals, which are frequently enclosed in the coarser pale-green augite. The hornblende is quite fresh and unresorbed; it is greenish-brown, and lacks the deep absorption tints of the usual basaltic hornblende.

### Andesites in Mid-Mesozoic Rocks at Port Waikato.

At a point on the south bank of the Waikato River about a mile and a half up-stream from Port Waikato a well-marked conglomerate with rounded pebbles up to 5 in. in diameter outcrops amongst finer plant-bearing mid-Mesozoic sediments. The pebbles include many sedimentary rocks, such as quartzite, shale, and greywacke, and several varieties of andesite. Similar pebbles are frequent in irregular bands along the "strike" coast south of the mouth of the river.

There are several highly feldspathic types of andesite, one with perfect trachytic groundmass and practically no ferro-magnesian mineral, though magnetite is fairly abundant in specks in the groundmass. There are also augite andesites and one hornblende type rich in fresh greenish-brown hornblende and with very coarse plagioclase.

Andesitic, rhyolitic, and other pebbles are found in the basement sediments of Coromandel Peninsula,* and in the "Maitai" shales on the east shore of Palliser Bay, Wellington,† and thus in rocks, so far as we know, roughly coeval with those at Port Waikato.

In the Mount Somers district, Canterbury, the varied rhyolites and andesites are Jurassic, according to Marshall,‡ though other statements about them conflict with this view.§

Another well-known occurrence of pebble-beds of igneous rocks in sediments belonging to the same Trias-Jura succession is in the hills near Nelson; the included pebbles there are largely derived from plutonic rocks.||

### Gneissic Diorites, Albany, near Auckland.

An interesting occurrence of gneissic diorites or dioritic gneisses was made known recently to the writer by some specimens collected at Albany by Mr. G. B. Battersby from boulders up to several feet in diameter which were unearthed by farming operations. As they are located a moderate distance from the water's edge it is very unlikely that they have been brought thither by vessels trading up Lucas Creek, and they more probably come from a boulder-bed, belonging to the Miocene Waitemata series, known

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* W. J. Sollas and A. McKay, *Rocks of Cape Colville Peninsula*, vol. 1, 1905, p. 52; C. Fraser and J. Adams, The Geology of the Coromandel Subdivision, *N.Z. Geol. Surv. Bull., No. 4*, 1907, pp. 45 and 52.

† W. J. Sollas and A. McKay, *Rocks of Cape Colville Peninsula*, vol. 2, 1906, pp. 178 *et seq.*

‡ P. Marshall, Distribution of the Igneous Rocks of New Zealand, *Rep. Austral. Assoc. Adv. Sci.*, vol. 11, 1907, p. 6 of reprint.

§ *Cf.* J. Park, *Geology of New Zealand*, Wellington, 1910, pp. 82–83.

|| P. Marshall, Boulders in a Triassic Conglomerate, Nelson, *Trans. N.Z. Inst.*, vol. 36, 1904, pp. 467–71. Since the above was written Professor Marshall has informed me that a thick conglomerate with similar pebbles of even greater variety outcrops in the Mesozoic rocks at Kawhia.

to outcrop in that creek, which has not yet been investigated by the writer.

One specimen is a quartz diorite with abundant greenish-brown hornblende. The plagioclase shows bent twinning lamellae, and its margins have been markedly granulated, as the photomicrograph (Plate XXVIII, fig. 1) shows. The margins of the hornblende are less perfectly granulated, but the fact that granulation is present indicates the probable primary character of the amphibole. Typical fine-grained dioritic gneisses are represented by a rock consisting of ragged green or bluish-green hornblende and plagioclase with much granulated material, and possessing a banded structure.

A most interesting discovery was made later when small pebbles of several diorites were found in the alluvium laid bare by wave-attack in a small flood-plain on the west shore of Shoal Bay, Auckland Harbour. They were greatly weathered, but their character was readily decipherable. One diorite shows abundant greenish-yellow hornblende which has been largely chloritized, and very prominent and typical twinned ilmenite. The presumption is that these pebbles, like the Albany boulders, come from the Tertiary beds.

In June, 1916, Professor Marshall showed the writer a dioritic rock obtained from the Tertiary sequence near Komiti Point, Kaipara Harbour, so that diorites seem to have formed an important element in the pre-Tertiary terrain of the Auckland district.

It is interesting to note that similar gneissic rocks (hornblende gneiss, &c.) are present in a mid-Tertiary conglomerate in the gorge of the Waipaoa River, Poverty Bay.*

## GABBROITIC AND DIORITIC ROCKS, BATON AND GRAHAM RIVERS, NELSON.

There are several specimens of coarse basic rocks collected some years ago by Professor A. P. W. Thomas from the gravels of the Baton and Graham Rivers, Nelson, in the collections of Auckland University College, and a note upon them may be of interest, though full descriptions can serve no purpose.

They are essentially very coarse-grained hornblende rocks, with abundant coarse iron-ore (mainly ilmenite), usually secondary epidote, quartz in varying amounts, coarse apatite, a few flakes of biotite, and finally sphene. Pale pyroxene is generally present in large amount, and perhaps gives the clue to the origin of much of the hornblende.

There are several types of rock represented. In the majority, deeply pleochroic brown and often strongly schillerized hornblende is the predominant mineral, feldspar being comparatively unimportant. The amphibole usually encloses pale augite poecilitically, and the sharp outlines of this latter often show that much of the brown hornblende is not, as was suspected, uralite. There is, however, undoubted pale-green uralite present in most sections, which sometimes shows distinctly a transition or alteration into the deep-brown hornblende.

In two sections with very coarse, sharply idiomorphic hornblende a pleochroic deep-green to brownish-yellow hornblende borders the deep-brown variety, and is occasionally intergrown with plagioclase. In one of these

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* W. J. SOLLAS and A. MCKAY, *Rocks of Cape Colville Peninsula*, vol. 2, 1906, pp. 175 *et seq.*

sections—a very distinct type, perhaps outside the series—there are abundant idiomorphic crystals of the green hornblende, and a large proportion of cryptoperthite, whilst quartz is abundant.

It is evident from the foregoing description that it is difficult to classify these rocks: there is an element of doubt about the origin of much or most of the hornblende; but, from several considerations, it appears that they may provisionally be classed as quartz-hornblende gabbros.

Finally, the sections cut represent normal dioritic rocks, unlike the former in that the plagioclase is now predominant and the structure is hypidiomorphic. The hornblende in unaltered rocks is a deep-bluish-green to golden-brown variety. Quartz and augite are absent. Sections of another diorite show that it has been subjected to pressure which has caused partial granulation. The hornblende has been a strongly schillerized deep-brown variety, but is now converted in great measure to an opaque whitish-grey product.

## Trachyte, Miocene Breccia-conglomerate, Wairau Creek, Milford, Auckland.

Mr. C. E. Fox, in his admirable paper on the volcanic beds of the Waitemata series, Auckland, noted in the coarser fragmental beds that "besides the more basic fragments there others present the appearance of true trachytes, pale-grey in colour, with a specific gravity of 2·54."* From his statement in connection with the fragments, "On the whole, then, they may be taken as typical andesites, while a small percentage are basalts without olivine,"† one judges, perhaps wrongly, that he regards these trachytic rocks as a phase of the andesites.

There is an interesting assortment of andesites, some with a little olivine,‡ in the Wairau Creek volcanic breccia-conglomerates at Takapuna, but the trachyte that has been found there by the writer shows but little mineralogical resemblance to any of these. It was discovered in several boulders up to 10 in. in diameter, all most perfectly rounded, and contrasting sharply with the general subangular and rough material of the bed in which they were found.

Microscopically the trachyte consists of idiomorphic phenocrysts of clear orthoclase, slightly subordinate plagioclase, and a little pale augite, in a dense finely trachytic groundmass showing perfect fluxional arrangement. The feldspar laths enclose between them very fine granules of augite and magnetite. The proportion of plagioclase laths to those of alkali feldspar is somewhat higher than in typical trachytes, a feature to be noticed in most of our New Zealand trachytes.

Trachytes are rare in the North Island of New Zealand, the only occurrence *in situ* being at Pukekaroro, near Maungaturoto, and the presence of the rock in the Wairau Creek volcanic fragmental bed is therefore interesting.

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* C. E. Fox, The Volcanic Beds of the Waitemata Series, *Trans. N.Z. Inst.*, vol. 34, 1902, p. 426.

† C. E. Fox, *loc. cit.*

‡ See also E. K. Mulgan, On the Volcanic Grits and Ash-beds in the Waitemata Series, *Trans. N.Z. Inst.*, vol. 34, 1902, pp. 420, 423, 424, &c.

# ART. XXXIII.—*Concretions in the Recent Sediments of the Auckland Harbour, New Zealand.*

By J. A. BARTRUM, Auckland University College.

[*Read before the Auckland Institute, 13th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

Plate XXIX.

DURING dredging operations recently carried out in St. George's Bay, Auckland Harbour, a considerable number of concretions were brought up, along with fine sands and numerous molluscan shells, from a depth of about 28 ft. to 35 ft. below mean high-water level.

It is no new discovery that concretions can form contemporaneously with the beds in which they are found: deep-sea manganese oolitic grains and nodules are classical examples. It is, however, seldom that one finds definite mention in literature of contemporaneous concretions of the type to which these at Auckland belong.

## DESCRIPTION OF THE CONCRETIONS.

The majority of the concretions are irregular nodular masses varying in size from ½ in. up to 6 in. or more in diameter. (See Plate XXIX, fig. 1.) Their material is very hard and compact limestone (about 70 per cent. calcium carbonate) enclosing numerous angular grains of quartz, a few of glauconite, numerous specks of carbonaceous matter, small fragments of partially carbonized wood, and, as a rule, numbers of Recent fossils—diatoms, a few foraminifera, small crabs, and molluscs. In some concretions there are comminuted fragments of the more delicate shells, but the stronger shells are intact. Small crabs are exceedingly common nuclei of small rounded concretions, such as the smallest of Plate XXIX, fig. 1, and the mollusc *Atrina zealandica* frequently the nucleus of the larger ones. (See Plate XXIX, fig. 2.) It shows its peculiar tooth-like ornamentation unimpaired, and the prisms of its outer calcareous layer are still uncemented. Few of the other molluscs found in the concretions can be regarded as nuclei, as the photograph (Plate XXIX, fig. 3) shows well.

No attempt has been made to list the shells found in the nodules, but all belong, so far as the writer is able to determine them, to Recent species. Many, such as *Cominella maculosa* and *Fulgoraria gracilis* (depicted in Plate XXIX, fig. 3), show unbleached natural colours. *Amphibola crenata* (Plate XXIX, fig. 3), various species of *Turritella* (Plate XXIX, fig. 1), and small *Pecten* valves are frequent.

In a few of the larger concretions some very irregular drusy cavities up to ½ in. in diameter are present. They are arranged without any relation to the boundaries of the concretion, or its nucleus. Their irregularity prohibits their being considered hollow casts of some since-removed organism; nor do they show the characters of shrinkage cracks, although this last explanation seems to be the only feasible one. They cannot be regarded as solution cavities, because there is ample evidence that the harbour deposits containing the concretions have not been subjected to any change of conditions such as would be necessary to permit percolation and solution to be effective.

Examination with the microscope shows that the calcareous material of the concretions was deposited as a microgranular aggregate, which is so fine in grain that it often has infilled minute diatom capsules which are even yet arranged in their characteristic bead-like strings. The included quartz-grains are somewhat sparsely but uniformly scattered throughout the calcareous matrix, and the only direct evidence of their having been outcrowded during growth of the concretion is that the somewhat incoherent surface zones are crowded with sand-grains, which, however, can equally well be accounted for by mechanical intermixture during pumping operations. Concentric structures and bedding-planes are absent.

It is evident from the facts already stated—the largely uncarbonized nature of many included wood fragments and the preservation of the natural colours of the shells in particular—that these concretions not only are contemporaneous with the beds in which they exist, but, further, have been formed at no very distant date.

## Origin of the Concretions.

It is agreed by practically all geologists that the manganese nodules of deep-sea deposits, the phosphatic concretions near shore, and the minute pisolites and oolites of many limestones, with many other similar chemically precipitated accretions, are contemporaneous in origin with the beds in which they lie. With respect to numerous accretionary nodules of other types there is less agreement, and the criteria of primary origin set forth by one writer may be construed by another as criteria of secondary origin. For example, the passage of bedding-planes through a concretion is considered by Geikie* to be evidence of contemporaneous origin, but by Chamberlin and Salisbury† to indicate secondary origin. The last-named authorities indicate the general lack of decision on this point in the following statement: "Some concretions probably form during the accumulation of the beds in which they lie."‡

Because such indecision is shown by many authors in dealing with concretions of this type the writer feels justified in emphasizing the indubitably contemporaneous origin of those described herein. There is no possibility that they have come by virtue of wave-action from the soft mid-Tertiary sandstones forming the prominent cliffs of the shores of Auckland Harbour, for these beds contain very few molluscan fossils, and, further, the concretions themselves have not been subjected to any erosive action.

The large quantity of calcium carbonate present in the matrix of the nodules cannot have been derived from the inferior amount constituting the included shells. Percolation cannot be effective under the conditions obtaining in this instance, so that the calcareous material must have been precipitated directly from sea-water by much the same process as that explaining the formation of the "coal-balls"§ of the English Coal Measures and similar accretionary bodies.

This long-established principle of direct precipitation has been suggested by one or two writers in explanation of the concretions in many magnesian

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* Sir A. Geikie, *Text-book of Geology*, vol. 1, 4th ed., 1903, p. 647.

† T. C. Chamberlin and R. D. Salisbury, *Geology*, vol. 1, 2nd ed., 1909, p. 496.

‡ *Loc. cit.*, p. 439.

§ M. C. Stopes and D. M. Watson, *Phil. Trans. Roy. Soc. Lond.*, ser. B, vol. 200, 1907, pp. 167–218.

FIG. 3.

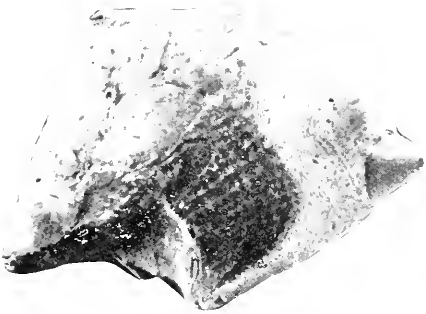

FIG. 2.

FIG. 1.

CONCRETIONS FROM AUCKLAND HARBOUR

limestones,* and without doubt it has led to the oft-made statements, such as that quoted above from Chamberlin and Salisbury, to the effect that many concretions are contemporaneous in origin with the beds enclosing them.

The writer has been unable to find any description of concretions mentioned by Chapman as occurring in muds at Melbourne,† but imagines that they are comparable with those of the Auckland Harbour.

## CAUSE OF THE PRECIPITATION OF THE CALCIUM CARBONATE.

The cause of the precipitation of the calcium carbonate in the Auckland Harbour concretions is often uncertain, for many of them lack definite nuclei. Some pencil-like ones probably formed around a decaying twig or some such organic remnant, when the organic compounds liberated induced precipitation of the carbonate. The commonest nuclei are shells of the mollusc *Atrina zealandica* and of a small crab; the skeletal parts are almost invariably filled by the material of the concretion, and this fact is perhaps evidence that the soft parts had disappeared before the shells came to rest. Probably precipitation was initiated by the decomposition of the organic matter in the epidermis of molluscs such as *Atrina* and the hard parts of the crabs. This seems the more probable since molluscs lacking a horny epidermis are very abundant in the harbour sands and yet seldom, if ever, form the true nuclei of the nodules described.

## SUMMARY AND CONCLUSION.

The writer has described certain calcareous concretions forming in present-day sands and other silts of the shallow, sheltered waters of Auckland Harbour (N.Z.), and contemporaneous with these sediments. He considers that they result largely from direct precipitation of calcium carbonate from sea-water. He wishes to bring forward this example of such nodules in order to supplement the somewhat vague available information about concretions which have formed as primary component parts of a stratum.

In conclusion, the writer wishes to thank Mr. M. Ongley, New Zealand Geological Survey, for considerable help in looking up literature.

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## POSTSCRIPT.

Through the courtesy of the members of the Geological Section of the Wellington Philosophical Society, the above paper was discussed at the June meeting (20th June, 1917) of the section, and several very relevant criticisms and suggestions were put forward.‡

It was suggested, *inter alia*, that (i) the concretions may have been dredged from the underlying mid-Tertiary Waitemata standstones; (ii) the evidence for the Recent age of the concretion-bearing sands and silts set forth in the paper was inconclusive.

Mr. Hamer, Engineer to the Auckland Harbour Board, has very kindly allowed the writer to see the mapped records of many scores of bores, and

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* *Cf.* A. J. JUKES BROWNE. Concretions in Magnesian Limestones, *Geol. Mag.* (n.s), dec. iii, vol. 8, 1891, p. 528.

† F. CHAPMAN. On Concretionary Nodules with Plant-remains in the Old Bed of the Yarra at South Melbourne. *Geol. Mag.* (n.s.), dec. v, vol. 3, 1906, pp. 553–56.

‡ Communicated to the writer by Dr. C. A. Cotton, Victoria University College.

of the soundings taken before and during dredging in the area of the harbour concerned.

Dealing with the suggestion that portions of the Waitemata beds have been dislodged and brought up, it need only be mentioned that the dredge employed was of the suction type and quite incapable of disrupting the coherent Waitemata sandstones disclosed beneath the silts by boring. The possibility of the concretions being a rewash of the Waitematas has already been considered.

The Harbour Board bores and the more recent physiographic history of the Auckland area prove, in the writer's opinion, that the concretions belong to beds now forming, which have had an uninterrupted course of deposition since their inception.

The pertinent facts of the recent physiographic history of Auckland are that the Auckland Harbour represents a former stream-valley drowned by invasion of the sea within fairly recent geological times, and that, subsequent to the drowning, the only recognizable movement of elevation (evidenced by wave-cut platforms) is one involving an uplift of not more than 5 ft. or 6 ft.

The bores demonstrate that the concretion-bearing sediments occur in a steep-walled narrow gut, with its bed approximately 30 ft. below mean low-water level (the Harbour Board datum), flanked by a level platform of firm sandstone (Waitemata) approximately 3 ft. or 4 ft. below low-water level. This gut is a continuation of the well-marked gulch spanned by Grafton Bridge. Gut and platform alike, prior to the commencement of dredging, were masked by sands and muds which raised the harbour-bottom to within about 2½ ft. of low-water level. The filling of the gut was everywhere unconsolidated.

*Auckland, 24th August, 1917.*

## Art. XXXIV.—*Kermadec Island Fleas.*

By F. W. Hilgendorf, D.Sc.

[*Received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

In 1908 Mr. W. R. B. Oliver brought back from the Kermadec Islands two species of fleas, and the fact that these have never been recorded has been overlooked. One of the fleas was found on a sandy beach, and the other on *Mus exulans*, the Maori rat. The identifications were kindly made by Lord Rothschild.

*Pysgiopsylla hilli* is an Australian flea which has been found on the mainland of Australia on several hosts. It has not been recorded from beyond the Australian region.

*Xenopsylla cheopis* is of wide distribution, being the common tropical flea on rats. It is instrumental in spreading plague, and is found in practically all warm countries. There is apparently no record of this or any other flea having been taken from *Mus exulans* in New Zealand.

## ART. XXXV.—*The Fossil Plains of North Otago.**

By C. A. COTTON, D.Sc., F.G.S., Victoria University College, Wellington.

[*Read before the Wellington Philosophical Society, 27th October, 1915; received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

Plates XXX, XXXI.

A FOSSIL is a thing "dug up," and to the palaeontologist the term "fossil" indicates something buried a very long time ago and dug up very recently. By the term *fossil plain*, therefore, may be understood a plain which, after coming into existence as a plain of erosion, has been buried by sediment and long afterwards re-exposed by renewed erosion. The sloping plateau surfaces to which the name is here applied are the most striking features in the character-profiles of North Otago.†

As a rule, in that district a fossil plain forms one side of the unsymmetrical valley developed in a fault-angle. On the one side is a fault-scarp more or less dissected; and on the other is the tilted surface of the next earth-block, from which the weak cover has been stripped, revealing the planed surface of the undermass.

As is more fully explained in another paper,‡ the dissection of the surfaces, though they are inclined, is generally shallow, because of the close spacing of numerous consequent§ streams, which, combined with the small rainfall, gives such streams steeply sloping profiles even when fully graded. Only a few larger streams trench deeply. Thus the fossil plain, once stripped, is a stable form under the climatic conditions prevailing in North Otago, and this accounts for its common occurrence.

### THE SHAG VALLEY FAULT-ANGLE.

The fault-angle depression known as the Shag Valley is an excellent example of the type. This depression is really a branch of the Central Otago depression-system, and it connects that system with the greatest of all depressions—the Pacific Ocean. The divide between the head of the south-eastward-flowing Shag River and the streams flowing westward to the Maniototo Plain is situated in an area of mature topography developed on covering strata strengthened by the presence of abundant volcanic rock. There is thus, as it were, an artificial separation of the Shag Valley depression from the Maniototo depression, the most easterly member of the Central Otago system proper, which would be much less prominent but for this local strengthening of the overmass.

The fault-scarp of the Kakanui Range, which forms the north-eastern boundary of the Maniototo depression, continues south-eastward along the front of that portion of the highland block termed the Horse Range, and thus forms the boundary of the Shag Valley depression also, being here opposed by one of the most perfect sloping plateaux in Otago—a fossil plain (see fig. 1, and Plate XXX, fig. 1)—which descends at a low angle north-eastward and eastward, passing, towards the sea and in the seaward portion

* The subject-matter of this article formed part of a paper on "Block Mountains in New Zealand," read before the Wellington Philosophical Society, part of which has been published in the *American Journal of Science* (vol. 44, 1917, pp. 249–93).

† C. A. COTTON, The Structure and Later Geological History of New Zealand, *Geol. Mag.*, dec. 6, vol. 3, 1916, pp. 243–49, 314–20 (see p. 315).

‡ *Loc. cit.* (1917), pp. 256–58.

§ More strictly termed "*superposed* consequent" at the present stage of their history.

of the depression, under marine covering strata, while on its surface are a number of remnants of cover, the largest of which are composed mainly of volcanic rock. Some of these which now form conical hills on the seaward part of the sloping plateau are probably necks.

The Shag River does not follow the fault-angle closely, but is in places superposed on the sloping plateau of the south-western side at a distance of several miles from the axis of the depression.

As the fault-scarp of the Kakanui - Horse Range is followed inland (north-westward), remnants of the covering strata are found at its immediate base inclined towards the scarp at the same angle as the stripped floor farther back. Some of these remnants, moreover, may be seen to rest upon a floor of schist (of which rock the whole of the sloping plateau of the south-western side is also composed), but the rock of the fault-scarp at the foot of which they lie is greywacke. Thus we have here not only a clear demonstration of the tectonic nature of the depression, but also an example of the general relation between the presumably older schist and the presumably younger greywacke along the border of the northern highland of Otago—namely, that the older rock is on the downthrow side of the fault-junction, indicating a reversal of the sense of movement, or, rather, that the youngest faults, where they have followed the lines of older dislocations, have done so merely because here lay lines of crustal weakness, and not because the latest movements were a continuation of those of a former period.

The excavation of the overmass in the lowest portion of the depression has followed a regional uplift much later than the movements by which the depression was formed, and the effects of this are here important owing to the fact that the course of the Shag River to the sea is a short one. Composite topography, though traceable, is not sufficiently prominent to vitiate the general account of the relief given above, which has, for simplicity, been stated as though the whole feature had been developed in a single cycle.

For the explanation of one curious detail of the mature fault-scarp of the Horse Range, forming the north-eastern side of the depression, the two-cycle origin must be borne in mind. One of the streams of the fault-scarp is exceptionally large, heading far back in the range, and this stream, instead of debouching cleanly into the fault-angle, turns sharply to the left while yet within the range-front, and flows for a mile or two parallel with the scarp and separated from the fault-angle depression by a long narrow spur of the undermass. It would seem that this stream when it entered the depression at a higher level had built forward a large fan at the base of the already mature fault-scarp, and that when rejuvenation occurred it had been flowing down that radius of the fan which lay closest to the scarp, so that when it cut downward it became superposed on the undermass of the range-front.*

## The Oamaru District.

The fault-scarp which forms the north-eastern side of the Shag Valley dwindles in height towards the south-east. The block which it bounds (Kakanui - Horse Range block) is strongly tilted to the east, and its surface on that side is now a fossil plain sloping eastward and north-eastward towards the sea, and dipping under and forming the floor of the marine Tertiary rocks of the Oamaru district.

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* *Loc. cit.* (1917), see fig. 9.

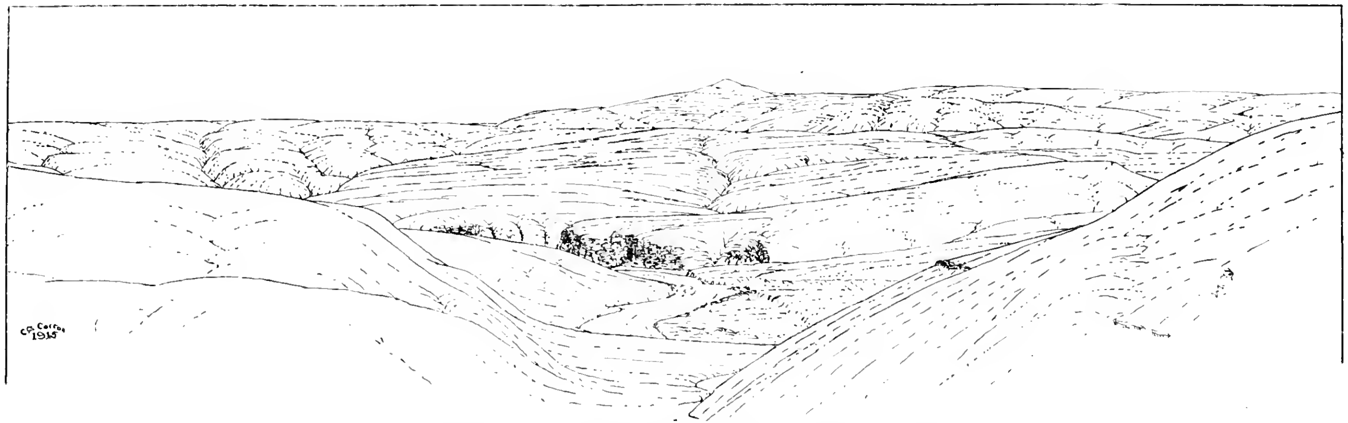

Fig. 1.—Fossil plain descending to the Shag Valley from the south-west. A residual hill capped by lava is on the distant sky-line. Subdued hills of the covering strata preserved in the fault-angle are seen in the foreground, and the Shag River is in the centre. The undermass is schist.

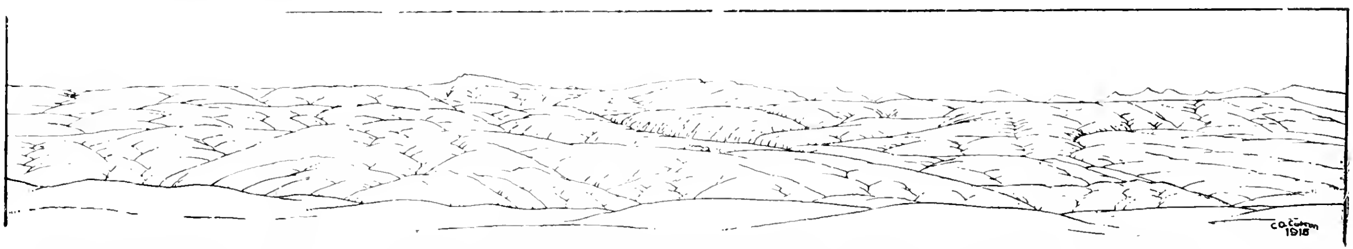

Fig. 2.—Fossil-plain surface of the Kakanui – Horse Range block descending north-eastward to the Oamaru district, and covered by marine strata in the foreground.

This fossil plain is strikingly similar to that of the Shag Valley fault-angle. Obviously it had a similar origin, and it is practically certain that the two were continuous prior to the Kaikoura orogenic movements (though at that time deeply buried under covering strata).

The surface is somewhat undulating, being "folded" to some extent like the adjacent covering strata. This has introduced slight irregularities in the pattern of the consequent drainage, but the majority of the streams run north-eastward in the direction of the general slope.

While the dissection is in general shallow, some master streams—*e.g.*, the Waianakarua (Plate XXXI)—are deeply incised in steep-walled gorges, which necessarily become deeper as they are followed back from the debouchures, the gradients of the streams being decidedly less steep than the slope of the fossil plain.

## The Waitaki Graben.

The Waitaki River is consequent on the Kaikoura deformation. The middle and lower Waitaki follow a straight course in an east-south-east direction through a somewhat complex graben between the highland blocks of North Otago and those of South Canterbury. Its tributary the Hakataramea enters from a great northerly-trending fault-angle depression.

In the Waitaki graben there are several small blocks of great interest as examples of tectonic forms. One small tilted block just behind Kurow exhibits an almost perfectly preserved back-slope and even crest-line (see fig. 3).

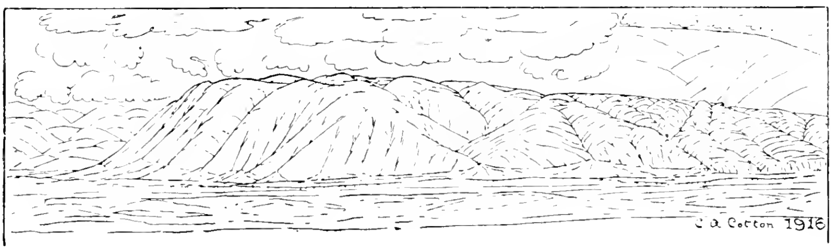


Fig. 3.—Small tilted block in the Waitaki Valley graben. View looking south-westward across the bed of the Waitaki River. The height of the scarp at the eastern end is about 1,000 ft. At the western end a glimpse is caught of the crest-line of the northern highland of Otago.

Another striking feature is a splinter from the northern fault-scarp of the graben just opposite Duntroon (Plate XXX, fig. 2). The fossil plain or stripped surface of the greywacke undermass, which is similar to that of the back-slope of the Hunter's Hills,* forms a plateau considerably over 1,000 ft. above the level of the valley-floor, and a strip of it descends in a westerly direction along the splinter, coming right down to the level of the low terraces bordering the river. While the cover has been removed, the fossil plain is almost untouched by erosion. The fault-scarp at the back of the splinter is well preserved; that in the front has been sharpened by the river.

* C. A. Cotton, *loc. cit.* (1916), fig. 2, p. 316.

[C. A. Cotton, photo.

Fig. 1.—Fossil plain of the south-western side of the Shag Valley, sloping down towards Palmerston.

[C. A. Cotton, photo.

Fig. 2.—A splinter from the fault-scarp of the northern side of the Waitaki graben. View looking northward from Duntroon.

[C. A. Cotton, photo

A portion of the fossil plain shown in text-fig. 2, showing the gorge of the Waianakarua.

## ART. XXXVI.—*Geology of the Central Kaipara.*

By Professor P. MARSHALL, M.A., D.Sc., Professor of Geology, Otago University.

[*Read before the Otago Institute, 5th December, 1916; received by Editors, 30th December, 1916; issued separately, 30th November, 1917.*]

[Plates XXXII, XXXIII.

THE discussions that have so frequently taken place in regard to the age of the lowest strata of the younger rock series of New Zealand have often involved statements as to the stratigraphy of those outcrops that occur in the north of the Auckland Province. The most recent of these statements have been made by Park,* Morgan,† and Marshall. The first of these geologists, in accordance with his later views in regard to the stratigraphy of New Zealand, believes that there are Cretaceous and Tertiary formations. The Cretaceous formation is supposed to terminate at the horizon of the top of the so-called hydraulic limestone, the southern equivalent of which is the Amuri limestone. Morgan appears to adopt a similar view, though he does not make any precise statement. Marshall‡ describes some points in the palaeontology of the limestones of this district. He shows that the lowest limestone (Whangarei type), generally admitted to be near the base of the formation, contains a large amount of *Amphistegina*, and that its characters in general are those of the so-called Miocene limestones of New Zealand. On the other hand, the formation known as the hydraulic limestone, a large part of which is not really calcareous, is shown to be a *Globigerina* ooze when it has a calcareous nature.

Since it appears that no collection of mollusca has been made in this locality for nearly twenty-five years, it was considered advisable to visit it and to study the stratigraphy so far as time would permit, and to collect all the mollusca that could be found. The author has now visited the locality on three occasions with those objects in view, and this paper embodies the results of his work.

The shore of the Kaipara Harbour between Port Albert and Matakohe is the portion of the district on which the observations have been made, for it is on this portion that earlier workers have found those sections on which their conclusions have been based. The general physiography of Kaipara Harbour is well known. The inlet penetrates deeply into the land and ramifies far into the ranges of hills along several drowned valleys. Several of these drowned valleys have deep-water channels, and in places the depth is as much as 20 fathoms. The arms of the harbour are generally bordered by cliffs, which rise in places to 100 ft.; but in many localities there are extensive mangrove flats, and the lines of cliff are much interrupted by the full development of mature stream-valleys which are tributary to the drowned valleys now forming the main arms. The whole topography is thus that of a maturely dissected lowland much depressed and drowned but the depression took place at a time sufficiently remote to allow of considerable cliff-erosion on the sides of the inlets that were formed by it.

* J. PARK, *Geol. Mag.*, dec. v, vol. 8, 1911, p. 546; also vol. 9, 1912, p. 493.

† P. G. MORGAN, *10th Ann. Rep. N.Z. Geol. Surv.*, 1916, p. 11.

‡ P. MARSHALL, The Younger Limestones of New Zealand, *Trans. N.Z. Inst.*, vol. 48, 1916, pp. 87–99 (see p. 91).

The rock structure is at once seen to be dominated by the development of white sediments that appear to be limestones, though it is found on a closer examination that many of these rocks are highly siliceous and that they are associated with marls, mudstones, and sandstones. There are also volcanic tuffs and lavas to a more restricted extent. The district has been greatly disturbed by earth-movements, and the rock outcrops show much folding, and probably faulting has taken place. There is also much and rapid change in the direction of the strike of the rocks, which necessarily greatly increases the difficulty of the stratigraphical problems.

The only parts of the district that were closely examined were the following: (1) Otamatea Arm from Komiti to one mile and a half above Batley; (2) Arapaoa Arm to one mile above Pahi; (3) Pahi Arm; (4) Oruawharo Arm from Port Albert to Oneriri. (See fig. 1.) The information gained from observations within this area cannot be regarded as in any way complete, though some general conclusions were arrived at. It appears that the lowest rock in the district examined is the limestone of the Gibraltar Rocks, in the Pahi Arm. This was also Park's conclusion. This limestone has often been correlated with the Whangarei limestone and with the Waiomio limestone. In the last locality, near the Kawakawa coal-mine, in the Bay of Islands, a bore showed that this type of limestone occurred very nearly at the base of this younger series of rocks and certainly below the hydraulic limestone.* Above this Whangarei limestone there is a series of marls and mudstones which is perhaps 500 ft. thick, at any rate in the Pahi Arm. Interstratified with the marls there are some bands of limestone not very different from that of the Gibraltar Rocks, and, like it, containing some glauconite. In places the glauconite forms thick beds of greensand, especially in the Pahi neighbourhood. Locally this greensand appears to give place to some very soft marly mudstones, which are of special importance in the Otamatea Arm half a mile to the north-east of Batley, and on the Arapaoa Arm two miles to the north-west of Batley. In the Pahi Arm it appears that some *Globigerina* limestone, called generally "hydraulic limestone," occurs beneath the greensand, for it is in this material that the bands of Whangarei limestone already mentioned are found. This *Globigerina* limestone is highly arenaceous and contains a good deal of glauconite, but in places it is siliceous. Occasionally this siliceous character is shown in the presence of flinty bands, though typical rounded flints are seldom found.

The main mass of the "hydraulic" or *Globigerina* limestone is found above the greensands. This relationship is particularly clear near Pahi, on both the Arapaoa and the Pahi Arms. The greater part of this limestone is composed of broken tests of *Globigerina* (Plate XXXII, fig. 3), but in places it contains a great number of sponge spicules and marine diatoms and radiolaria (Plate XXXII, figs. 1, 2). This is markedly the case at the main bluff at Batley and at Kaiwaka. In the upper part of this formation extremely fine sediment makes its appearance and the organic contents dwindle. The fine-grained sediment consists almost entirely of very minute grains of quartz, well rounded, and seeming therefore to owe their transport to aeolian influences rather than to those of water. This material forms the top of the Batley Cliff, Paukihi, and also the whole of the cliff on the opposite side of the Arapaoa Arm. On the foreshore of this cliff and farther to the

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* J. Hector, *Progress Report, N.Z. Geol. Surv., 1892–93*, 1894, p. xv, section A B, opp. p. xii.

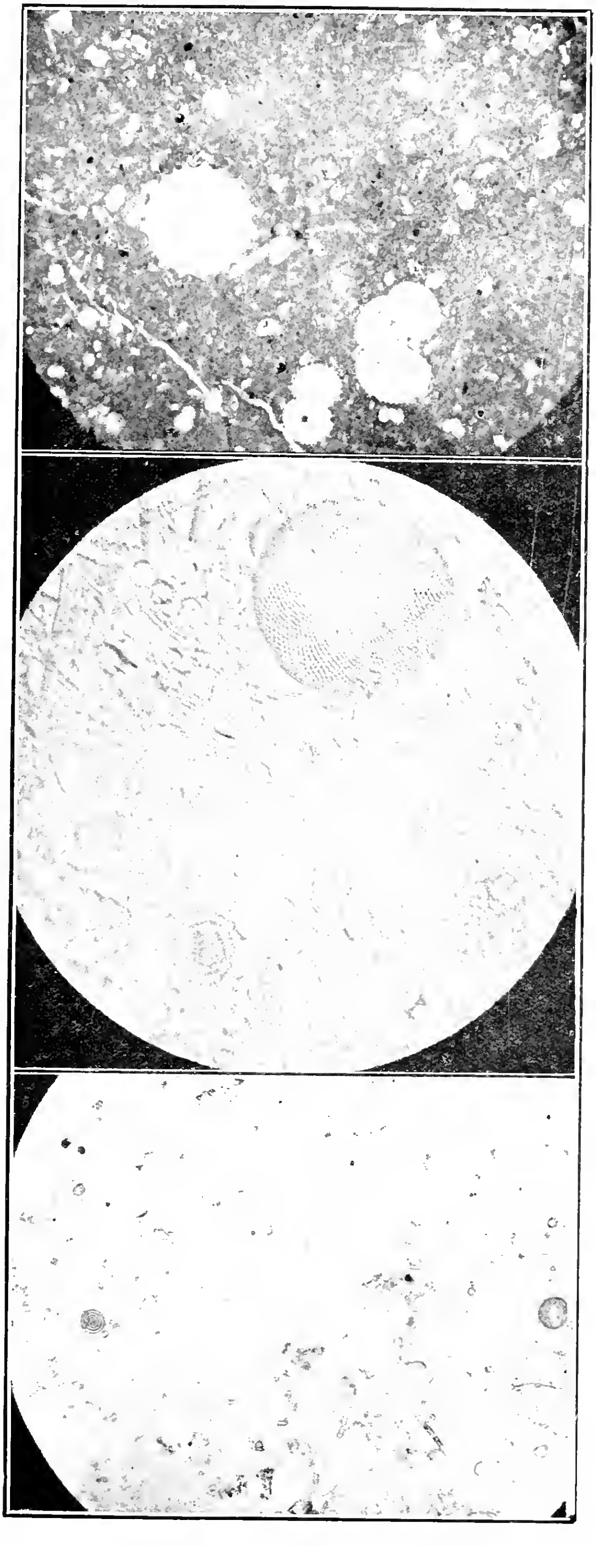

Fig. 3.

Fig. 2.

Fig. 1.

Fig. 1. Siliceous organisms of ooze, Paukihi. 22.
Fig. 2. Siliceous organisms of ooze, Paukihi. 110.
Fig. 3. Microsection of *Globigerina* ooze, Batley Wharf. 22.

Face p. 434.]


FIG. 1.—*Kossmaticeras tenuicostatum* n. sp. $\frac{1}{3}$.
FIG. 2.—*Kossmaticeras zelandicum* n. sp. Nat. size.
FIG. 3.—*Lytoceras* sp. Nat. size.
FIG. 4.—*Panopea worthingtoni* Hutton. Nat. size.

south this white material becomes somewhat harder, and then is succeeded rather abruptly, but along an uneroded stratification-plane, by a dark-grey marly bed. Forty yards farther along the foreshore these beds are succeeded along another parallel stratification-plane by a more arenaceous bed with some tufaceous material. These beds form the prominent Pakaurangi Point at the north-west end of the Funnel. In previous reports this point has been generally called Komiti Point, and the beds of which it is formed have been called the Komiti Point beds. This, however, is a misnomer, and it is likely to lead to much confusion, as Komiti is at the other end of the Funnel and is now the location of a considerable settlement of fruitgrowers.

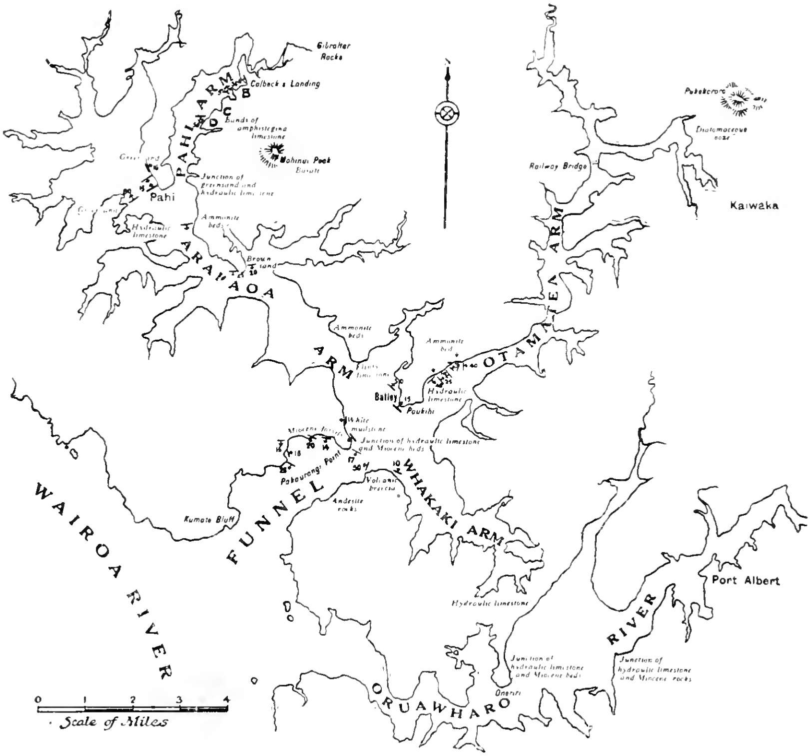


FIG. 1.—Map of Central Kaipara.

These Pakaurangi Point beds, under the name of the Komiti Point beds, have been correlated with the Waitemata series of Auckland, which is referred to the Miocene period. The stratification of these beds is much disturbed on both sides of the Funnel. The upper members, especially as seen on the south side of the Funnel, have a highly variable strike, and they are composed of coarsely tufaceous material, amongst which are numerous fragments of hydraulic limestone. The presence of these fragments does not, in the opinion of the author, imply erosion of the limestone before the Pakaurangi beds were deposited. Their occurrence in this tufaceous material is rather due to volcanic action, which was extremely violent whilst the land was still submerged and sedimentation was still in progress. Evidence of this is found at Mohinui, which is a volcanic neck It is here clearly seen that water penetrated into the crevices of the volcanic rock and caused its sudden solidification in the vitreous state. It is also noticeable that the scoriaceous volcanic matter round this neck is quite unoxidized. This inclusion of fragments of sedimentary beds in the volcanic material of submarine eruptions is well seen at Cape Horn, on the western shore of the Manukau Harbour. Here large masses of the Waitemata beds are included with the andesitic volcanic matter deposited by contemporaneous volcanic eruption.

There appears to have been a centre of volcanic activity near the western entrance of the Funnel, for a large mass of andesitic lava occurs here. The rock is a typical hypersthene-andesite. On the shore opposite to Pakaurangi Point the rocks have been violently disturbed, hydraulic limestone, "Waitemata beds," and volcanic lava being closely associated. The only visit paid to this locality took place at high tide, and the details could not be observed. It is probable that the formation would be uncovered at low tide to a sufficient extent to allow of an interpretation of the structure being found.

At this point there is a coarse conglomerate resting apparently with unconformity on the Pakaurangi beds. This conglomerate has an interest beyond the ordinary in that it contains some pebbles of a diorite which is not known to occur in place anywhere in this district. The nearest locality where plutonic rocks are definitely known to occur in place is Ahipara on the west side and Mangonui on the east side of the North Island respectively, but both of these places are some seventy-five miles distant.

In the series of rocks thus arranged no distinct stratigraphical break was observed, though this point is most difficult to decide because of the extent to which the rocks have been disturbed. Even at Pakaurangi Point, where the stratification is clear and the exposures continuous, there are some difficulties, and the strata are here clearly seen to be so disturbed as to change completely in strike and dip within very short distances.

Some previous observers have described several stratigraphical breaks in this rock series. S. H. Cox* in 1879 represented the hydraulic limestone as Cretaceo-Tertiary in age, while the limestone of the Gibraltar Rocks is classed as Eocene, and is represented as folded in a synclinal manner while resting on a highly eroded surface of the hydraulic limestone. However, Cox correlates the limestone of the Gibraltar Rocks with the Waiomio limestone at Kawakawa. In that place, as mentioned earlier, a bore has clearly shown that the Waiomio limestone is lower in the series than the hydraulic limestone. Cox also places the fossiliferous beds of Pakaurangi Point (called by him Komiti Point) in the Miocene period, but he does not indicate precisely the stratigraphical relation between the Pakaurangi beds and the limestone of the Gibraltar Rocks which he calls Eocene.

Park† in 1885 classed the beds of Pakaurangi Point in the Eocene, but all the other strata in the district are classed in the Cretaceo-Tertiary. In 1887 Park reported further on the same district. The Pakaurangi (Komiti) Point beds are in this second paper placed in the Miocene. Most of the other strata are placed in the Cretaceo-Tertiary. However, the white clays

* S. H. Cox, Geology of the Rodney and Marsden Counties, *Rep. Geol. Explor. dur. 1879-80*, 1881, pp. 18, 19.

† J. Park, On the Kaipara District, *Rep. Geol. Explor. dur. 1885*, 1886, pp. 164–70.

on which the Pakaurangi beds rest and the concretionary beds at Batley in which *Inoceramus* was recorded were classed in the Jurassic. A strong unconformity is indicated in a section showing the stratification of the Pakaurangi Point. This break is represented as occurring between the "chalky marls" (called in the present paper "white mudstones") and the "Waitemata beds"* or tufaceous beds with fossils. The former of these beds are said to strike north-west and south-east and to dip 60° to the north-east, and the latter strike east and west and dip 20° south. Careful observations failed to support these statements. The white mudstones are traversed by numerous prominent joints which have nearly the bearings stated, and it appears that these have been mistaken for stratification-planes. The true stratification-planes are hard to distinguish, but when found it is seen that they strike 157° and dip 24° north-east. This result was obtained twice in different parts of the exposure at an interval of three years. The first of the observations was made in company with Dr. C. A. Cotton, of Wellington.

Some 150 yards farther south-east as seen on the foreshore close to Pakaurangi Point the mudstones acquire a bluish tint rather abruptly along a well-defined plane. The strike is here 120°, and 40 yards farther on, where the beds become more sandy and tufaceous (Waitemata beds of Park and Cox), the strike becomes 107°, and again the plane of contact shows no sign of erosion. Though this change of strike within the short distance mentioned may appear considerable and important, other variations as great are found in the Pakaurangi, or tufaceous, beds themselves. The strike here changes from 65° to 110° within a distance of 30 yards, and afterwards to 170°, with accompanying great changes in the dip, as shown in the map of the district. In order to see the stratigraphical facts mentioned the district must be visited at low tide.

At the extreme end of Pakaurangi Point there is considerable irregularity in the stratification. This is represented by Park as a fault. It might almost as well be represented as a disconformity. The beds here consist of tufaceous material and fine brecciated matter, and at the extreme point contain a large number of fossils of *Miogypsina*, which is also found below the disconformity. There are also some mollusca, such as *Pecten aldingensis* Tate, which are also common in the rest of the sandy beds between the sandy white mudstones and the point. The structure at the end of the point is therefore of very little importance.

McKay† subsequently visited the district and reported a complete conformity from the *Inoceramus* beds to the top of the hydraulic limestone. He did not, however, visit the region of Pakaurangi Point.

The sequence of the younger rocks of New Zealand, so far as it is developed in the Central Kaipara district, appears to give no indication of such a break as is required to mark the dividing-line between two periods of sedimentation—that is, between two geological systems. Since the hydraulic limestone has always been correlated with the Amuri limestone of North Canterbury, it is natural in this place to review the additional observations that have been made in regard to the stratigraphical relation between this rock and the Weka Pass limestone which rests on it. It must again be stated that this is the dividing plane between Hutton's Cretaceous and

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* J. PARK, Kaipara and Wade Districts, Auckland, *Rep. Geol. Explor. dur. 1886–87*, 1887, pp. 219–29 (see esp. p. 221, and section repeated, *Geol. Mag.*, 1911, p. 546).

† A. MCKAY, On the Geology of the Northern District of Auckland, *Rep. Geol. Explor. dur. 1887–88*, 1888, pp. 37–57 (see p. 54).

Miocene, and within late years between Park's Cretaceous and Miocene also. Morgan, however, suggests that the rocks are of Eocene and Miocene age respectively. Additional evidence consists very largely in the rediscovery by Morgan* of a number of phosphatic nodules between the two rocks. Wherever the two rocks occur the one rests on the other without any change in dip or strike, and both are mainly foraminiferal. The phosphatic nodules are apparently regarded as rolled pebbles derived from some phosphatic stratum, which, however, has never been located. It would be much more reasonable to regard them as nodules formed on the sea-floor *in situ*. It is well known that such nodules are of relatively common occurrence in dredgings from water of moderate depth. From the Agulhas Bank several phosphatic nodules were dredged by the "Challenger"† from depths of 98 and 150 fathoms. The form is capricious—generally rounded, but also angular. The concretions from the shallower depths were the larger (6 cm. in diameter) and contained much more glauconite, and therefore possessed a green external appearance. The concretions are said to be more abundant along coasts where there are great and rapid changes of current, which cause frequent deaths of organisms. Merrill‡ states that it seems probable that Cretaceous and Tertiary deposits have been formed under similar conditions in all parts of the world. Stutzer also accepts the "Challenger" results as accounting for many phosphate deposits.§ F. W. Clarke, in the *Data of Geochemistry*, p. 104, describes the methods of formation of such nodules.||

It thus appears that the phosphatic nodules are probably original marine deposits. Their occurrence implies rapid current changes, which are also implied by the replacement of the *Globigerina* ooze of the Amuri limestone by the arenaceous glauconitic limestone called the "Weka Pass stone" that rests on it. The phosphatic nodules occur just where they would be expected in a conformable rock succession deposited on a rising sea-floor.

The gritty limestone of the Gibraltar Rocks is similar in most respects to the hard bands in the hydraulic limestone in the Pahi Arm. As stated by Marshall in the paper previously referred to, the limestone of the Gibraltar Rocks consists mainly of Polyzoa, echinoderm fragments, and Foraminifera belonging to the following genera: *Carpenteria*, *Globigerina*, *Rotalia*, and *Amphistegina*. At Colbeck's Landing the rock is mainly mudstone, but on the west side there is a band of gritty limestone which contains many joints of stems of *Pentacrinus*. Some distance to the south-east of the landing, at the point B (fig. 1), there is a thick mass of white limestone with a highly crystalline appearance. This appearance is due to the abundance of echinoderm fragments, and with these there are a few Foraminifera, mainly *Globigerina*. Some distance farther south, at C, there is some more limestone much silicified and apparently brecciated. Close to it there is a

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* P. G. Morgan, *10th Ann. Rep. N.Z. Geol. Surv.*, Parl. Paper C.-2B, 1916, pp. 25, 26.

† J. Murray and A. Renard, Deep-sea Deposits, "*Challenger*" *Reports*, 1891, p. 391.

‡ G. P. Merrill, *Non-metallic Minerals*. New York, 1904, p. 264.

§ O. Stutzer, Über Phosphatlagerstatten, *Zeitschr. für prakt. Geol.*, vol. 19, 1911, p. 7.

|| This has been stated definitely by Collet and Lee: "La glauconie et les concrétions phosphatées se forment actuellement sur le fond des mers. . . . Les concrétions phosphatées sont pour ainsi dire l'image du fond dans lequel on les rencontre ce qui prouve bien leur formation in situ." (Recherches sur la Glauconie, *Proc. Roy. Soc. Edin.*, vol. 26, pt. 4, 1906, p. 266.)

small outcrop of compact limestone. This rock consists almost solely of *Globigerina*. In the large bluff of hydraulic limestone at D there are three distinct hard bands of polyzoal limestone. The most northerly of these bands is mainly polyzoal, but there are numerous Foraminifera, including *Amphistegina*, *Rotalia*, *Cristellaria*, and *Textularia*, with some *Globigerina*. There are a few echinoderm fragments and much *Lithothamnium*. Of inorganic material there is a good deal of glauconite and a little quartz. The middle hard band 120 yards distant consists mainly of small Foraminifera, especially *Globigerina*, and a small *Rotalia*. There are only a few echinoid and polyzoan remains. Glauconite and quartz are in relatively large quantity. The southern band of this limestone consists mainly of Polyzoa. There are many echinoid plates and Foraminifera, amongst them *Amphistegina*, *Globigerina*, *Textularia*, *Rotalia*, and *Carpenteria*. There is a good deal of glauconite and of brown micaceous matter and small grains of quartz. There are also round grains of brown volcanic glass. The hydraulic limestone in which these bands are stratified consists mainly of *Globigerina*. Calcified sponge spicules are numerous. There are no other organic remains, but much glauconite, brown mica, and quartz.

## AMMONITE BEDS.

These are mainly formed of a fine muddy substance of a peculiarly unctuous nature. It has a dark-brown colour, and its incoherence allows it to slip easily, and it therefore presents extremely poor exposures. Thus near Batley and to the south-east of Pahi, where these beds outcrop, the hillside is gradually slipping into the harbour, and well-developed outcrops are exceedingly hard to find. At a third locality on the north side of the Arapaoa Arm, about two miles from Batley, the material is more stable, though even here the hillside is gradually slipping downwards.

These beds contain a large number of concretions. Usually the concretions are merely portions of the country that contain a higher percentage of carbonate of lime. Microscopical examination shows that they consist mainly of fine quartz sand cemented with calcareous matter. There is a little glauconite, and much brown matter, apparently of vegetable origin. Some of these concretions are composed wholly of pisolitic spherules 2·5 mm. in diameter. The pisolites are composed of radiating crystals of calcite. The concretions are of very different shapes and of varying size, though few of them are more than 1 ft. in diameter. Cone-in-cone structure is often associated with them in all the localities where the beds outcrop. Near Batley the beds contain concretions which are far more glauconitic than elsewhere. I am at present wholly unable to give a satisfactory explanation of the origin and formation of these concretions.

## GREENSANDS.

These are best developed at Pahi and to the north-west of that township along the shore of the Arapaoa Arm. The sands are in places almost pure glauconite, but they appear to have been deposited in relatively shallow water, for at places they are finely conglomeratic. They contain many concretions the exterior of which has been largely converted into limonite. Several of these concretions near Pahi enclose a large variety of molluscan fossils, and in one of them Mr. J. A. Bartrum found a reptilian bone. The concretionary matter that contains fossils is particularly abundant at three localities—(1) Arapaoa Arm, on the north-east shore near Pahi; (2) Arapaoa

Arm, south-west shore, opposite Pahi, at Coates's Landing; (3) Pahi Arm, opposite Pahi Township, near Jackman's. The greensand at these three places is clearly seen to lie below the main mass of the hydraulic limestone. Farther south the glauconitic nature of these sandstones seems to decrease and the brown sandstone next described takes its place.

These brown sandstones are of considerable thickness on the north side of the Arapaoa Arm at a prominent point two miles below Pahi. These sands contain very little glauconite, but, like the greensands, they are strongly concretionary. Amongst the concretions there are a few small ones of siderite. No fossils were found in any of the concretions in this brown sand. Near Batley this brown sand is exposed near the Maori settlement of Mateanui. It certainly lies below the ammonite beds in this locality, and appears to be separated from them by a bed of very siliceous hydraulic limestone.

Barite occurs from time to time in this rock series at various horizons. Near Kaiwaka it has been found lying on the surface of the hydraulic limestone. A large concretion was found at the point B near Colbeck's Landing, and another was found in the ammonite beds on the north side of the Arapaoa Arm close to Pahi. It is, of course, a fact that concretions of barite have been found in some ocean dredgings. It is thought that the greensands, brown sand, and ammonite beds are practically the same horizon. It is certainly true that the ammonite beds are not older than the greensands, for near Batley there is a large angular boulder of greensand embedded in the ammonite beds. The angular nature of this boulder shows that it has been transported a very short distance, a consideration that is emphasized by the incoherent nature of the greensand, which does not bear transport. The boulder almost gives the impression of being merely a local phase of the ammonite marls. In the same ammonite beds there are many concretions that have the appearance of those that are so common in the greensands. Thus the impression is formed that the ammonite beds and the greensands are different local phases of the same formation.

## Hydraulic Limestone.

This name has been used for a number of strata that have a general similarity in appearance, though in composition they prove to be widely different. The name "hydraulic limestone" has apparently been applied to them under the impression that they are so constituted that they can readily be converted into hydraulic cement. This may actually be true with reference to a small portion of the strata known under this name, but it is wholly misleading with reference to the greater part of the formation. In the Pahi section, for instance, hydraulic limestones are represented by Park over the greater part of the distance between McMurdo's and Colbeck's Landing (*loc. cit.*, 1887, p. 222, and section). The Batley Heads are also said to be composed of hydraulic limestone (*loc. cit.*, p. 229). A microscopic examination of these materials shows that the external similarity of the rocks actually conceals great differences in composition and structure.

In the Pahi Arm the beds near Colbeck's Landing are mudstones and sandstones almost destitute of calcareous matter. At Awakino the material is a *Globigerina* limestone, but it contains a large amount of glauconite, quartz, and other impurities. At Batley the small bluff near the wharf is a glauconitic limestone, but the material of the main bluff, Paukihi, is almost wholly siliceous. Near the base it is very white and compact, but shows no organisms when examined under the microscope. In many places the hydraulic limestone is highly siliceous, and in places it is distinctly flinty. No organisms have been recognized in these flinty types. It cannot at present be definitely stated whether the flinty type occurs only at one definite horizon or whether there are several different flinty strata. A little higher up the cliff the rock consists mainly of *Globigerina* tests, but it also contains a great variety of diatom* and radiolarian remains, with an abundance of sponge spicules. In the rock from the upper part of the cliff no organic remains could be distinguished, and the rock is merely a white mudstone that consists almost entirely of very minute rounded particles of quartz.

On the north-west side of the Arapaoa Arm, near Pakaurangi Point, this series of rocks is continued. The continuation has already been described in demonstration of the fact that the unconformity described by Park between his chalk marls (actually white mudstones above the hydraulic limestone) and his Komiti Point beds (here called "Pakaurangi Point beds") does not in reality exist. It is only necessary to repeat here that the white mudstones become dark-coloured and are finally succeeded by the tufaceous Pakaurangi Point beds without any sign of erosion.

## PAKAURANGI (KOMITI) POINT BEDS.

These are moderately coarse sandy beds mainly composed of material of volcanic origin, and are therefore rightly described by Hector as tufaceous. As the beds are followed farther westward and southward the material becomes coarser and the sediments are in places breccia or conglomerate beds. The upper beds at the apex of Pakaurangi Point still have a species of *Amphistegina* and a great abundance of *Miogypsina* aff. *irregularis* (*Orbitoides* of Park), and is probably of Lower Miocene age.

It is well known that flint-beds are associated with the fine-grained *Globigerina* limestone—the so-called Amuri limestone of North Canterbury and Marlborough. An account of these has just been published by Thomson. In his article he states that "The absence of such skeletons [Radiolaria, sponges, and diatoms] in any of the numerous microscopic sections examined removes any ground for accepting such an explanation [organic source] for the origin of the silica in the present case. . . . In view of the widespread occurrence of the flint-beds, apparently at a definite horizon, the theory of original deposition [chemical precipitate] seems most acceptable."†

In a paper published last year I recorded the occurrence of Radiolaria in the Amuri limestone at Kaikoura and at the Amuri Bluff, in both of which localities there are some flints in the limestone. In addition, further instances of the occurrence of sponge spicules were recorded in the North of Auckland in the hydraulic limestone at Kaiwaka and at Port Albert. In the last locality the spicules were calcified. Also at Kaiwaka there is a diatomaceous and radiolarian ooze associated with the limestone.‡ In addition, the present paper records the presence of *Globigerina* ooze with abundant Radiolaria and diatoms at Batley. The *Globigerina* limestone

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* Mr. J. H. Grenfell, of Oamaru, has kindly mounted some slides of these diatoms. He says, "The following are the diatoms in these slides which appear similar to those from Oamaru: *Actinoptycus*, *Coscinodiscus*, and *Triceratium*."

† J. A. THOMSON, The Flint-beds associated with the Amuri Limestone of Marlborough, *Trans. N.Z. Inst.*, vol. 48, 1916, pp. 48–58 (see p. 56).

‡ P. MARSHALL, The Younger Limestones of New Zealand. *Trans. N.Z. Inst.*, vol. 48, 1916, pp. 87–99 (see p. 94).

one mile north of Pahi also contains an abundance of calcified sponge spicules, and a re-examination of the limestone from Wellsford, and from Limestone Island, in Whangarei Harbour, shows that calcified sponge spicules are frequent in those rocks also.

Thus in this group of rocks, Amuri limestone and hydraulic limestone, which have always been correlated together, we have the following records of the occurrence of the skeletons of siliceous organisms :—

(1.) Diatomaceous and radiolarian ooze : (*a*) Kaiwaka, (*b*) Batley, (*c*) Oamaru (immediately beneath the polyzoal limestone).

(2.) *Globigerina* ooze with Radiolaria : (*a*) Kaikoura, (*b*) Amuri Bluff.

(3.) *Globigerina* ooze with sponge spicules usually calcified : (*a*) Pahi, (*b*) Kaiwaka, (*c*) Port Albert, (*d*) Wellsford, (*e*) Limestone Island, Whangarei.

It is thus evident that siliceous organisms have contributed to some extent in many localities to the material of the Amuri limestone and hydraulic limestone, and that at times the siliceous remains occur to the exclusion of all other material. It is certainly true that at Ward and in many other localities where the limestones have the hard siliceous character the remains of siliceous organisms have not yet been distinctly recognized. A further examination of the specimen from Ward seen after a study of the specimens from Batley makes it appear probable to me that diatoms and Radiolaria are present, though much calcified and much destroyed by solution. In all the localities of the hydraulic limestone that have been mentioned there are also pronounced siliceous and flinty horizons. In view of the very general occurrence of the remains of organisms with siliceous skeletons, and of the fact that in many of the occurrences much of the siliceous matter is calcified, it is natural to come to the conclusion that the silica of these flinty rocks has been derived from the solution of the skeletons of siliceous organisms.

The Auckland rocks called collectively hydraulic limestone appear to have the same stratigraphical position as the Amuri limestone — that is, there are Cretaceous fossils below and Tertiary fossils in the strata that rest on them. The presence of radiolarian remains in some of these South Island deep-sea rocks, and their similar stratigraphical position to the hydraulic limestone, which almost certainly owes its frequent siliceous character to organic skeletons, renders it probable that these South Island flinty rocks also owe their siliceous contents to organic remains. In the light of our present knowledge this explanation seems more in accord with those facts that we know than any hypothetical explanation based upon the precipitation of silica from oceanic water.

As thus described it will be seen that the whole series of younger rocks in this district has near the base a limestone which is largely composed of Foraminifera and is of relatively deep-sea orgin. For some time the sea in which this limestone was deposited remained of considerable depth, but the coast-line was sufficiently close to this locality to allow of the accumulation of much terrigenous matter. The amount of sediment varied, and from time to time it was reduced to such an extent and oceanic currents changed so far as to allow of the deposition of greensands. At times tests of *Globigerina* constituted the main portion of the deposit. During this time ammonites with the affinities of species belonging to the Senonian fauna were in existence, though the mollusca had something of a Cainozoic aspect. There are also hard bands of limestone at various horizons which contain species of *Amphistegina* and give to the formation more than ever a Tertiary aspect.

After a great thickness of sediment had been accumulated on this sea-floor a further movement of depression of an important nature took place, and a bed of *Globigerina* ooze of great thickness was formed. The depth of the water increased to such an extent that over the calcareous matter there was formed a stratum of diatomaceous and radiolarian ooze. When elevation took place again it appears that conditions were unfavourable to the life of *Globigerina*, and the diatomaceous ooze is succeeded directly by a fine white mudstone composed almost entirely of minute rounded particles of quartz. It is extremely difficult to suggest the exact origin of this material. The well-rounded form of the quartz certainly leads to the belief that the deposit was of aeolian origin. It may be of the same nature as the white clay, or white clay with ooze, now covering the sea-floor fifty miles distant from Cape Maria van Diemen on the western side of the North Island. There appears to have been very little life on the sea-floor at this time.

The elevation of the sea-floor continued gradually, and the deposit became marly. A varied molluscan fauna then appeared, and at the same time simple flabelloid corals and an abundant *Miogypsina* life. Volcanic action took place on many occasions. Volcanic glass is found in the hard limestone near Pahi. Marahemu Hill is formed of volcanic rock due to submarine activity, and, lastly, there are the great beds of tuff and the lava rocks at Komiti and on the south-east side of the Funnel. Further evidence of submarine volcanic activity is found in the large beds of tuff and breccia at Wayby and near Kaiwaka, where in the rock used for the railway ballast specimens of *Amphistegina* were found in microscopical preparations. Lastly, there is a small cone near Port Albert. The volcanic rock here is quite glassy, and though distinct proof was not found it seems that this material also was formed by submarine eruption.

## Palaeontology.

The following rocks were found to contain fossils: (1) The gritty limestone at Gibraltar Rocks, and bands of similar material between that point and Pahi; (2) the hydraulic limestones; (3) the greensands near Pahi; (4) the mudstones with concretions near Batley, or ammonite beds; (5) the sandy and tufaceous beds near Pakaurangi Point. The gritty limestones of the Gibraltar Rocks have been described previously. The following genera of Foraminifera are represented: *Carpenteria*, *Globigerina*, *Rotalia*, and *Amphistegina*. No specific determinations were possible. In the absence of specific identifications it is not possible to state the exact horizon to which the limestone belongs, though the presence of abundant *Amphistegina* appears to point to the Miocene age. The same remarks apply to all the other bands of gritty limestone between the Gibraltar Rocks and Pahi.

### The Ammonite Beds.

These marly beds contain relatively few fossils, though those that have been found have a peculiar interest. Up to the present time only five species have been discovered, and three of these are ammonites.

### Kossmaticeras de Groussouvre, 1901.

This genus was established to include species derived from *Pusozia* and *Uhligella* which show a close similarity to *Holcodiscus*, though these types are supposed to owe their resemblance to phylogenetic convergence.

**Kossmaticeras zelandicum** n. sp. (Plate XXXIII, fig. 2.)

Diameter, 75 mm.; thickness, 27 mm.

Last whorl only seen in the specimen for about half its extent. Ribs large and distinct, some 36 being developed in the half-circle. The ribs for the most part take their origin in tubercles situated on the border of the umbilical wall. The tubercles are 10 in number in the half-circle. There are a few ribs situated in the intervals between the tubercles. A few additional ribs arise half-way between the umbilicus and the siphon. These additional ribs are intercalated between those that arise on the umbilical wall. The ribs are crenulated some twelve times between the tubercles and the siphuncle. The suture-line is comparatively simple, and closely resembles that of *K. karpadense,* and less closely that of *K. bhawani* Stoliczka.*


Fig. 2.—Suture-line of *Kossmaticeras zelandicum.* × 3.

This species is closely related to *K. antarcticum,* described by Kilian and Reboul from Seymour Island, and to *K. kalika* Stoliczka from the Arrialoor of India. From the former its ornamentation differs in its ribs and tubercles being more numerous. On the other hand, the ribs and tubercles are both less numerous than in the Indian species. These two species are included by Kilian and Reboul in the subgenus *Gunnarites.* There appears to be no doubt that the present species should be placed in the same group, though it is sufficiently distinct to be regarded as a separate species.

In regard to the age that is indicated by the fossil the following statement of Kilian and Reboul (*loc. cit.*, p. 64) may be quoted: "Les faunes etudiées qui appartiennent incontestablement au type indopacifique du cretacé superieur (Neocretacé) sont caracterisées par les *Kossmaticeras.*" "Les assises crétacées à *Kossmaticeras antarcticum* et *Koss. bhavani* de la terre de Graham, des îles de Snow Hill et de Seymour se placent sensiblement au même niveau que des couches de Quiriquina (Chili), les couches d'Algarobo, celles de Tejon group en Californie, les couches supérieures de Chico, les Phoenix and Henly Beds dans l'Oregon, l'assise de Nanaimo dans la Colombie britannique, les

* F. Stoliczka, *Palaeontologia Indica,* Cretaceous Fauna of Southern India, vol. 1, pl. lxix, fig. 7; also Kilian and Reboul, Les Cephalophodes neocretacées, *Wiss. Ergeb. der swed. sudp. Exped. 1901–3,* Bd. 3, Lief. 6, p. 22, 1909.

Trichinopoly et Aryaloor Beds de l'Inde, les couches à *Pachydiscus* de Patagonie (Hauthal), correspondant à la grande transgression sénonienne qui parait avoir atteint également Bornéo et la Nouvelle Zélande."

Kossmaticeras tenuicostatum n. sp. (Plate XXXIII, fig. 1.)

The only specimen is large, measuring 142 mm. in diameter and 45 mm. in thickness. Aperture oval. Shell extremely thin, ornamented with a large number of very fine ribs which are not bent in the siphonal region but they have a slight bend forward at the region about half-way between the siphuncle and the umbilicus. There are no umbilical tubercles. The

FIG. 2.—Suture-line of *Kossmaticeras tenuicostatum.* × 1½.

suture-line is complicated. It is but little different from that of *Ammonites beudanti* Brogniart from the Trichinopoly beds of India. (*Pal. Ind.*, Cret. Ceph., pl. lxxii.) The suture-line shows a distinct resemblance to that of *Kossmaticeras gemmatum* Huppé, though there are considerable differences in detail. The ornamentation is, however, completely different from that of *K. gemmatum.* (Kilian and Reboul, *loc. cit.*, p. 22; Steinmann, *Neues Jahrb. für Min.*, &c., Bd. 10, 1895.)

Lytoceras sp. (Plate XXXIII, fig. 3.)

The only specimen of this genus is a fragment. The specimen measured 46 mm. in diameter and 18 mm. in thickness. Cross-section nearly circular. The specimen has been silicified, and that appears to have destroyed the external ornamentation, though in one portion it is still visible as a series of extremely fine ribs. The specimen consists of the body-chamber, but part of the next whorl remains, and on this a suture-line is distinct which has the typical character of *Lytoceras*. The species appears to be closely related to *Am.* (*Lytoceras*) *cola* Forbes from the Ootatoor of India. (*Pal. Ind., loc. cit.*, pl. lxxv, fig. 5.)

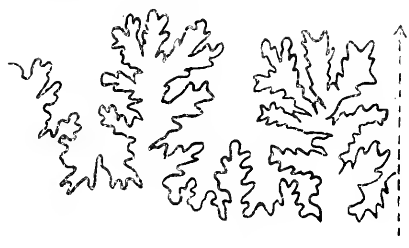

FIG. 4.—Suture-line of *Lytoceras* sp. × 7.

### Lamellibranchia.

**Panopea worthingtoni** Hutton. (Plate XXXIII, fig. 4.)

This specimen was identified for me by Mr. Suter. The species comes very near *P. orbita* Hutton. It is not uncommon in the Cainozoic rocks of New Zealand. It is recorded by Hutton from Lake Wakatipu and the Broken River.

**Phacoides (Here)** sp.

This specimen occurs as a cast only, and it has been classed for me by Mr. Suter. No other specimen of this genus has yet been recorded from New Zealand. In regard to the subgenus *Here* Cossmann remarks, "Il est douteuse que ce sous-genre ait veçu dans l'Eocene." (Cossmann et Peyrot, *Conchologie de l'Aquitaine*, 1911, livraison 2, p. 687.)

*Inoceramus* fragments (Park, *Geol. Rep. N.Z.*, 1886–87): I have found no remains of this genus.

This collection is of special interest. From a stratigraphical standpoint there hardly seems any room for doubt that this bed is of a higher horizon than the limestone of the Gibraltar Rocks. As stated earlier, this limestone contains a considerable amount of *Amphistegina*, and has other characteristics that cause Chapman to regard it as of Miocene age. A similar limestone almost at the base of the younger series of rocks at Waiomio is also stated by Chapman to be of the typical Miocene character. On the other hand, this ammonite bed lies distinctly below the hydraulic limestone. From a palaeontological standpoint the determination of the age of the beds offers much difficulty. It is clear that the ammonite fauna, poor as it is, clearly indicates a Senonian age. On the other hand, *Panopea worthingtoni* occurs widely in New Zealand in beds that are always classed as Tertiary, and generally as Miocene. This suggestion is apparently emphasized by the occurrence of *Here.* (A further collection has now been made, and many more species of ammonites, lamellibranchs, and some gastropods have been found. These will be described subsequently.) Hector placed these beds in the Cretaceo-Tertiary, Cox in the Lower Greensand, and Park agrees with Hector (?) that they are Jurassic.

### The Pahi Greensands.

The fossils in these beds are in a bad state of preservation, and identification of the species has proved so difficult that no list can be given at present.

### Pakaurangi Point Beds.

The beds at Pakaurangi Point have been long known to contain fossils. Hector collected some from here in 1876. Cox added to the collections in 1879. Park gave a list of some seventy forms in 1879, though in most cases the generic position only of the species was given. The following list contains the species collected in 1912 and in 1916 by myself, assisted by Mr. J. A. Bartrum. The material in which the fossils are embedded is a soft gray mudstone, and the specimens are for the most part in an excellent state of preservation. Fossils are most plentiful in the low cliffs on the western (or Funnel) side of the Pakaurangi Point. I am much indebted to Mr. H. Suter for identifying the species. Those marked * are Recent species.

*Vaginella* n. sp.
**Emarginula striatula* Q. & G.
*Solariella stoliczkai* Zittel.
*Calliostoma* n. sp.
*Astraea subfimbriata* Suter.
*Turritella semiconcava* Suter.
*Turritella* sp.
*Cerithiopsis* sp.
*Struthiolaria cincta* Hutton.
*Crepidula gregaria* Sowerby.
**Calyptraea maculata* L.
**Natica zelandica* Q. & G.
*Polinices gibbosus* Hutton.
*Ampullina suturalis* Hutton.
*Epitonium browni* Zittel.
**Epitonium zelebori* Hutton.
**Trivia avellanoides* McCoy.
*Cymatium minimum* Hutton.
**Phalium achatinum pyrum* Lamarck.
*Galeodea senex* Hutton.
*Architectonica* n. sp.
*Heliacus* n. sp.
*Fusinus kaiparaensis* Suter.
*Fusinus morgani* Suter.
*Dolicholatirus* (*Pseudolatirus*) n. sp.
*Ptychatractus pukeuriensis* Suter.
**Siphonalia dilatata* Q. & G.
*Siphonalia* n. sp.
*Coptochetus* n. sp.
*Cominella carinata* Hutton.
*Phos* n. sp.
*Phos* n. sp.
*Alectrion socialis* Hutton.
**Murex angasi* Crosse.
*Murex zelandicus* Q. & G.
**Murex zelandicus komiticus* Suter.
*Cymbiola corrugata* Hutton.
*Cymbiola* n. sp.
*Cymbiola* n. sp.
*Cymbiola* n. sp.
**Ancilla australis* Sowerby.
*Ancilla papillata* Tate.
*Ancilla* n. sp.
*Ancilla* n. sp.
*Marginella conica* Harris.
*Marginella harrisi* Cossmann.
*Surcula climacota* Suter.
*Surcula fusiformis* Hutton.
*Surcula* n. sp.
*Surcula* n. sp.
*Surcula* n. sp.
*Surcula* n. sp.
*Leucosyrinx alta transenna* Suter.
*Turris* n. sp.
*Turris* n. sp.
*Drillia awamoaensis* Suter.
*Drillia imperfecta* Suter.
*Drillia* n. sp.
*Borsonia* (*Cordieria*) n. sp.
*Bathytoma haasti* Hutton.
*Bathytoma sulcata excavata* Suter.
**Mangilia dictyota* Hutton.
*Conus armoricus* Suter.
*Conus* (*Leptoconus*) n. sp.
*Conus* (*Lithoconus*) n. sp.
*Terebra orycta* Suter.
*Acteon ovalis* Hutton.
**Acteon craticulatus* Murdoch & Suter.
*Crenilabium* n. sp.
*Cylichnella enysi* Hutton.
**Dentalium ecostatum* T. W. Kirk.
*Dentalium pareoraense* Suter.
*Dentalium solidum* Hutton.
**Cadulus delicatulus* Suter.
*Leda semiteres* Hutton.
**Leda fastidiosa* A. Adams.
*Sarepta* n. sp. ?
*Anomia* n. sp.
**Arca novae-zelandiae* Smith.
*Arca subvelata* Suter.
*Glycymeris subglobosa* Suter.
*Cucullaea alta* Sowerby.
*Cucullaea australis* Hutton.
*Mytilus* n. sp.
*Pecten aldingensis* Tate.
*Pecten burnetti* Zittel.
*Pecten huttoni* Park.
*Pecten* n. sp.
*Pecten* n. sp.
*Spondylus* n. sp.
*Lima colorata* Hutton.
*Ostraea wuellerstorfi* Zittel.
*Ostraea nelsoniana* Zittel.
**Cardita calyculata* Linné.
*Venericardia subintermedia* Suter.
**Thyasira flexuosa* Mont.
**Tellina eugonia* Suter.
**Tellina glabrella* Deshayes.
*Crossatellites attenuatus* Hutton.
**Dosinia greyi* Zittel.
*Dosinia* n. sp.
*Macrocallista assimilis* Hutton.
*Macrocallista pareoraensis* Suter.
*Cytherea chariessa* Suter.
*Chione meridionalis* Sowerby.
*Paphia curta* Hutton.

*Cardita* (*Glans*) n. sp.
*Chama huttoni* Hector.
*Corbula canaliculata* Hutton.
*Corbula kaiparaensis* Suter.
**Corbula macilenta* Hutton.
*Corbula* n. sp.
**Panopea zelandica* Q. & G.

Of these 113 species only twenty-three are Recent, a percentage of 19·9. The genera *Dolicholatirus*, *Coptochetus*, *Crenilabium*, and *Spondylus* have not previously been found in the New Zealand fauna, fossil or Recent. The species *Acteon craticulatus*, *Cadulus delicatulus*, and *Thyasira flexuosa* have not previously been found fossil.

The rather low percentage of Recent species may be due to the northern locality, for it is probable that many species would tend to recede northwards as the climate became somewhat colder in the Pleistocene. The absence of littoral waters any considerable distance farther north would have caused some of these species to become extinct. This also may account for the presence of four genera which are now absent from the New Zealand fauna. The age of the Pakaurangi Point beds is probably about that of Target Gully if the suggestion made is regarded as valid so far as the extinct species are concerned.

## Rocks of Igneous Origin.

Igneous rocks have been found in the following localities: The Otamatea Funnel, Mohinui (or Marahemu), Port Albert, Pukekaroro.

### *Conglomerates of the Otamatea Funnel.*

A considerable outcrop of volcanic rocks is found on the south-eastern side of the Funnel. It appears to be *in situ* in this locality, though it was seen in the form of large boulders only.

This rock is moderately coarse, and shows feldspar crystals of considerable size in the hand-specimens. In section these crystals are found to be irregular, often zoned, and always twinned, showing in sections at right angles to the brachypinacoid an extinction angle of 30°, thus indicating a type of labradorite. Many of the crystals enclose a great number of minute particles of glassy matter and of augite. Hypersthene is abundant in small well-formed crystals showing the usual pleochroism. In one case a crystal of hypersthene is mantled with a thin coating of augite. Augite is infrequent as compared with the hypersthene. The groundmass consists mainly of minute microlites of feldspar, but there are also many granules of augite and crystals of magnetite, which mineral is also often found enclosed in the crystals of hypersthene.

### *Mohinui, or Marahemu.*

Mohinui is the name given on the Admiralty chart, but Marahemu is used on the Survey maps. The rock of which it is composed is black in colour, and it shows conspicuous crystals of feldspar, augite, and olivine.

In section the feldspar crystals are seen to be irregular, and they are occasionally in aggregates and show zonal structure. The species is labradorite, for the extinction angle in sections at right angles to the brachypinacoid is 32°. The augite is often in well-formed crystals, and is frequently twinned. It may reach 2·5 cm. in diameter, and is of a greenish colour. Olivine is common, and the crystals are sometimes well formed. Most of them show serpentinization along crevices and along the borders. The groundmass is mainly feldspar in microlites. There is also much augite and magnetite.

### *Port Albert.*

A black rock, dense, and with an irregular fracture. The only mineral visible in section is feldspar in small sharp crystals. These are so fragmentary that it is impossible to identify them. The index of refraction is higher than that of Canada balsam. The feldspar crystals are bordered with dark margins of amorphous matter, as are the crystals in the glassy basalts of Savaii and similar vitreous basic rocks. The rest of the rock is brown glassy matter showing feathery crystallitic growths and incipient spherulitic structure. The rock has all the appearance of a basic glass, but the absence of olivine crystals suggests that it has the composition of an andesite rather than a basalt.

### *Conglomerates on the South Side of the Otamatea Funnel.*

A large number of these boulders have in hand-specimens distinctly the appearance of plutonic rocks. The specimens vary somewhat in coarseness and in relative abundance of the ferro-magnesian constituent. The feldspar has no regular outlines, and the arrangement of the grains suggests a gneissic structure. There are many minute inclusions, and lamellar albite twinning is general. The extinction angle is 20°, and the refractive index 1·560. It is therefore a basic variety of andesine. Hornblende is very abundant in irregular ragged crystals. It includes much dusty ferruginous matter, and sometimes distinct crystals of magnetite. Pleochroism, green to straw-colour. The appearance of this hornblende suggests that it is of secondary origin. There is much magnetite and apatite.

No rock that closely resembles this has yet been found *in situ* in the North Island. It is quite different from the diorite of Mangonui and from the other plutonic rocks near Ahipara and Hokianga.

### *Pukekaroro.*

This rock is light grey in colour, and is without any conspicuous crystals in hand-specimens. In section it is largely composed of short small crystals of feldspar with idiomorphic outline. The crystals are often polysynthetically twinned, and the angle indicates that they are andesine. In many cases they are zoned. The finer matter of the rock consists of colourless material which in some specimens has a most irregular form but in other slices is regularly quadrilateral. In all cases it has small inclusions of dark matter which could not be identified. I am indebted to Professor J. P. Iddings for pointing out to me that this mineral is quartz. When it has the irregular form its arrangement suggests the micropoecilitic structure described by Sollas in the dacites of the Coromandel Peninsula. The ferro-magnesian mineral in this rock is completely chloritized, and the chlorite has much dusty magnetite associated with it. So far as the shape of the chloritic pseudomorph can be recognized, the original mineral appears to have been biotite. The rock must therefore be classed as a dacite.

The age of these igneous rocks cannot be very distinctly stated, and it is even unlikely that all the volcanic rocks are of the same age. The diorite is evidently derived from some relatively ancient rock-mass which has not yet been discovered *in situ*.

The Marahemu basalt constitutes a neck that traverses the hydraulic limestone in one of its flinty horizons. As the rock is glassy on the selvages and along the crevices, and at the same time the associated tuffs are not oxidized, it becomes probable that the eruption was of a submarine nature.

Its intrusion was evidently subsequent to the deposition of the siliceous hydraulic limestone. The same remarks apply to the Port Albert rock, which forms a small neck about two miles to the east of Port Albert. The dacite of Pukekaroro forms a hill of considerable height which is a prominent point over the greater part of the central Kaipara, is surrounded by hydraulic limestone, and is certainly of later origin than that rock.

The hypersthene andesite of the Funnel was evidently emitted at the time of the deposition of the Pakaurangi beds or immediately afterwards. Small fragments of basic glass were found in the bands of polyzoal and *Amphistegina* limestone on the Pahi Arm. It is thus evident that volcanic activity was in progress whilst the deposition of the hydraulic limestone was taking place. There are also quarries for railway ballast on the line two miles south of Kaiwaka Station and near Wayby. The rock that is quarried is a volcanic breccia. It is black in colour, and at once gives the impression of formation under submarine conditions. This opinion is confirmed by microscopical examination, which reveals Foraminifera amongst the volcanic fragments. Amongst the Foraminifera is a specimen of *Amphistegina*. The tufaceous matter includes small greenish grains of augite similar to the augite of the Marahemu basalt. It is thus evident that volcanic activity of an extensive nature took place in this district during and after the deposition of the limestone, for the breccia appears to rest conformably on a phase of the hydraulic limestone.

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## Art. XXXVII.—*The Wangaloa Beds.*

By Professor P. Marshall, M.A., D.Sc., Professor of Geology, Otago University.

[*Read before the Otago Institute, 5th December, 1916; received by Editors, 30th December, 1916; issued separately, 7th December, 1917.*]

Plates XXXIV–XXXVII.

In a paper dealing with the relations that exist between the Cretaceous and Tertiary rocks, published in the last volume of the *Transactions of the New Zealand Institute*, a list was given of the species of mollusca that had been found in the beds at Wangaloa (p. 114). Further collections have lately been made in the same beds, and these have added a few other species, and have also revealed better specimens of some of the species that had been previously found. Since this formation contains species of mollusca that suggest quite different geological ages, it has been thought advisable to write a fuller paper, giving descriptions of the species that are considered new, as well as illustrations of them.

I am indebted to many people for assistance in collecting and classifying the fossils—in particular to Mr. H. Suter, whose extensive knowledge of Recent and Tertiary species of New Zealand mollusca was liberally placed at my disposal. Much assistance was also given by the authorities of the National Museum at Melbourne. Mr. C. T. Trechmann also rendered me some aid. I am much indebted to Dr. T. W. Stanton, of the United States Geological Survey, for the comparison of some of the species with typical members of the Californian fossil mollusca. Several people have also given me much assistance in collecting.

The following list represents the results that have been obtained up to the present time, but it is certain that many additions will yet be made as the result of further collecting. It is, however, unfortunately the fact that it is hard to extract the fossils in a satisfactory state of preservation from the resistant matrix in which they are embedded: *Nucleopsis major* n. sp., *A. semispiralis* n. sp., *A. subovalis* n. sp., *Ampullina spiralis* n. sp., *Architectonica inornata* n. sp., *Avellana curta* Marshall, *A. paucistriata* Marshall, *Chione* sp., *Cominella sublurida* n. sp., *Corbula zelandica* Q. & G., *Cucullaea alta* Sowerby, *Cylichnella enysi* Hutton, *Daphnella multicincta* n. sp., *D. ovata* n. sp., *Dentalium mantelli* Zittel, *D. pareoraense* Suter, *Dosinia greyi* Zittel, *Drillia awamoaensis* Hutton, *Epitonium parvicostata* n. sp., *E. simplex* n. sp., *Gibbula* n. sp. (near *G. strangei* A. Ad.), *Glycymeris convexa* n. sp., *Haminea cingulata* n. sp., *Heliacus conicus* n. sp., *Heteroterma zelandica* n. sp., *Latirus (Mazzalina) longirostris* n. sp., *Tudicula sulcata* n. sp., *Limopis aurita* Brocchi, *Mactra crassa* Hutton ?, *Malletia elongata* n. sp., *Minolia* sp., *Natica australis* Hutton, *Niso neozelanica* Suter. *Nucula sagittata* Suter, *Omalaxis planus* n. sp., *Panopea orbita* Hutton, *Perissolax obtusa* n. sp., *Phos conicus* n. sp., *P. ordinarius* n. sp., *Polinices gibbosus* Hutton, *Protocardia pulchella* Gray, *Pugnellus australis* Marshall, *Pupa* n. sp., *Roxania* n. sp., *Siphonalia compacta* Suter ?, *Struthiolaria fruzeri* Hutton, *S. minor* n. sp., *S. (Pelicaria)* n. sp., *Surcula fusiformis* Hutton, *Teredo heaphyi* Zittel, *Turris multicincta* n. sp., *T. striatus* n. sp., *T.* sp. ind., *Turritella semiconcava* Suter, *T. symmetrica* Hutton, *Venericardia difficilis* Desh., *V. patagonica* Sowerby, *V. zelandica* Desh. ?

**Scala (Epitonium) parvicostata** n. sp. (Plate XXXIV, fig. 3.)

Shell of moderate size, 20 mm. by 7 mm., elongated and turreted. Sculpture consisting of numerous low axial ribs extending from suture to suture in each whorl. About 22 axial ribs in each whorl: these are crossed by about 20 spiral striae: these striae are continued on the base. Spire elongated: 5 whorls only showing in the specimen; whorls convex and suture deeply impressed. Aperture suborbicular. Umbilicus covered with a growth of the peristome.

One specimen only, in a moderate condition of preservation. Type in the Otago Museum.

This specimen was doubtfully classed by Suter as *Bittium*.

**Scala (Epitonium) simplex** n. sp. (Plate XXXIV, figs. 1, 2.)

Shell small, 12 mm. by 4 mm., turreted. Sculpture consisting of numerous broad rounded axial ribs: these are continuous over the whorls, and there are about 18 on each whorl. Spiral lines about 5 on each whorl, crossing the costae and interstices without interruption; the spiral lines are much more numerous on the body-whorl. Spire of 7 whorls, each whorl strongly convex. Suture deeply impressed. Aperture suborbicular; peristome thick on the inner lip. Protoconch of 3 smooth whorls.

This species was provisionally classed by Suter as *Cerithiopsis*, but more perfect specimens showing the aperture cause me to place it here.

The genus extends from the Jurassic to the present day.

**Struthiolaria minor** n. sp. (Plate XXXIV, figs. 12, 13.)

Shell small, 18 mm. by 10 mm., oblong in shape with a subtruncate base. Sculpture consisting of vertical costae and spiral grooves. Costae 16 in each whorl, extending almost from suture to suture, and bent slightly backwards into a shallow crescent. Spiral threads sharp, 10 in the penultimate whorl, 8 in the whorl above it; the threads pass over the costae without any interruption. Body-whorl with a large shallow groove in the middle, thus forming two carinae; the costae stop at the upper end of this groove, but the spiral threads are continuous to the end of the canal. Spire of 5 whorls, each shouldered; suture impressed but not canaliculate. Aperture with a thick inner lip, the callosity covering part of the base.

Several specimens, in a moderate state of preservation. Type in the Otago Museum.

In size this species closely resembles *S. parva* of Hutton, but it is more elongated and the costae and spiral bands are more distinct. The genus *Struthiolaria* occurs in the Tertiary formations of Chile and Patagonia, but the age of these is uncertain. Wilckens regards them as Miocene. In the Cretaceous of those countries *Struthiolariopsis* occurs, but this genus is not admitted by Cossmann.

**Struthiolaria (Pelicaria)** sp.

A large specimen, 52 mm. by 45 mm. Shell nodulous and turreted with three carinae on the body-whorl. A very large callosity extends to the top of the spire. Not well enough preserved for a full description.

**Ampullina spiralis** n. sp. (Plate XXXIV, fig. 17.)

Shell of moderate size, 25 mm. by 20 mm., a larger specimen 25 mm. wide. Shell subglobose, striated. Sculpture consisting of somewhat shallow spiral grooves with intervening flat ridges of irregular width; lines of growth numerous and thin, with an occasional thick one; a strong spiral groove just below the suture. Spire low, conoidal, consisting of 4 convex whorls. Body-whorls large in proportion, suture slightly impressed. Aperture nearly vertical, semilunar; outer lip thin; inner lip with some callus. Umbilicus distinct.

Three specimens, in moderate state of preservation. Type in the Otago Museum.

Suter remarks that this genus occurs in the Tertiary.

**Architectonica inornata** n. sp. (Plate XXXIV, fig. 9.)

Length, 6 mm. width, 13 mm.

Shell subdiscoidal. Whorls spirally unisulcate near the suture. Lines of growth conspicuous. Body-whorl with a prominent carina. One spiral ridge on the base a quarter of the distance from the carina to the umbilicus; 2 small spiral ridges above the carina; 2 others and a large rounded rib near the suture; the intervening distance between the upper and lower ridges with very fine spiral lines. Suture distinct but not strongly marked. Lines of growth numerous and distinct all over the body-whorl. Umbilicus large, its border much crenulated.

One specimen only. Type in the Otago Museum.

*Architectonica* is said by Suter to occur in the Tertiary. Cossmann, who uses Lamarck's name *Solarium* for this genus, mentions the occurrence of two doubtful species from the Eocene, one from the Oligocene, and a number from the Pliocene and subsequent periods.*

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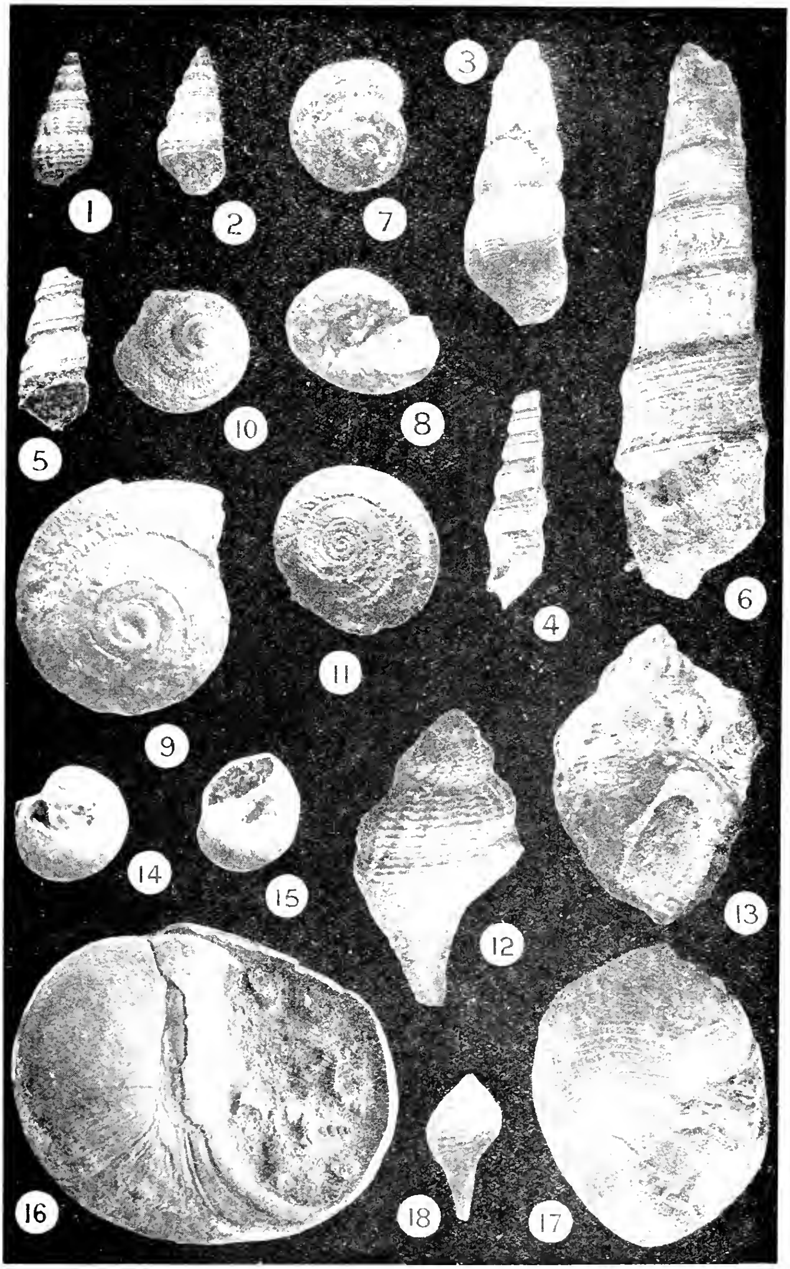
* *Ess. de Conch. comp.*, 1915, p. 165.




FIGS. 1, 2.—*Epitonium simplex* n. sp. 2½.
FIG. 3.—*Epitonium parvicostata* n. sp. 2½.
FIGS. 4, 5.—*Turritella symmetrica* Hutton. 2½.
FIG. 6.—*Turritella semiconcava* Suter. Nat. size.
FIGS. 7, 8.—*Gibbula* n. sp. 2½.
FIG. 9.—*Architectonica inornata* n. sp. 2½.
FIG. 10.—*Heliacus conicus* n. sp. 2½.
FIG. 11.—*Omalaxis planus* n. sp. 2½.
FIGS. 12, 13.—*Struthiolaria minor* n. sp. 2½.
FIGS. 14, 15.—*Natica australis* Hutton. 2½.
FIG. 16.—*Polinices gibbosus* Hutton. Nat. size.
FIG. 17.—*Ampullina spiralis* n. sp. Nat. size.
FIG. 18.—*Latirus (Mazzalina) longirostris* n. sp. 2½.

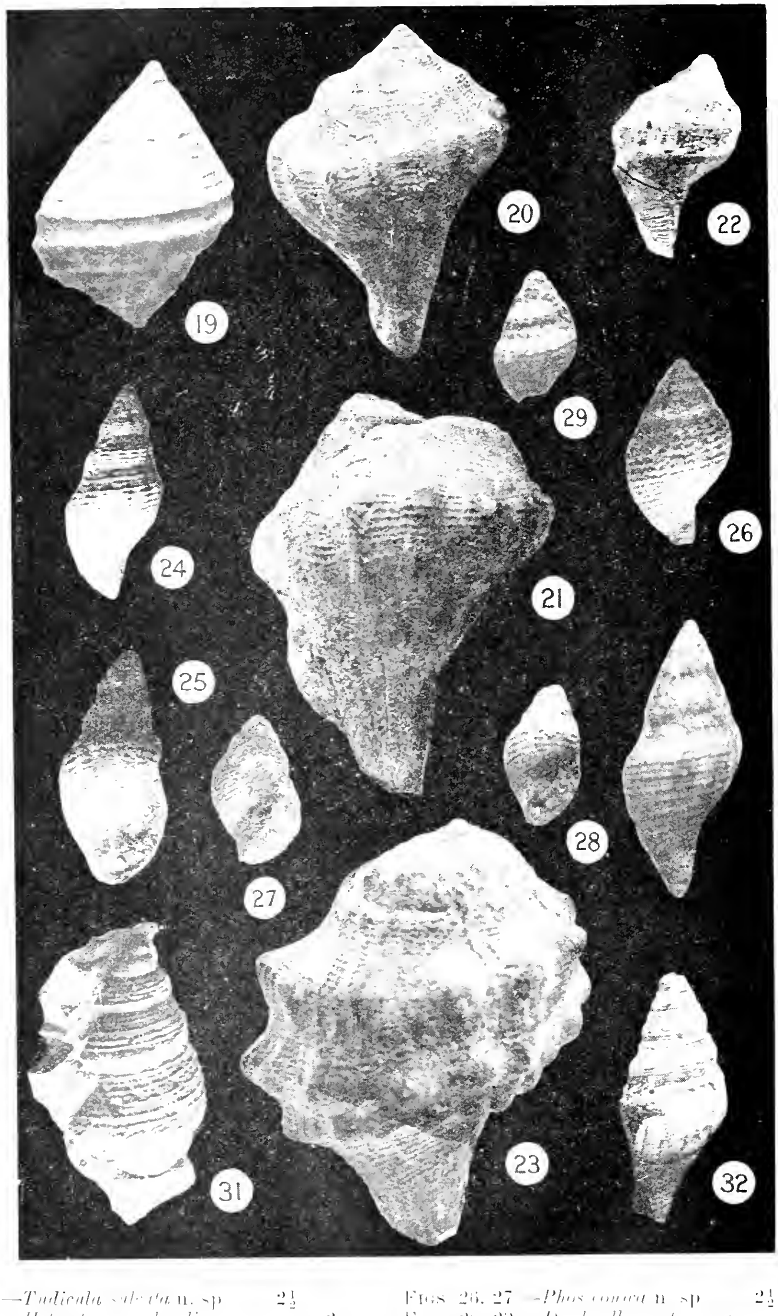



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FIG. 19.—*Tudicula selecta* n. sp. 2½.
FIG. 20.—*Heterotoma zelandica* n. sp. 2.
FIG. 21.—*Heterotoma zelandica* n. sp. Nat. size.
FIG. 22.—*Perissolax obtusa* n. sp. 2.
FIG. 23.—*Perissolax obtusa* n. sp. 2½.
FIGS. 24, 25.—*Phos ordinarius* n. sp. 2.
FIGS. 26, 27.—*Phos conica* n. sp. 2½.
FIGS. 28, 29.—*Daphnella ovata* n. sp. 2½.
FIG. 30.—*Daphnella multicincta* n. sp. 2½.
FIG. 31.—*Turris striatus* n. sp. 2.
FIG. 32.—*Turris multicinctus* n. sp. 2.

**Heliacus conicus** n. sp. (Plate XXXIV, fig. 10.)

Shell small, conical, 7 mm. by 7 mm. Sculpture consisting primarily of 3 prominent cinguli on each whorl: the highest is close to the suture, and is distinctly beaded; the middle cingulus is the widest, but it is less distinctly beaded; there are 4 or 5 other cinguli less marked and less beaded. Base with numerous cinguli cut up by fine oblique radiate sulci. Umbilicus moderate, margined by a stout and crenulate cord. Spire moderate, conical, higher than the aperture. Outline of whorls convex, suture impressed. Whorls 5. Protoconch of 2 small whorls. Aperture not distinct.

One specimen only, in a good state of preservation. Type in the Otago Museum.

Two fossil species of this genus have hitherto been found in New Zealand. They occur in the Target Gully beds, near Oamaru, and the genus is also Recent. Suter states that the genus is of Tertiary occurrence.

**Omalaxis planus** n. sp. (Plate XXXIV, fig. 11.)

Shell discoid, small, 10 mm. by 3 mm. Spire of 5 whorls, almost flat, but body-whorl slightly concave. Suture much impressed, almost canaliculate. Upper whorls with a smooth surface; body-whorl with 2 moderate carinae round the periphery. A strongly beaded line surrounds the suture. From the beads small elevated lines with a curved form extend across the greater part of the body-whorl. Umbilicus large, surrounded by a prominent crenulated margin.

A single specimen, well preserved. Type in the Otago Museum.

*Omalaxis* has not previously been obtained in the fossil state in New Zealand. The genus appears to be restricted to the Tertiary period.

**Heteroterma zelandica** n. sp. (Plate XXXV, figs. 20, 21.)

Small complete specimen, 15 mm. by 8 mm.; larger specimen, nearly complete, 24 mm. by 17 mm.; large specimen, 44 mm. broad. Shell large, shortly fusiform. Spire very short. Each whorl with spiral ridges; those on the whorl next to the body-whorl 7 in number; interspaces about three times as wide as the ridges, with a faint discontinuous median ridge. Body-whorl large, somewhat angulated above the middle, abruptly contracted into the beak below; shape above the middle slightly concave; surface marked by fine lines of growth and with 10 large spiral ridges one-third the width of the interspaces, which have a fine median ridge; middle of body-whorl with 14 short prominent longitudinal plications; base of the shell and the beak marked with spiral lines similar to those on the rest of the body-whorl. Anterior canal long; the curved lines of growth indicate a shallow posterior sinus of the aperture.

In the list of the Wangaloa mollusca published last year this species was classed by Suter as *Euthriofusus* n. sp. (*Trans. N.Z. Inst.*, vol. 48, p. 115). The great similarity between these specimens and those of *Heteroterma gabbi*, described and figured by Stanton (*17th Ann. Rep. U.S. Geol. Surv.*, 1895–96, Part I, p. 1046), caused me to forward my specimens to him with the request that he would compare them with the Californian species. This he has kindly done, and he has sent me some critical notes of great value, which it is advisable to quote:—

"After comparing the specimens I agree with you that your fossils are similar to *Heteroterma gabbi* Stanton, though I think there can be no question that they are specifically distinct. I would comment on them as follows:

Has almost exactly the same form as *H. gabbi*, and the same general type of sculpture, but the spiral lines are much more numerous and more nearly of uniform size over the entire surface. While specifically distinct, it seems to me certainly congeneric with H. *gabbi* and *H. trochoidea*, the latter being the type of the genus *Heteroterma*, which Gabb described in *Palaeontology of California*, vol. 2, p. 151, 1869. This genus seems to me to have escaped mention in the manuals and text-books, and so far as I know has had no authoritative treatment since the time of Gabb, who referred it to the Pleurotomidae."

Cossmann remarks on this genus (*Essais de Paléoconchologie comparée*, 4e livraison, p. 69), "Peut-être est ce dans ce dernier Genre (*Tudicula*) qu'il y a lieu de placer *Heteroterma* Gabb qui, ainsi que j'ai indiqué dans le 3e livraison de ces Essais ne paraît pas bien classé dans la famille Pleurotomidae. La coquille a une forme de *Tudicula* mais l'auteur indique l'existence d'une échrancure à la suture. En definitive cette question demande à être revisée." Cossmann* also places *Pyropsis* Conrad in this genus *Tudicula*. Species of *Pyropsis* are mentioned by Wilckens from the Quiriquina beds of Chile and from south Patagonia. Wilckens lays emphasis on the Cretaceous age of this genus. I am informed by Dr. Stanton that *Heteroterma gabbi* comes from the Martinez beds, which constitute the oldest Eocene formation of California.

Four specimens. Type in the Otago Museum.

**Perissolax obtusa** n. sp. (Plate XXXV, figs. 22, 23.)

Small complete specimen, 17 mm. by 8 mm; another specimen, nearly complete, 55 mm. by 30 mm. Shell of moderate size, with four rapidly increasing whorls somewhat shouldered. Upper whorls nearly smooth, though the last whorl is ornamented with rounded tubercles, about 12 to the whorl. Body-whorl large, with 3 distinct carinae, each of which bears a row of rounded tubercles—the upper 9, the middle 11, and the lowest 13 in number: those on the anterior carina are smaller than the others. Thus the tubercles do not occur in distinct vertical rows, as they frequently do in this genus. Suture markedly undulating. Spire with no ornamentation other than the tubercles. Body-whorl with a number of spiral lines: 12 of these lie between the suture and the upper row of tubercles, 13 between the first two rows, and 8 lines between the second and third rows of tubercles: these spiral lines are continued on the side of the anterior canal, where they become larger and somewhat more oblique. Canal moderately long and slightly bent inwards in the middle.

Type in the Otago Museum.

In the list of the Wangaloa fauna that was published last year this species was classed under *Euthriofusus* n. sp., but as it was apparent that there was an extremely close relationship between this species and *Perissolax brevirostris* Gabb a specimen was sent to Dr. Stanton. He has been good enough to examine the specimen, and has sent me the following critical remarks:—

"This species is apparently congeneric with *Perissolax brevirostris* Gabb, which it resembles in general form and style of sculpture; but it is somewhat shorter, and differs in all details of sculpture. The spiral lines are

* In a letter just received Cossmann says, "J'ai examiné *Heteroterma* qui me semble bien déterminé génériquement."

more numerous and more nearly equal, and the tubercles are relatively larger, borne on more widely separated spiral carinae, and are not arranged on definite vertical costae. The canal in both this species and *P. brevirostris* is shorter than in typical forms of *Perissolax*. Fischer treats *Perissolax* as a subgenus under *Tudicula*."

Dr. Stanton further says that *P. brevirostris* is found in the Chico formation, of Cretaceous age, and this is separated by an unconformity from the Martinez formation, of Lowest Eocene age, in which *Heteroterma gabbi* is found.

Cossmann says of the genus *Perissolax* (*loc. cit.*, p. 72), "Bien que je sois persuadé que ce sous-genre est bien réalité identique à *Pyropsis*—c'est a dire, à *Tudicula*—et que les differences signalées sont due à l'état de conservation de ces fossiles crétaciques, je conserve provisoirement *Perissolax*, qui ne m'est connu que par des figures, probablement inexactes ou restaurées d'après les moules ou des contre-empreintes."*

**Tudicula sulcata** n. sp. (Plate XXXV, fig. 19.)

Shell small, 17 mm. by 7 mm. Shell piroidal with a short spire. The whorls of the spire are almost flat, with impressed sutures but without distinct sculpture. Body-whorl large, with a large anterior canal longer than the spire. Carina with a prominent ridge, with a somewhat smaller one on either side. Five smaller spiral ridges between these and the suture. Other similar but smaller ridges on the anterior canal. Outer lip thin. Inner lip with a thin callus.

Several specimens, but only one of them shows the beak complete. Type in the Otago Museum.

This species was first placed by Mr. Suter in the genus *Latirus* (*Mazzalina*), but a more perfect specimen caused him to classify it with *Tudicula*.

**Latirus (Mazzalina) longirostris** n. sp. (Plate XXXIV, fig. 18.)

Shell small, 8 mm. by 5 mm., piroidal with a long anterior canal. Spire short, consisting of 4 whorls, which have a smooth surface. Suture distinct, impressed. Body-whorl large, marked with 10 prominent spiral striae about as broad as the intervening grooves; similar striations extend to the end of the anterior canal, which is long and straight. Outer lip thin. Inner lip covered with a thin callus.

Several specimens, in moderate condition. Type in the Otago Museum.

The genus extends from the Cretaceous to the present day. I am indebted to Mr. Suter for the reference of this species to the genus. Better specimens, however, make it probable that a change will have to be made.

**Cominella sublurida** n. sp. (Plate XXXVI, fig. 33.)

Shell moderate size, 26 mm. high and 13 mm. wide. Shape ovate, spirally lirate and axially costate. Sculpture consisting of flat spiral lirae of unequal size with linear interspaces. Axial costae present on all the whorls, extending from the angle of the shoulder to the suture-line in front, but

* Cossmann in a letter makes the same remark on this species as on *Heteroterma zelandica*. In a recent publication Roy E. Dickerson records species of *Perissolax* from the Martinez (Lower Eocene) and from the Tejon (Upper Eocene) of California. (R. E. DICKERSON, Fauna of the Martinez Eocene of California, *Bull. Dep. Geol. Univ. Cal.*, vol. 8, No. 6, 1914, p. 110; Stratigraphy and Fauna of the Tejon Eocene of California, *Bull. Dep. Geol. Univ. Cal.*, vol. 9, No. 17, 1916, p. 451.)

nearly effaced on the upper part of each whorl. Spire elevated, conical, about equal in height to the length of the aperture. Whorls 5; outlines slightly convex, but slightly concave above the angle of each whorl. Suture distinct. Aperture subvertical, oval.

One specimen. Type in the Otago Museum.

This species closely resembles the Recent species *C. lurida*, but its costae continue farther forward and are less numerous—9 in a whorl in place of 12.

Cossmann records no species from any horizon below the Palaeocene, but Wilckens describes a species from the Upper Cretaceous of south Patagonia.

**Phos ordinarius** n. sp. (Plate XXXV, figs. 24, 25.)

Shell of moderate size, 17 mm. by 7 mm., turriculate, axially costate and spirally striate. Spire of 4 whorls, each strongly convex, and show costae and striae. The costae are continuous from suture to suture, but they are far more pronounced near the middle of each whorl than near either septum. Eighteen costae on the body-whorl; costae crossed by numerous spiral threads about as wide as the intervals between them. Spire longer than aperture. Suture not deep. Aperture slightly oblique, with a short broad canal which is turned slightly to the left. Columella with a slight anterior fold.

Suter remarks that this species closely resembles *P. tenuicostatus* Ten.-Woods, which is a Recent species.

The genus *Phos* has a wide distribution. It appears to be restricted to the Tertiary. Cossmann mentions a Tasmanian species from the Eocene, but according to the latest researches the actual horizon seems to correspond with the Oligocene. In Europe the genus makes its first appearance in the Eocene.

Several specimens. Type in the Otago Museum.

**Phos conica** n. sp. (Plate XXXV, figs. 26, 27.)

Shell small, 10 mm. by 5 mm., oval, vertically costate and spirally lirate. Costae not prominent: about 17 on each whorl, extending from the anterior suture of each whorl almost to the posterior one. Spiral ribs rather wider than the grooves and moderately sharp. Seven of the spiral lirae on the penultimate and 18 on the body-whorl. Spire composed of 4 whorls, rather short, conical, but whorls rather convex. Suture impressed. Aperture oval; anterior canal slightly bent to the left.

Several specimens, in a moderately good state of preservation. Type in the Otago Museum.

**Turris multicinctus**, n. sp. (Plate XXXV, fig. 32.)

Shell small, turriculate, nodulous. Spire long. Sculpture: a large number of spiral cinguli, amounting to 15 or 20, in the lower whorls; the cinguli are rounded, and about equal in size to the intervening grooves. Nodulous costae 10 in number on each whorl; the size of the costae diminishes at a point about a quarter of the length of the whorl below the upper suture, then greatly increases to the middle of the whorl, and diminishes again to the lower suture. Growth-lines distinct on the body-whorl: they are bent backwards, with the apex of the bend on the nodulous projection of the costae. Canal not complete.

One specimen. Type in the Otago Museum.

**Turris striatus** n. sp. (Plate XXXV, fig. 31.)

Shell of moderate size, 20 mm. high. 11 mm. wide. Spire with 4 whorls, each with a prominent carina near the posterior border, giving the shell a turreted appearance. Each whorl with strong spiral ridges; on the penultimate whorl there are 7 of these behind the carina, and 3 small ones in front of it. The number of spiral lines is less on the upper whorls, and the highest whorl is almost smooth. The strong development of the growth-lines makes these spiral lines appear somewhat tuberculate. Body-whorl with prominent carina and spiral lines make this species quite distinct from other New Zealand Turritidae.

The only Eocene species mentioned by Cossmann comes from South Australia, and this horizon is now generally considered to be of later age. Dickerson has recently reported several species from the Eocene of California.

One specimen. Type in the Otago Museum.

**Daphnella multicincta** n. sp. (Plate XXXV, fig. 30.)

Shell small, 14 mm. by 5 mm., oval, biconical, distinctly spiralled. Sculpture consisting of blunted spiral ribs rather narrower than the intervening grooves, of which there are 25 on the body-whorl: these are crossed by numerous growth-lines. Whorls 5, gradually decreasing, slightly concave above. On the concave portion the spiral lines are much less distinct than elsewhere. Growth-lines bent backward on the concave portion. Suture well marked.

Several specimens, in good condition. Type in the Otago Museum.

Cossmann records one species from the Loire inférieure, of Eocene age. All other species are recorded from later horizons.

**Daphnella ovata** n. sp. (Plate XXXV, figs. 28, 29.)

Shell small, 8 mm. by 5 mm., but the majority of specimens are much smaller than this. Form ovate; vertically costate and spirally striate. Costae about 15 on a whorl, extending from suture to suture; the costae on the body-whorl extend to rather below the middle. Spiral striae rather flattened, about as wide as the grooves. There are 5 of these striae on the penultimate whorl, and about 20 on the body-whorl. Growth-lines are not noticeable. The posterior part of each whorl almost destitute of spiral lines. Spire consisting of 5 whorls, each convex, though the backward slope to the suture is slightly concave. Suture very distinct. Aperture oval; canal very short.

Three specimens, well preserved. Type in the Otago Museum.

**Acteon semispiralis** n. sp. (Plate XXXVI, figs. 35, 36.)

Shell oval, small, 10 mm. by 5 mm. Sculpture of well-formed spiral bands, 3 in number on the lower part of each whorl; on the body-whorl these are 17 in number, but they are absent from the portion between the suture and the rounded shoulder of the whorl. Interstices about the same width as the bands; no axial threads can be distinguished in the interstices. Spire conical, less than half the height of the shell. Whorls 5, each whorl distinctly angled above. Suture deep, canaliculate. Aperture narrowly oval. Columella with a large fold near the top.

Several specimens, fairly well preserved. Type in the Otago Museum.

The genus *Acteon* extends from the middle Cretaceous to the present day.

**Acteon subovalis** n. sp. (Plate XXXVI, fig. 37.)

Shell small, 9 mm. by 4 mm., narrowly oval. Sculpture consisting of several rounded spiral bands; interstices narrow except on the body-whorl, where they are as broad as the bands; 5 bands on the penultimate and 20 on the body whorl. The interstices between the spiral bands on the body-whorl are marked by exceedingly small cross-lines: these are somewhat oblique above, but are rectangular to the spiral bands in the middle of the whorl. Spire with 5 whorls. Suture deeply impressed or canaliculated. Columella with a prominent fold near the top.

Three specimens, in an indifferent state of preservation. Type in the Otago Museum.

**Nucleopsis major** n. sp. (Plate XXXVI, fig. 38.)

Shell small, 10 mm. by 7 mm., shortly oval or subturbinate. Sculpture, flat spiral bands with narrow interstices: there are 9 of these on the penultimate and 28 on the body whorl. No transverse striae can be seen in the narrow grooves. Spire short, turriculate, consisting of 5 whorls, each strongly shouldered. Suture canaliculate. Aperture oval; inner lip somewhat thickened, but no fold on the columella. Umbilicus large.

One specimen, in a good state of preservation. Type in the Otago Museum.

This genus has few representatives. This species is placed in it because there are no folds on the columella and the umbilicus is distinct. The genus appears to be restricted to the Eocene. Another shell recently found in this bed belonged to *Tornatellaea*.

**Haminea cingulata** n. sp. (Plate XXXVI, fig. 39.)

Shell of moderate size, nearly oval, 18 mm. high, 7 mm. wide. Sculpture consisting of flat grooves; spiral grooves about one-quarter of the width of the intervening flat ridges; the ridges are arranged spirally, about 30 to 35 in number, and are crossed by numerous growth-lines; the grooves become narrower towards the base; there are minor narrow grooves on the flat ridges—3 on the anterior, but decreasing to 1 only on the posterior ridges. Vertex imperforate: lip reflexed. Body-whorl oval, broadly rounded above, convex in the middle, and narrowly rounded below. Aperture as high as the shell, broad above and produced considerably above the vertex, but narrowed somewhat below. Outer lip thin, but thickened near the vertex. Middle nearly straight, slightly convex below.

The genus does not occur in strata below the Miocene.

The genus was kindly identified for me by Mr. Suter. The shell is certainly very similar to that of *Bulla*, and I am by no means satisfied that it is correctly placed.

Several specimens. Type in the Otago Museum.

**Malletia elongata** n. sp. (Plate XXXVI, fig. 41.)

Shell of moderate size, 28 mm. by 13 mm. Form elongated oval with a posterior extension; anterior end shorter than the posterior; dorsal surface slowly descending, then regularly rounded; basal margin rounded; posterior and anterior and dorsal margins of the valvea form a moderate keel. Sculpture consisting of about 40 equidistant rounded concentric ribs; the ribs are close together near the umbones, but farther down they become narrower than the intervening grooves.

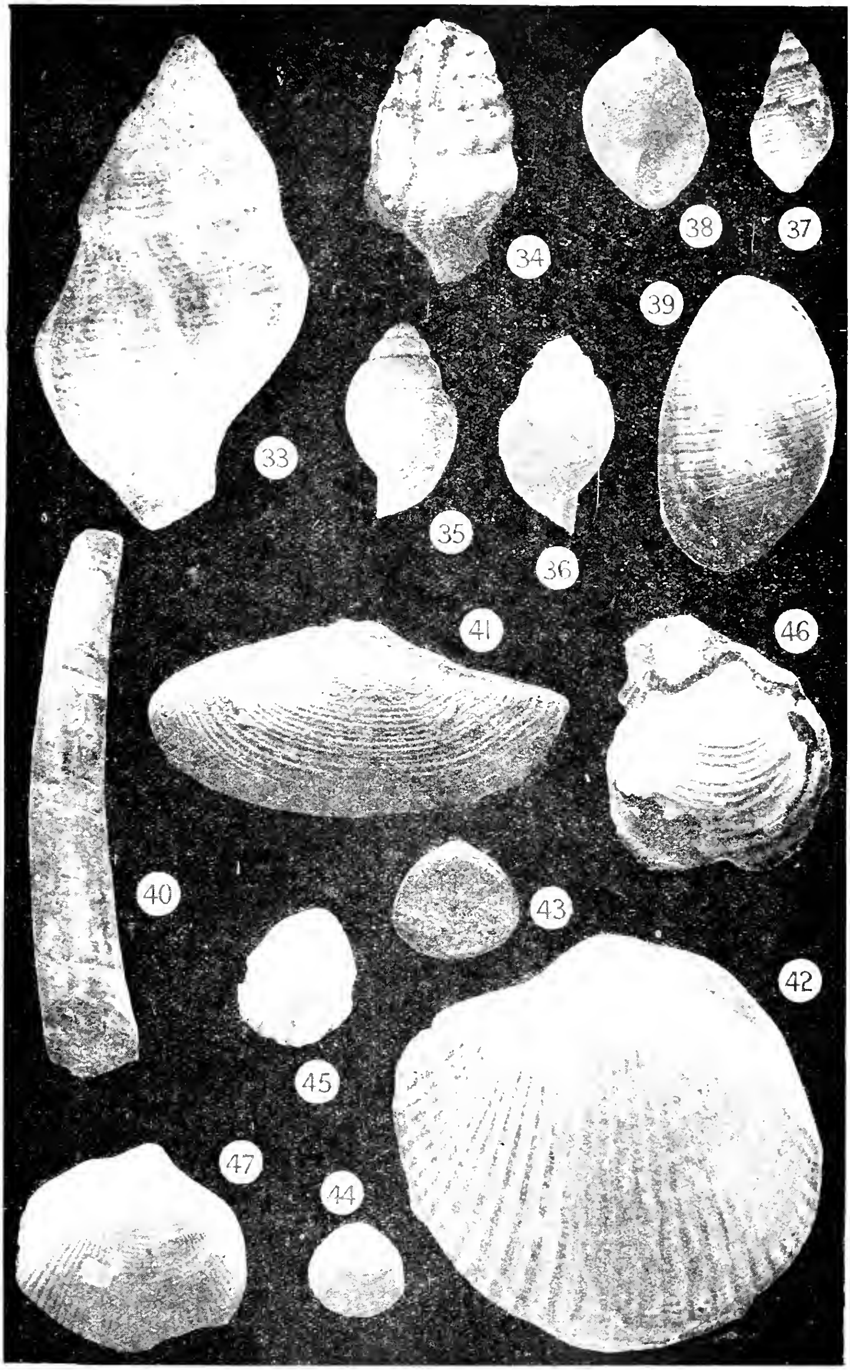


FIG. 33.—*Cominella sublurida* n. sp. 3.
FIG. 34.—*Surcula fusiformis* Hutton. 2
FIGS. 35, 36.—*Acteon semispiralis* n. sp. 2½.
FIG. 37.—*Acteon suboralis* n. sp. 2½
FIG. 38.—*Nucleopsis major* n. sp. 2½
FIG. 39.—*Taminea cingulata* n. sp. 2
FIG. 40.—*Dentalium pareoraense* Suter. 2½
FIG. 41.—*Malletia elongata* n. sp. 2.
FIG. 42.—*Glycymeris concava* n. sp. Nat. size
FIGS. 43, 44.—*Limopsis aurita* (juv.) Brocchi. 2½
FIG. 45.—*Venericardia zelandica* Desh. 2.
FIG. 46.—*Dosinia greyi* Zittel. Nat. size.
FIG. 47.—*Protocardia pulchella* Gray. 2½

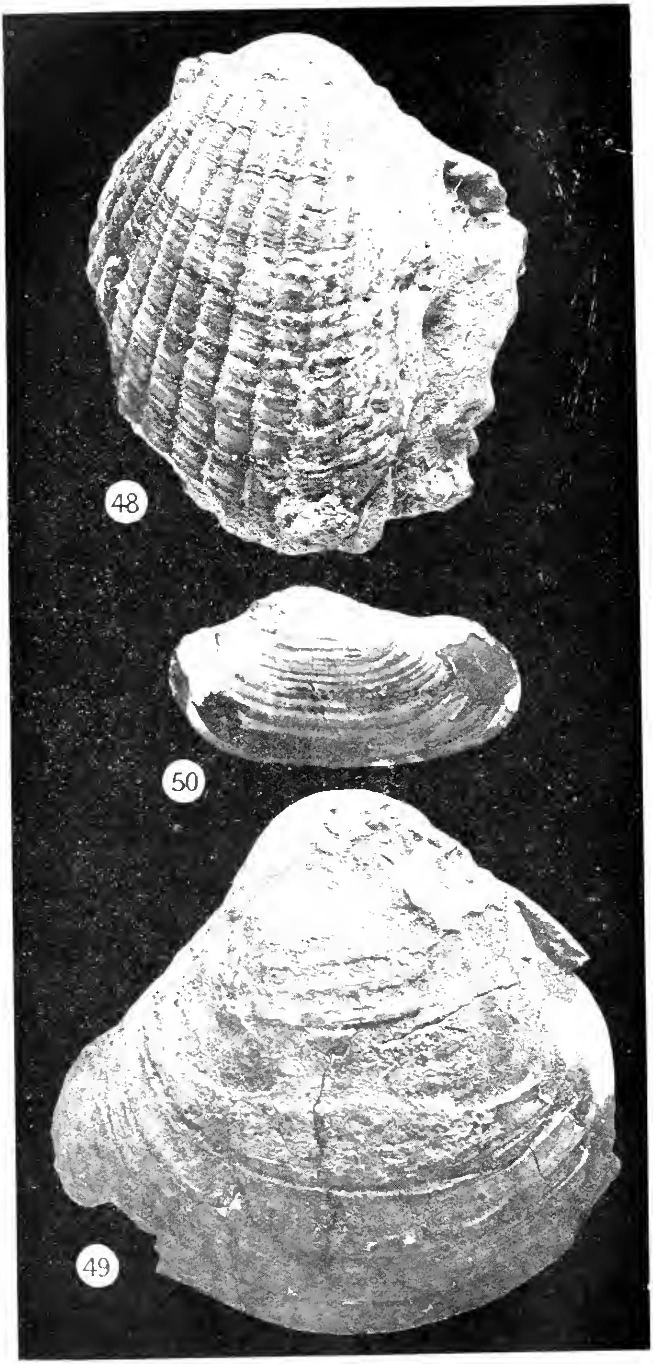


Fig. 48.—*Venericardia patagonica* Sowerby. Nat. size.
Fig. 49.—*Mactra crassa* Hutton? Nat. size.
Fig. 50.—*Panopea orbita* Zittel. Nat. size.

*Malletia* is commonly regarded as a Tertiary genus, but Wilckens records species from the Cretaceous of Quiriquina, Patagonia, and Seymour Island. Suter quotes von Ihering to the effect that the genus originated in South America in the Cretaceous and migrated to New Zealand in the Miocene.

The specimens are not in very good condition. The species is evidently closely related to *M. pencana* Wilckens, Phil. of Quiriquina.

Type in the Otago Museum.

**Glycymeris concava** n. sp. (Plate XXXVI, fig. 42.)

Shell attaining a large size: the largest measures 65 mm. by 65 mm. Shell thick and solid, strongly convex, almost equilateral, convex at both ends; beaks distant, strongly incurved; dorsal margin straight. Sculpture consists of rather sharply rounded radiating ribs, about 40 in number; they are continuous to the margin, but become rounder towards the ventral margin. Teeth somewhat oblique, apparently 10 on each side, 11 in large specimens. Ligamental area moderate, with few grooves. Growth-lines not well marked except near the margin.

Several specimens fairly complete. Type in the Otago Museum.

This species is very similar to an undescribed form from the Selwyn Rapids.

As thus classified the collection is obviously one of great interest. The species of *Pugnellus** and of *Perissolax* suggest that the age of the strata is Senonian, at the latest. *Heteroterma*, *Gilbertia*, and *Nucleopsis* are apparently restricted to the Lowest Eocene. The following genera are entirely of post-Eocene age: *Struthiolaria*, *Ampullina*, *Architectonica*, *Heliacus*, *Omalaxis*, *Phos*, *Daphnella*, *Drillia*, *Haminea*. In addition, *Cominella* has a single Cretaceous species in South America.

*Struthiolaria* and *Malletia* are of special interest, for both are supposed to have originated in South America in late Senonian or early Tertiary time, and to have subsequently migrated to New Zealand. It is now, however, clearly seen that they were in existence in New Zealand before some characteristic Cretaceous species had become extinct. The Cretaceous complexion of these beds is still more strongly maintained by the occurrence of belemnites at Brighton in beds that are admittedly of the same age as those at Wangaloa. Some years ago I sent some specimens of this belemnite to Wilckens for identification. He replied as follows: "I sent the fossils to Professor Stolley, of Brunswick, who has worked much on the belemnites. After examination he says as follows: 'The little belemnites from New Zealand do not allow of palaeontological nor stratigraphical determination. They belong to *Hibolites*, and can be from Upper Jurassic or Lower Cretaceous beds. It seems that older and younger beds are excluded.' Further, I had an opportunity of showing the belemnites to Professor Steinmann, of Bonn, and Professor Holzapfel, of Strassburg, who both said that an exact determination was impossible because of the bad preservation. They regarded it as a similar form to *Belemnites minimus* of the Chalk." Park had much the same experience with a specimen sent to Bather. Recently further specimens have been sent to Cossmann, who

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*Cossmann now states, "Or, en examinant bien les figures assez fidèles et en m'aidant des spécimens que leur auteur a bien voulu m'envoyer, je constate que *Pugnellus australis* appartient très probablement au genre *Struthiolaria*." (*Rev. Crit. de Paléozool.*, No. 2, 1917, p. 64.)

kindly informs me that he sent the specimens to the specialist M. Lissajous, who reports, "Les bêlemnites appartiennent au genre *Neohibolites* Stolley; elles sont assez voisines de *N. ewaldi* Straubeck, de l'Aptien, et appartiennent probablement au même niveau (c'est à dire, crétacé inférieure)."

Still further support for the Cretaceous age of these lower beds is found at Chatton, where Mr. R. A. Sutherland, M.Sc., has found a species of *Nerinaea* in a sandstone associated with the coal-beds. In that locality, as at Wangaloa, the Cretaceous genus is associated with a high proportion of well-known New Zealand Miocene species, some of which extend to the Recent fauna. Further, as stated elsewhere in this volume, at Hampden, eighty miles farther north, in beds rather higher in this series, there are again the Cretaceous genera *Trigonia, Avellana, Dicroloma,* or some other apporhaid, and *Volutoderma.*

This belemnite was first classed by Hector as *Belemnites lindsayi* (*N.Z. Geol. Sur. Rep. 1873–74,* p. xiii). Afterwards this name was treated by him as a synonym of *B. australis* Phillips (*Trans. N.Z. Inst.*, vol. 10, 1879, p. 487). Thus in closely associated strata of this region we have the following species belonging to typical Cretaceous genera: *Belemnites lindsayi* Hector, *Pugnellus australis* Marshall, *Nerinaea* sp., *Dicroloma* sp., *Volutoderma*, sp., *Trigonia neozelanica* Suter, *Trigonia* n. sp., *Perissolax obtusa* Marshall. In addition, the following species are distinctly of Lower Eocene age—viz., *Gilbertia curta* Marshall, *G. paucistriata* Marshall, *G. tertiaria* Marshall, *Heteroterma zealandica* Marshall, *Nucleopsis major* Marshall, and *Belophos* n. sp.

M. Cossmann, the distinguished author of the *Essais de Paléochonchologie comparée,* has been good enough to examine specimens of *Pugnellus* and *Avellana.* He writes as follows: "Vos deux *Avellana,* de Wangaloa et Hampden, sont à la base du Tertiaire d'après mon opinion. Ce ne sont d'ailleurs pas des *Avellana* mais des *Gilbertia,* genre representé en Europe par une espèce paléocenique du bassin de Paris et peut-être aussi a Aix la Chapelle dans le Maistrichtien supérieur. Quant a *Pugnellus australis,* la couche dont il provient doit être au dessous de celle à *Gilbertia*—c'est à dire, dans le crétacé très supérieur."

In the three localities here mentioned—Wangaloa, Chatton, and Hampden—the well-known Tertiary species *Cucullaea alta* and *Bullinella enysi* occur, and in each of the localities there are a large number of other Tertiary species that have a wide occurrence in New Zealand, such as *Dentalium solidum, Siphonalia nodosa, Bathytoma sulcata, Fulgoraria corrugata,* and *Epitonium rugulosum lyratum.* The occurrence of such species as these forbids us from placing these beds in a different geological system from others that contain the same forms but have no Cretaceous species. Such a separation is particularly inadvisable when the stratigraphical evidence is strongly against such separation, as has already been shown to be the case in connection with the younger rocks of New Zealand.

The age of the Wangaloa beds must obviously be very old Tertiary—perhaps even older. Mr. C. T. Trechmann, who collected them with me, thinks that the age should be regarded as Maestrichtian, or even Danian, but certainly higher than the Selwyn Rapids beds, which are of Senonian age. Further collecting and more complete identification of the fossils are necessary to finally settle this point.

## ART. XXXVIII.—*Additional Fossils from Target Gully, near Oamaru.*

By Professor P. MARSHALL, M.A., D.Sc., Professor of Geology, Otago University.

[*Read before the Otago Institute, 5th December, 1916; received by Editors, 30th December, 1916; issued separately 7th December, 1917.*]

IN a paper written in 1914 a list was given of all the species of Mollusca that had been found at Target Gully. The total number of species then obtained was 155. A number of additional species has been obtained since then, of which the following is a list :—

*Subemarginula intermedia* Reeve.
*Trochus chathamensis* Hutton.
*Heliacus variegatus* Gmelin.
*Circulus helicoides* Hutton.
*Triphora lutea* Suter.
*Seila bulbosa* Suter.
*Anachis pisaniopsis* Hutton.
*Ampullina carinata* Hutton.
*Natica australis* Hutton.
*Epitonium zelebori* Dunker.
*Turbonilla prisca* Suter.
*Eulima obliqua* Hutton.
*Rissoina emarginula* Hutton.
*Fusinus climacotus* Suter.
*Megalatractus maximus* Tryon.
*Vexillum fenestratum* Suter.
*Vexillum marginatum* Hutton.
*Siphonalia caudata* Q. & G.
*Euthria callimorpha* Suter.
*Cominella ordinatis* Hutton.
*Ancilla papillata* Tate.
*Marginella fraudulenta* Suter.
*Erato neozelanica* Suter.
*Drillia costifer* Suter.
*Surcula pareoraensis* Suter.
*Bathytoma albula* Hutton.
*Turris regius* Suter ?
*Mangilia pukeurensis* Suter.
*Mangilia praecophinodes* Suter.
*Mangilia dictyota* Hutton.
*Mangilia gracilicostata* Suter.
*Hemiconus ornatus* Hutton.

The *Trivia* n. sp. mentioned in previous lists is *T. avellanoides* Tate. *Mitra* n. sp. is *M. armorica* Suter. There is also a new variety of *Venericardia intermedia.*

There are also new species of the following genera :—

*Vermicularia.*
*Marginella.*
*Besanconia.*
*Tornatina.*
*Sveltia.*
*Basilissa.*
*Eglisia.*
*Cyclostrema.*
*Eulima* (two n. sp.).
*Rissoina.*
*Merica.*
*Drillia.*
*Fusinus.*
*Latirus.*
*Surcula.*
*Chione.*
*Streptochetus.*
*Phos.*
*Odostomia* (two n. sp.).
*Cuna.*
*Barnea.*
*Loripes.*
*Calyptraea maculata* (Q. & G.) n. var.

These make an additional 57 species, which added to my previous list of 155 species makes a grand total of 212. In addition Professor Park has found several species, which raises the total to 220, of which 72 species are Recent—that is, 30·3 per cent.

This collection is of special interest, for it is the first time that the small species have been collected in beds of such a low Tertiary horizon in New Zealand. Hutton has stated that the Pliocene is distinguished from the Miocene in New Zealand by the presence of the following genera : *Trophon, Columbella* (*Anachis*), *Turricula* (*Vexillum*), and *Mytillicardia* (*Cardita*).*

* *Macleay Mem. Vol. Linn. Soc. N.S.W.*, 1893, p. 35.

All of these genera, however, have now been found in rocks admitted to be of Miocene age.

In general it appears that, apart from purely littoral forms, of which we have comparatively few fossils, there have been no important generic additions to our molluscan fauna since early Tertiary times. The collection of over two hundred species from the small bed at Target Gully suggests that mollusca were more abundant in New Zealand waters in this Miocene period than at the present time, and that generically the fauna was much richer.

Specimens of some seventy-five of the Target Gully species were sent to M. Maurice Cossmann, the distinguished palaeoconchologist, of Paris. He has been good enough to examine the shells, and has forwarded the following notes :—

" *Limopsis aurita* (non Brocchi), elle est plus trigone, plus gouflée, la charnière est plus épaisse avec les dents plus grosses. Il faut reprendre le nom *zealandica* Hutton.

" *Cytherea meridionalis* aucun rapport avec *Chione meridionalis* du Pliocène, il faut reprendre le nom *vellicata* Hutton.

" *Chione oblonga* de Target Gully est également differente de *C. oblonga* Hanley, du Pliocène ; je propose *C. suboblonga* Cossm.

" *Chione mesodesma* de Target Gully n'a de même aucune analogie de forme, d'ornamentation ni de charnière avec celle du Pliocène, je propose donc *C. marshalli* Cossm.

" Ces trois espéces sont du reste des *Ventricoloidea* Sacco (v. le vol. i de ma *Conchol. néog. de l'Aquitaine*).

" *Turbonilla oamarutica* probablement *Acissella*.

" *Latirus acuticingulatus* et *L. compactus* sont des *Tritonidea*.

" *Latirus brevirostris* probablement *Leucozonia* ou un nouveau genre.

" *Mangilia canaliculata* est un *Ptychatractus*.

" *Mangilia nodosolirata* est une *Bela* (*Buchozia*).

" Les deux *Cylichnella* sont des *Bullinella*.

" *Leptothyra fluctuata* est un *Tiburnus*.

" *Admete praecursoria* est un *Actaeon*."

A copy of these notes was sent to Mr. Suter, who in reply wrote to me as follows : " With regard to *Cytherea oblonga* and *Chione meridionalis* and *C. mesodesma* I do not agree with Cossmann." It is thus evident that a good deal of latitude must be allowed for personal opinion, and a corresponding difference in the percentage of Recent species in a collection classified by two different authorities.

The following general remark is made by M. Cossmann about the Target Gully bed : " Le gisement de Target Gully, près Oamaru, me semble bien se rapporter a l'époque miocènique, et je crois que les espéces de le niveau sont bien distinctes de celles des mers actuelles aussi bien que de Pliocène. Aucune ne m'a semble pareille a celles du Miocène d'Australie que je possède."

M. Cossmann makes frequent reference to the replacing of Lamarck's names by those of Bolten, and maintains that this is unnecessary and inadvisable. While fully sympathizing with him in this view, it is advisable in this country to use Bolten's names so far as Recent genera are concerned as they have been adopted, in Suter's *Manual of the New Zealand Mollusca*.

# ART. XXXIX.—*Fossils and Age of the Hampden (Onekakara) Beds.*

By Professor P. MARSHALL, M.A., D.Sc., Professor of Geology, Otago University.

[*Read before the Otago Institute 5th December, 1916; received by Editors, 30th December, 1916; issued separately, 7th December, 1917.*]

A PRELIMINARY reference to the Hampden beds was made by me last year.* At that time the collections that had been made had not been fully worked out. and the following species only were recorded : *Avellana tertiaria* Marshall, *Surcula hamiltoni* Suter, and *Trigonia* n. sp. A specimen of the *Avellana* has since been sent to M. M. Cossmann, of Paris, but he identifies the species as belonging to the closely allied genus *Gilbertia*, which is restricted to the Palaeocene.

That these beds of the Onekakara Beach, three miles north of Hampden, were fossiliferous was known long ago. Mantell made the first collection in 1849, and published the results in the *Quarterly Journal of the Geological Society*.† He classed the beds as Pleistocene or newer Tertiary. Twelve species of Mollusca are listed, but this list is now of little value.

Hutton in 1875‡ placed the beds in the Miocene formation. He gives a list of twenty-one species of Mollusca, but possibly some of these come from neighbouring localities. In 1887 he gave a more detailed description of the locality.§ A section shows the exact spot at which fossils are found. He obtained specimens of fourteen species of Mollusca, of which three species are Recent.

McKay in 1884 classed the beds as Cretaceo-Tertiary, but gave no list of fossils.‖ He suggests that Recent species that had been placed in other lists had been embedded in the strata as a result of slipping of overlying formations. McKay further discussed the position of these beds in 1887.¶ Again they are classed as Cretaceo-Tertiary, but it is stated that no exact list of the species can be given.

Park in 1905 classed the formation as Miocene.** He gave a list of twenty-three species of Mollusca, with a percentage of 41·5 per cent. of Recent species.

The actual rocks consist of argillaceous sands with much glauconite, in places becoming characteristic greensands. They have some concretions, both calcareous and pyritic. The fossils are poorly preserved, and are difficult to extract in a condition that admits of identification. Some four days altogether were spent in collecting.

McKay's†† statements as to the stratigraphy appear to be substantially correct. The fossiliferous beds rest directly on the strata that contain the well-known Moeraki concretions. These pass downwards into the concretionary but more sandy Kartigi beds, which in turn rest on the

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* *Trans. N.Z. Inst.*, vol. 48, 1916, p. 116.
† Vol. 6, 1850, p. 330.
‡ F. W. HUTTON and G. H. F. ULRICH, *Geology of Otago*, Dunedin, 1875, p. 57.
§ *Trans. N.Z. Inst.*, vol. 19, 1887, p. 426.
‖ *Rep. Geol. Explor. dur. 1883–84*, 1884, p. 62.
¶ *Rep. Geol. Explor. dur. 1886–87*, 1887, pp. 6, 238.
** *Trans. N.Z. Inst.*, vol. 37, 1905, p. 506.
†† *Loc. cit.*, 1887.

Shag Point conglomerates that contain the coal. The length of coast-line between the Onekakara beds and Shag Point is about twelve miles, but as it is generally parallel to the strike of the strata the actual thickness of strata exposed within this distance is small. Probably no more than 300 ft. separate these fossiliferous beds from the conglomerates at Shag Point. Above the fossil-bearing beds there are the volcanic tuffs and breccias called the Waireka tuffs, and these are sometimes associated with basaltic lava-flows. These in turn lie below the Oamaru (Ototara) limestone.

In identifying the Mollusca I am greatly indebted, as on previous occasions, to Mr. H. Suter, who kindly undertook the rather tedious task. The following is the list of species :—

*Aturia* sp.
*Circulus* n. sp.
*Cerithidea* n. sp.
*Cerithiella* n. sp.
*Turritella symmetrica* Hutton.
*Turritella ornata* Hutton.
*Turritella* n. sp. cf. *aldingae* Tate.
*Struthiolaria cincta* Hutton.
*Sinum* (*Eunaticina*) *elegans* Suter.
*Ampullina waihaoensis* Suter.
*Ampullina suturalis* Hutton.
*Erato* n. sp.
*Cymatium minimum* Hutton.
*Galeodea senex* Hutton.
*Epitonium rugulosum lyratum* Zittel.
*Epitonium* n. sp.
*Turbonilla* n. sp.
*Dicroloma ?*
*Fusinus solidus* Suter.
*Fusinus* n. sp.
*Exilia waihaoensis* Suter.
*Latirus* n. sp.
*Siphonalia nodosa* Martyn.
*Siphonalia turrita* Suter.
*Belophos* n. sp.
*Volutoderma* n. sp.
*Cymbiola* (*Miomelon*) *corrugata* (Hutton).
*Ancilla novae-zelandiae* Sowerby.
*Marginella* n. sp.
*Turris duplex* Suter
*Turris nexilis bicarinatus* Suter.
*Turris complicatus* Suter.
*Turris complicatus* nov. var.
*Turris regius* Suter.
*Turris* n. sp. cf. *neglectus* and *regius.*
*Turris* n. sp. cf. *neglectus.*
*Surcula hamiltoni* Hutton.
*Surcula serotina* Suter.
*Surcula* n. sp.
*Surcula* n. sp. cf. *pareoraensis.*
*Bathytoma sulcata* Hutton.
*Terebra costata* Hutton.
*Terebra* n. sp.
*Gilbertia tertiaria* Marshall.
*Bullinella cuysi* Hutton.
*Dentalium mantelli* Zittel.
*Malletia* n. sp.
*Cucullaea alta* Sowerby.
*Sarepta obolella* Tate.
*Sarepta* n. sp.
*Arca novae-zelandiae* Smith.
*Arca* (*Bathyarca*) n. sp.
*Limopsis zitelli* Ihering.
*Trigonia* n. sp.
*Lima angulata* Sowerby.
*Atrina* sp.
*Ostrea wuellerstorfi* Zittel ?
*Cardium* sp.
*Cardium* (*Papyridea*) sp.
*Pecten huttoni* Park.

There are thus altogether sixty species, of which the following six are Recent: *Turritella symmetrica* Hutton, *Siphonalia nodosa* Martyn, *Ancilla novae-zelandiae* Sowerby, *Sarepta obolella* Tate, *Arca novae-zelandiae* Smith, *Lima angulata* Sowerby. It thus appears that no more than 10 per cent. of these sixty species are Recent—a very low result when compared with those obtained by previous collectors. The following show Mesozoic affinities: *Volutoderma*, *Dicroloma*, *Trigonia* n. sp. The specimens referred to *Dicroloma* are not well preserved. The species is certainly an Aporrhaid, but not *Aporrhais* or *Hemichenopus.* To these must be added *Trigonia neozelanica* Suter, which was collected by Hutton.

The following genera have been recorded from the Eocene only in those countries in which they occur: *Gilbertia, Belophos. Surcula hamiltoni* Suter and *Exilia waihaoensis* Suter have not been found above the limestone member of the Oamaru system. On the other hand, the genus *Turris* (*Pleurotoma* Lamarck), which is particularly well represented in this collection, is a Miocene genus with the single exception of one Australian species of supposed Eocene age; but there appears to be great doubt as to whether any of the Australian Tertiary formations are really older than the Oligocene, and by far the greater part of them are considered to be of Miocene age by Chapman. The genus *Terebra*, again, has no species in strata higher than the Miocene except in the doubtful horizons of Australia. No species of the genus *Erato* have yet been recorded from any formation below the Oligocene. *Struthiolaria* has not been found below the Miocene, though *Struthiolariopsis* has been found by Wilckens in the Cretaceous of South America. The same is true of *Malletia.*

Another point of importance is the absence of genera which are usually abundant in the Tertiary formations of New Zealand. Amongst these are *Venericardia, Crassatellites, Alectrion, Calyptraea*, and *Crepidula*. With the exception of *Venericardia* all of these genera are absent also from the beds of Wangaloa. In addition there is the low percentage of Recent species. Too much importance should not be attached to this, for the Onekakara material was deposited in water of considerable depth, and our knowledge of the Recent New Zealand Mollusca from any zone but the littoral is still extremely imperfect.

So far as New Zealand stratigraphy is concerned, it is probably correct to place the Onekakara beds as slightly higher than the Wangaloa horizon, though they are probably slightly older than the Chatton beds. It is extremely hard to suggest a European equivalent. The palaeontology of the Wangaloa, Onekakara, and Chatton beds strongly support the opinion that there is no geological break in the succession of the lower members of the Younger Rock series of New Zealand, elsewhere called by the author the Oamaru system. Even in these beds at Onekakara, where important Cretaceous and Eocene genera exist, there is still a great number of species that are common in the ordinary Tertiary beds of New Zealand, of which Target Gully can well be taken as a type. They also tend to show that the marginal terrigenous facies shows a variable age when different formations are compared. If the oldest sea-margin is represented in the beds of the Clarence Valley, as suggested by Thomson,* this margin appears to have extended southwards and westwards gradually. The following seems to be the approximate age of the basement beds in the different localities: Clarence Valley, Cenomanian; Amuri Bluff, Senonian; Waipara Gorge, Senonian; Wangaloa, Maestrichtian?;† Chatton, Oligocene?; Wharekuri, Miocene. These Onekakara beds seemed to be more rightly classed with the Eocene than with any other European system.

The large number of species of common occurrence in the higher Tertiary rocks of New Zealand which occur also in the basement beds of the Otago localities mentioned supports the belief that deposition was continuous in

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* *Trans. N.Z. Inst.*, vol. 48, 1916, p. 57.

† Mr. C. T. Trechmann, M.Sc., F.G.S., who collected at Wangaloa with me and took a collection away with him, at first regarded the strata as of Maestrichtian age. Afterwards he stated that the presence of *Pugnellus* appeared to justify a Danian age. (MSS. letter.)

the New Zealand area throughout this lapse of geological time. It is noticeable that where the basement beds are of greatest age, as at the Clarence Valley, and also at Batley, in the north of Auckland, the overlying limestone member of the series is a deep-sea ooze — globigerina, diatomaceous, or radiolarian.

While the palaeontological evidence at present available strongly supports the conclusions stated, it is certain that much still remains to be done. The collections that have already been made are capable of much extension even from the same localities, while doubtless other localities will yet be found that will add greatly to our knowledge of the fauna of the lowest members of this system of younger rocks.

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## Art. XL.—*On the Absorption of Lime by Soils: An Investigation of the Hutchinson-MacLennan Method of determining the Lime Requirements of Soils.*

By Leonard J. Wild, M.A., B.Sc., F.G.S., and James G. Anderson, M.Sc.

[*Read before the Canterbury Philosophical Institute, 6th December, 1916; received by Editors, 30th December, 1916; issued separately, 7th December, 1917.*]

Contents.



In a paper* read by one of us before this Society last year the Hutchinson-MacLennan method of determining the lime requirement of soils was described, and some preliminary trials of its reliability were recorded. It was stated that "a more practical test of the method would be to determine by it the lime requirements of two similar and adjacent soils, one of which had received a known dressing of lime at a sufficient time previously to allow of its being incorporated with the soil." It was also shown that "the result for any given soil varies with the strength of the solution."

The present paper consists of two parts: (1) A practical test of the method on lines indicated in the first quotation; (2) an investigation of the reason for the variable absorption.

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* L. J. Wild, Studies on the Lime Requirements of certain Soils, *Trans. N.Z. Inst.*, vol. 48, 1916, pp. 513–17.

## PART I.—PRACTICAL TEST OF THE METHOD.

This part includes a brief summary of the results already published* by one of us in the *Journal of Agricultural Science* (which periodical is not generally available to New Zealand readers), together with some additional matter.

In the summer of 1915–16 a soil-collecting tour was made in Southland, and a large number of pairs of adjacent limed and unlimed soils was obtained. Southland is a district where the farmers have no doubt as to the efficacy of lime—in fact, in some districts it is impossible to farm without it. The practice of liming was first introduced by the New Zealand Land Company on their Edendale Estate about 1890, after which the custom rapidly became popular. An excellent account of the history and practical methods of liming is given by W. D. Hunt in the New Zealand *Journal of Agriculture* for August, 1916.

In the following table we give the lime requirements indicated for pairs of adjacent limed and unlimed soils, together with the amount of lime put on, and the date of application. The conditions of experiment were: Weight of soil, 10 grammes; time of treatment, three to four hours; strength of bicarbonate solution, 0·02 normal.

TABLE I.—THE LIME REQUIREMENTS OF SOME ADJACENT LIMED AND UNLIMED SOUTHLAND SOILS.

| No. | Locality. | Treatment. | Lime Requirement (Percentage). | Difference from Adjacent Unlimed Soil. | |
|---|---|---|---|---|---|
| | | | | Percentage. | Pounds per Acre |
| S 3 | Wallacetown .. | No lime .. .. | 0·248 | .. | .. |
| S 4 | ,, .. | 1 ton lime, 1909 .. | 0·226 | 0·022 | 300 |
| S 7 | ,, .. | 1 ton lime, 1906 .. | .. | .. | .. |
| | | 1 ton lime, 1915 .. | 0·184 | 0·064 | 880 |
| S 9 | Branxholm .. | No lime .. .. | 0·205 | .. | .. |
| S 8 | ,, .. | 1 ton lime, 1901 .. | 0·113 | 0·092 | 1,250 |
| S 20 | Edendale .. | No lime .. .. | 0·270 | .. | .. |
| S 18 | ,, .. | 2 tons lime, 1896 .. | 0·250 | 0·016 | 220 |
| S 19 | ,, .. | 2 tons lime, 1910 .. | 0·243 | 0·027 | 370 |
| S 23 | Lochiel .. | Limed twenty years ago | 0·221 | .. | .. |
| S 21 | ,, .. | 8 cwt. lime, 1915 .. | 0·153 | 0·068 | 925 |
| S 22 | ,, .. | 6 cwt. lime, 1914 .. | 0·196 | 0·025 | 340 |
| S 62 | Longbush .. | No lime .. .. | 0·188 | .. | .. |
| S 61 | ,, .. | 8 cwt. carbonate, 1914 .. | 0·160 | 0·028 | 380 |
| S 65 | Morton Mains.. | No lime .. .. | 0·208 | .. | .. |
| S 64 | .. | 10 cwt. carbonate, 1915 | 0·192 | 0·016 | 220 |
| S 63 | .. | 30 cwt. lime, 1914 .. | 0·125 | 0·083 | 1,030 |
| S 17 | Woodlands .. | No lime .. .. | 0·180 | .. | .. |
| S 16 | .. .. | 1 ton lime, 1915 .. | 0·159 | 0·021 | 290 |

Out of these results the following conclusions emerge: (1) That an application of lime to a soil in the field is reflected in a diminution of the lime requirement, as indicated by the method under consideration; (2) that the diminution in the indicated lime requirement is not commensurate with the amount of lime added; (3) since practical experience shows that the applications of lime recorded above were sufficient to convert

* L. J. WILD, On some Soils of the South Island of New Zealand, with Special Reference to their Lime Requirements, *Journ. Ag. Sci.*, vol. 8, 1917.

unhealthy, infertile soils into healthy, fertile ones, then either (*a*) the Hutchinson-MacLennan method gives excessive estimates of the lime requirements of soils, or (*b*) it gives an optimum value that is greatly in excess of practical, or at all events of economical, requirements.

Pairs of soils were also obtained in Canterbury, and dealt with in like manner. The following table gives some results :—

Table II.—The Lime Requirements of some Adjacent Limed and Unlimed Canterbury Soils.

| No. | Locality. | Treatment. | Lime Requirement (Percentage). | Difference from Adjacent Unlimed Soil. | |
|---|---|---|---|---|---|
| | | | | Percentage. | Pounds Per Acre. |
| L 21B | Lincoln .. | No lime .. .. | 0·139 | .. | .. |
| L 21A | " .. | 6 cwt. lime, 1915 .. | 0·103 | 0·036 | 500 |
| C 129 | Ashley Dene .. | No lime .. .. | 0·156 | .. | .. |
| C 128 | " .. | 1 ton carbonate, 1915 .. | 0·113 | 0·043 | 590 |
| C 220 | Morven .. | No lime .. .. | 0·104 | .. | .. |
| C 219 | " .. | 1 ton lime, 1913 .. | 0·085 | 0·019 | 260 |
| C 122 | Longbeach .. | No lime .. .. | 0·120 | .. | .. |
| C 123 | " .. | Limed twenty years ago | 0·120 | Nil | Nil |

Taking these results in conjunction with the fact that liming has never "taken on" among the farmers of Canterbury (though the soils give an acid reaction to litmus), the high so-called lime requirement is noteworthy, though it is certainly much less than in the case of Southland soils. Liming here also seems to reduce the indicated lime requirement, but not to a degree commensurate with the quantity of lime applied.

There are, however, some areas in Southland where farming is successfully practised without the use of lime—namely, the flats of the Oreti and Aparima Rivers, especially the Dipton Flat and Bayswater. We do not say that lime will not give payable results, but merely that these soils do not demand lime in the insistent manner of, say, the Edendale soils.

In the next table we give the lime requirements of some of these different types of soils.

Table III.—Lime Requirements of some Southland Soils.

| (*a*.) Soils demanding Lime. | | | (*b*.) Soils not requiring Lime. | | |
|---|---|---|---|---|---|
| No. | Locality. | Lime Requirement (Percentage). | No. | Locality. | Lime Requirement (Percentage). |
| S 3 | Wallacetown .. | 0·25 | S 6 | Wallacetown Flat .. | 0·18 |
| S 9 | Branxholm .. | 0·21 | S 24 | Winton .. .. | 0·16 |
| S 14 | Rakahouka .. | 0·22 | S 26 | Lady Barkly .. | 0·14 |
| S 17 | Woodlands .. | 0·18 | S 29 | Centre Bush .. | 0·13 |
| S 18 | Edendale .. | 0·25 | S 30 | Kauana .. .. | 0·13 |
| S 20 | " .. | 0·27 | S 31 | " .. .. | 0·12 |
| S 62 | Longbush .. | 0·19 | S 36 | Dipton .. .. | 0·14 |
| S 65 | Morton Mains .. | 0·21 | S 69 | Bayswater .. | 0·14 |
| S 22 | Lochiel .. .. | 0·20 | S 70 | Upper Bayswater .. | 0·14 |
| S 23 | " .. .. | 0·22 | S 71 | Lower Bayswater .. | 0·11 |
| | Average .. | 0·22 | | Average .. | 0·139 |

In the next table we give the lime requirements of some typical Canterbury Plains soils. These, it will be remembered, give an acid reaction to litmus, but do not markedly respond to lime.

TABLE IV.—LIME REQUIREMENTS OF ACID BUT UNRESPONSIVE CANTERBURY PLAINS SOILS.

| No. | Locality. | Lime Requirement (Percentage). | No. | Locality. | Lime Requirement (Percentage). |
|---|---|---|---|---|---|
| L 21 | Lincoln College .. | 0·10 | C 141 | Lincoln .. .. | 0·14 |
| C 142 | Weedon's .. | 0·09 | E 1 | Ladbrook's .. | 0·06 |
| C 143 | ,, .. | 0·15 | C 217 | Willowbridge .. | 0·06 |
| C 218 | Waihao Flat .. | 0·09 | C 221 | ,, .. | 0·09 |
| C 219 | Morven .. .. | 0·11 | E 2 | Prebbleton .. | 0·05 |
| C 220 | ,, .. .. | 0·09 | E 8 | Springston .. | 0·10 |
| C 109 | Rakaia (West) .. | 0·11 | C 111 | Overdale .. | 0·14 |
| C 110 | ,, (East) .. | 0·12 | C 112 | Chertsey .. | 0·14 |
| C 120 | Eiffelton.. .. | 0·09 | C 122 | Longbeach .. | 0·12 |
| C 124 | Waterton .. | 0·12 | C 125 | Greenstreet .. | 0·11 |

Average lime requirement, 0·104 per cent.

These figures merely confirm what has already been observed—namely, that while the Hutchinson-MacLennan method enables us to distinguish between soils demanding lime and soils not requiring it so urgently, yet we cannot agree to the statement that a complete failure of crop is the accompaniment of an absorption of 0·18 per cent. For there are Southland soils naturally requiring lime that, after a dressing of lime that experience shows to be sufficient for the practical purpose of soil-amelioration, may still show as high an absorption as 0·24 per cent.; while those of the Canterbury Plains and of the Southland river-flats, though having an absorption of 0·104 and 0·139 per cent. respectively, have nevertheless not shown any marked demand for lime, and certainly are being farmed very profitably without it. Hutchinson and MacLennan would apparently, in the light of their experience, lime a soil till its absorption is reduced to nil. In connection with field experiments at Woburn Station they say, "Without necessarily indicating that the controlling factor in crop-production of these (barley) plots is one of physiological resistance to soil acidity, there is still a very close agreement between yields and soil reaction. In all cases where the soil is neutral in reaction high returns are obtained; where the requirement is more than 0·18 per cent. the crop shows almost if not complete failure. . . . Somewhat similar data were obtained with the soils from the permanent wheat plots, although in this case the crop was more resistant to acid conditions, and persisted until the soil showed an absorption of over 0·22 per cent."

Unfortunately, we have not in this country a series of experimental results bearing on this matter, but practical farm methods in the districts we have visited appear to indicate that the limits suggested in the above statement are too narrow for adoption here. Thus, to take the case of the Wallacetown soil, one giving a markedly acid reaction and with an indicated lime requirement of 0·265 per cent., it is found that a dressing of even 1 ton — and certainly of not more than 1½ tons — of burnt lime is ample for the practical purpose of putting the soil into condition to yield an abundant harvest, while, owing to the high price of lime, a phenomenal return would be required for a further application to prove profitable Another point is that the effect of lime is seen rather in the pastures than in the cereal or root crops. At Edendale they say that a want of something in the soil was seen not so much by low yields of oats or turnips as in the ill health and lack of condition of stock depastured in these fields.

Taking into consideration these facts, as well as observations of the absorption of average Canterbury Plains soils, we have come to the conclusion that, while lime is no doubt urgently needed where the absorption is greater than about 0·20 per cent., there is no proof from the point of view of crop-production that it is required where the absorption is less than about 0·10 per cent. To translate the indication of the Hutchinson-MacLennan method into practical terms, therefore, we suggest the use of this figure as a correcting value to be deducted from the actual indication in order to get the probable practical requirement. The quantity 0·10 per cent. is selected as being the present lime requirement indicated for field 21 of the Lincoln College Farm, which received 6 cwt. of lime in the winter of 1915, and which is now in an entirely satisfactory productive condition. A higher value—say, 0·14 per cent.—may perhaps be allowed for Southland soils.

Our conclusions, however, must be taken strictly in the sense in which they are here recorded. We do not attempt to insist that liming the soils of the Canterbury Plains will not pay; but it is certainly the case that while the benefits of liming have thrust themselves under the notice of Southland farmers, they have not been sufficiently obvious to those farmers in Canterbury who have made the experiment. Nor is it necessary for us to say that we fully recognize that a manurial application may be more than paying its way though the fact may not be obvious simply by viewing the plots without measurements. Our conservative attitude is dictated by the considerations — first, that there is as yet no positive experimental evidence proving the economic importance of lime to these soils; secondly, that satisfactory results are being obtained without liming; thirdly, that whereas a kind of natural selection operating among methods of farming the Southland Plains soils brought about the evolution of the practice of liming, the same processes have not achieved similar results in Canterbury.

Reason for greater acidity of Southland Plains soils: A search for reasons for the greater lime requirements of Southland Plains soils on the one hand, and those of the river-flats and of Canterbury Plains on the other, led to the conclusion that the greater acidity and higher lime requirement of the soils of the Southland Plains appears to be due to a combination of lack of natural under-drainage (owing to more or less impervious clay subsoil) and high rainfall, which together prevent aeration and oxidation of organic matter, so that "sour" humus accumulates in the soil. The reasons for this conclusion are set forth in the article in the *Journal of Agricultural Science* already mentioned.

## Part II.—An Investigation of the Theory of the Method.

The principal object of this investigation was to ascertain, if possible, the nature of the action by which lime is taken up by the soil. At least two explanations have been offered—

(1.) The phenomenon is a mass-action effect, the calcium base combining with the so-called humous acid of the soil.

(2.) The interaction between calcium salts and soil is due to "adsorption" by soil colloids.

The first explanation is put out of court by the consideration that if we were concerned only with a mass action, then the amount of lime withdrawn from solution by a given weight of the same soil would always be the same, provided always that sufficient time were allowed for the completion of the action. Variations in the concentration of the solution would not affect the result, provided that the solution has enough lime to satisfy the soil. Now, we have determined by preliminary experiments (see *Journ. Ag. Sci.*, vol. 8; also this article, p. 475) the time necessary for the completion of the action; but, even allowing this time, we have found a variable absorption of the kind already described. Within fairly wide limits, the greater the initial concentration of the solution the greater is the absorption.

We turn, therefore, to the second suggestion. The literature of "adsorption" by soils has been summarized by Patten and Waggaman* and more recently by Prescott.† The following is from Russell's *Soil Conditions and Plant Growth*, p. 58 (new ed., 1915):—

"Van Bemmelen has demonstrated a close parallelism between the various interchanges and absorptions shown by the soil and those shown by colloids; and there is considerable evidence in other directions that some of the soil constituents, especially the clay, possess all the properties of colloids. Now, the adsorption by colloids can generally be represented by the equation—

$$\frac{y}{m} = kc^{\frac{1}{n}}$$

where $y$ = amount absorbed by quantity $m$ of adsorbent; $c$ = equilibrium concentration of dissolved substance; $k$ and $n$ are constants depending on the nature of the solution and the adsorbent. Wiegner has shown that the interaction between ammonium salts and soil accords entirely with this reaction, and Prescott finds the same holds true with adsorption of phosphates from their solution by soil."

In this paper an attempt is made to test the applicability of this formula to the absorption of lime by soil. Table V shows some results obtained with the soil from field 21 (Lincoln College)—

TABLE V.—ABSORPTION OF LIME BY SOIL NO. L 21 FROM CALCIUM-BICARBONATE SOLUTIONS OF VARYING CONCENTRATIONS.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Initial concentration | 0·0246N | 0·0227N | 0·0211N | 0·0197N | 0·0184N | 0·0174N | 0·0164N | 0·0155N |
| Lime absorbed (grammes) | 0·161 | 0·160 | 0·157 | 0·143 | 0·134 | 0·133 | 0·131 | 0·120 |

These results are plotted in fig. 1. It is evident that the part of the curve that embraces the results with higher concentrations is of the parabolic type, and would presumably approach that form more nearly if determinations had been made with solutions of greater strength.

In order, therefore, to experiment with a solution richer in lime a saturated solution of lime-water was employed; and as with caustic lime a

* H. E. PATTEN and W. H. WAGGAMAN, Absorption by Soils, *U.S. Dept. of Agric., Bureau of Soils, Bull. No. 52*, 1908.

† J. A. PRESCOTT, The Phenomenon of Absorption in its Relation to Soils, *Journ. Ag. Sci.*, vol. 8, 1916, p. 111.

disturbing effect would be created by a high percentage of humus, we took a clay subsoil poor in organic matter. The conditions of the experiment were as follows: A saturated solution of $Ca(OH)_2$ was carefully prepared and kept in a stoppered bottle. In order to obviate the formation of $CaCO_3$ by the action of atmospheric $CO_2$ the air was displaced by coal-gas. Titration with standard acid gave the initial concentration as 1·7 grammes per litre. Ten grammes of soil was used in all the experiments,

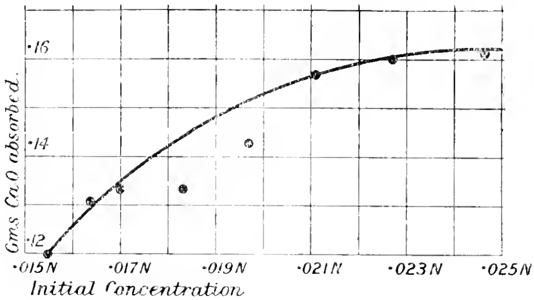



Fig. 1.

and the volume of solution was 300 c.c. in each case. After a preliminary shaking the contents were allowed to digest for three hours, after which 5 c.c. to 20 c.c. of the supernatant liquid were pipetted off and titrated with standard acid, phenol-phthalein being used as indicator. The end point was in all cases quite distinct. The equilibrium concentration of $Ca(OH)_2$ was then calculated, and the diminution in concentration so deduced.

Results: Several series were repeated, and very good agreement was obtained. The following set of values may be taken as typical:—

Table VI.—Absorption of Lime from Lime-water by Clay Subsoil.

| Initial Concentration: Grammes $Ca(OH)_2$ per Litre. | Final Concentration: Grammes $Ca(OH)_2$ per Litre. | Loss of Concentration: Grammes $Ca(OH)_2$ per Litre. | Constant: $4a$. |
|---|---|---|---|
| 1·7 | 1·0 | 0·7 | 0·49 |
| 1·475 | 0·834 | 0·64 | 0·49 |
| 1·14 | 0·59 | 0·55 | 0·51 |
| 0·875 | 0·46 | 0·44 | 0·42 |
| 0·575 | 0·235 | 0·34 | 0·49 |
| 0·28 | 0·08 | 0·20 | 0·50 |

The derivation of the figure in the last column ($4a$) will be explained later.

Graphical representation: From these values two curves may be drawn—(1) diminution in concentration of $Ca(OH)_2$ against initial concentration; (2) loss in concentration against final concentration of dissolved substance. Both these curves were found to be perfectly general in form, and it will be noticed that the majority of the points lie on the curves.

Evaluation of constant $4a$: Examination of the curve in fig. 2 will show that it is of the parabolic type. Now, the general equation for the parabola is $y^2 = 4ax$, where $a$ is a constant. From this curve the values given in the last column of Table VI were calculated, and here with one exception excellent agreement is obtained, the mean value being 0·49.

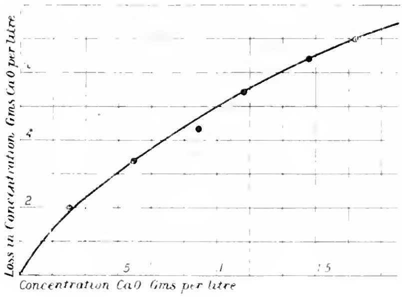



FIG. 2.

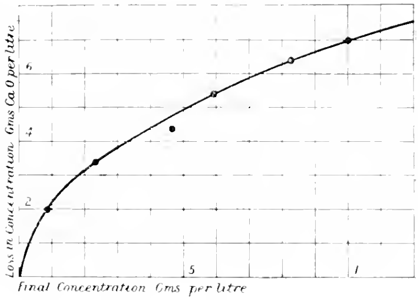



FIG. 3.

The equation for the parabola may now be compared with that for colloidal adsorption.

The general formula representing colloidal adsorption is—

$$\frac{y}{m} = kc^{\frac{1}{n}}$$

where the symbols have the significance given above (p. 471). Now, this may be transformed as follows:—

By squaring $\frac{y^2}{m^2} = k^2c^{\frac{2}{n}}$

let $n = 2$ (see observation below);

then $\frac{y^2}{m^2} = k^2c.$

therefore $y^2 = m^2k^2c$, analogous to

$y^2 = 4ax$ the equation for the parabola.

Therefore we may equate

$m^2k^2 = 4a$;

but $m = 10$,

therefore $k^2 = \frac{1}{100}\,4a$,

therefore $k = \frac{1}{10}\sqrt{4a}$

$= \frac{1}{10}\sqrt{\cdot 49}$

$= \cdot 07$

For this particular soil, therefore, the connection between the absorption of $Ca(OH)_2$ and the equilibrium concentration may be expressed—

$$\frac{y}{m} = \cdot 07\, c^{\frac{1}{2}}.$$

Observation: The selection of the value $n = 2$ is more or less arbitrary, and on it, of course, the value of $k$ depends. It is well known, however, that in the case of colloids adsorption varies with the valency of the ion that is being adsorbed. Calcium functions as a dyad; and for that reason, as well as for the consequent conformity with the general parabolic equation which the experimental curve seems to postulate, 2 has been adopted provisionally as the value of this constant.

Further trials of a similar nature were made with other soils, and the results of these were of the same general form. Two typical sets of results are given below—

Table VII.—Absorption of Lime from Lime-water by Wanganui Soils.

| Initial Concentration: Grammes $Ca(OH)_2$ per Litre. | Final Concentration: Grammes $Ca(OH)_2$ per Litre. | Loss of Concentration: Grammes $Ca(OH)_2$ per Litre. | Constant: *k*. |
|---|---|---|---|
| | *Soil A.* | | |
| 1·558 | 0·7479 | 0·8101 | 0·095 |
| 1·2984 | 0·5651 | 0·7333 | 0·096 |
| 1·0388 | 0·3513 | 0·6575 | 0·111 |
| 0·7792 | 0·2440 | 0·5352 | 0·109 |
| 0·5196 | 0·1300 | 0·3896 | 0·108 |
| 0·2600 | 0·0444 | 0·2156 | 0·103 |
| | *Soil B.* | | |
| 1·558 | 0·7759 | 0·7821 | 0·089 |
| 1·2984 | 0·5590 | 0·7394 | 0·098 |
| 1·0388 | 0·4490 | 0·5898 | 0·089 |
| 0·7792 | 0·2658 | 0·5134 | 0·100 |
| 0·5196 | 0·1483 | 0·3713 | 0·096 |
| 0·2600 | 0·0214 | 0·2386 | 0·152 ? |

Average value of soil A, 0·104. Average value of soil B, 0·094.

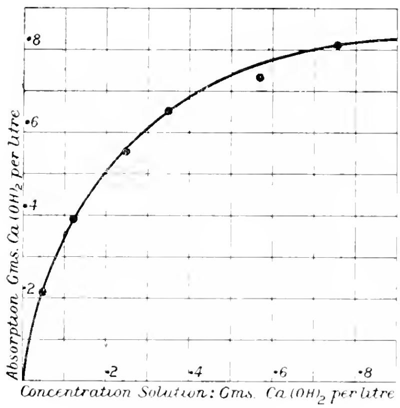



Fig. 4.—Soil A.

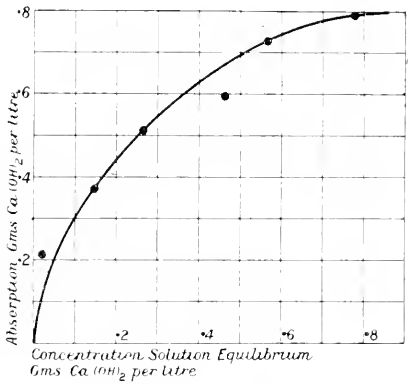



Fig. 5.—Soil B.

It will be noticed that the graphs are of quite similar form to those previously obtained, and the values of the constants for any set show approximate agreement. In certain cases, however, it would seem that this relationship ceases to hold when the concentration becomes very small.

Time curves: In preliminary experimentation we had obtained some information as to the rate at which the reaction proceeds with varying initial concentrations; and it was decided to investigate this more fully in the hope of deducing further confirmatory evidence. Typical sets of values are as follows:—

| *Set 1.* Time, in Hours. | | Final Concentration : Grammes per Litre. | *Set 2.* Time, in Hours. | | Final Concentration : Grammes per Litre. |
|---|---|---|---|---|---|
| — | .. | 1·7 | — | .. | 0·85 |
| ½ | .. | 1·47 | ½ | .. | 0·725 |
| 1 | .. | 1·3 | 1 | .. | 0·625 |
| 1½ | .. | 1·17 | 1½ | .. | 0·542 |
| 2½ | .. | 1·0 | 2½ | .. | 0·380 |
| 3½ | .. | 1·0 | 3½ | .. | 0·380 |

These results are shown graphically in fig. 6, (*a*) and (*b*).

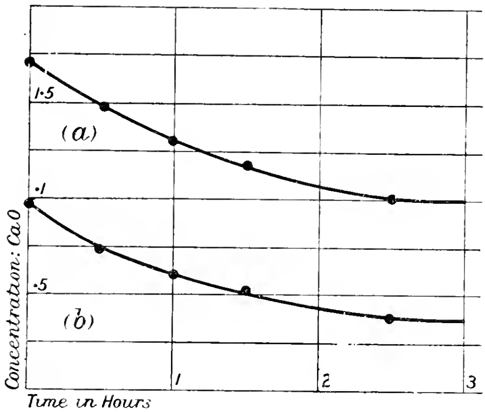



FIG. 6

It will be noticed that the form of the two curves given is almost identical; and, further, that the time taken to complete a certain fraction of the reaction appears, within the limits of the experimental error, to be independent of the initial concentration. For instance, the time taken to complete one-third of the reaction is approximately half an hour in both cases. Now, this is characteristic of reactions of the *first order* (Ostwald)—*i.e.*, reactions where only one substance undergoes any alteration. Many colloidal reactions are of this type, and it may be that here the soil colloid remains of constant activity and that the course of the reaction is conditioned solely by the concentration of the calcium hydroxide.

## GENERAL CONCLUSIONS.

The results recorded in this paper appear to us to indicate conclusively that the interaction between soil and solution of calcium bicarbonate or hydrate is a colloidal phenomenon. If this is the case, then it follows that a method of determining the lime requirement of a soil based on this (such as the Hutchinson-MacLennan method) is entirely without scientific foundation. The Hutchinson-MacLennan method, however, taken merely as an empirical method and operated under standard conditions, promises to be of great utility, as has already been shown in the first part of this paper. It is certainly better than any method based on chemical analysis, and compared with other methods of a similar kind hitherto used it has the advantage of ease of manipulation.

## Art. XLI.—*On the Proposal for a Soil Survey of New Zealand.*

By Leonard J. Wild, M.A., B.Sc., F.G.S., Lecturer in Chemistry, Canterbury Agricultural College.

[*Read before the Canterbury Philosophical Institute, 6th December, 1916; received by Editors, 30th December, 1916; issued separately, 7th December, 1917.*]

Contents.



### I. General Methods of Soil Survey.

In considering the relative advantages of the various methods of soil survey that have been proposed it is reasonable to demand that a method shall take into account to the greatest degree possible all those features that most profoundly affect the agricultural potentialities of the soil. These are (1) local climate; (2) soil texture; (3) composition; (4) nature of subsoil. It is difficult to arrange these in order of relative importance, but it can be shown that, except in abnormal cases, *chemical composition is of least consequence; while soil texture and nature of subsoil deserve most consideration*, in that they determine the suitability of the soil as the abode of the plant in respect of moisture-supply, air-supply, and temperature. On local climate depends to a considerable extent the suitability or otherwise of a soil area to the growth of various kinds of agricultural plants.

The various methods of soil-classification hitherto proposed may now be considered. According to Tulaikoff,* all classifications of soils yet proposed may be divided into two groups: (*a*) *scientific classifications*, which are based on the natural characteristics of the soil; and (*b*) "*applied*" *classifications*, which are based on the suitability of soils for certain crops, or on the revenue that may be derived from them. In New Zealand the practical man uses such an "applied" method when he loosely classifies land as (1) dairying land, which comprises the heavier soil with a rainfall of, say, over 25 in.; (2) sheep country, which comprises hill pastures inaccessible to the plough, as well as the "lighter" and drier soils at lower levels; (3) cropping land, intermediate between these.

According to the features on which the study of soils is based, the "scientific" classifications are divided into—(1) the *geologico-petrographical*,

* N. M. Tulaikoff, The Genetic Classification of Soils, *Journ. Ag. Sci.*. vol. 3, 1908, p. 81.

in which the soils are grouped according to the geologico-petrographical character of the rocks which make up the soil (the classification of Fallow, Mayer, and others); (2) the *chemical* or *chemico-petrographical*, according to the main chemical features of the soil (Knop); (3) the *physical*, according to the mechanical composition and the physical characteristics derived from it (Thaer, Schubler, the classification adopted by the Bureau of Soils of the United States); (4) the *combined* classification, by which soils are divided into groups, for example, according to their mechanical composition, and subdivided according to either their chemical composition or other features (Senft, Kosticheff, and others); (5) the *genetic*, by which soils are divided into groups depending on their origin and development (Professor Docuchaiev, Professor Hilgard, Professor Ramman (in part), and Professor Sibirtzev).

The last-named, the genetic classification of Sibirtzev, provides a means of differentiating in a broad way the soils of continental masses by means of features that ultimately depend wholly on climate. Thus, while the method provides a comprehensive classification in areas, such as Eurasia, with more or less definite climatic zones, it cannot be applied to smaller countries lying wholly within one climatic zone (such as England), nor is it suited to a soil survey the objects of which are such as are outlined in the second part of this paper. The method is well criticized by Hall and Russell,* and no apology is necessary for quoting at length their remarks on the subject, since what applies to Great Britain in this connection applies equally well in New Zealand: "The genetic classification of soils such as has been suggested by Sibirtzev divides soils into a series of great types which are really determined by climatic zones. In the steppe area, for example, where the black soils (Tchernozem) prevail, climatic conditions have led to the accumulation of large proportions of mild or neutral humus until it has become the dominant factor in determining the character of the soil; whether the original substratum be sand or clay the amount of organic matter causes the soil to work lightly and yet retain moisture. In such an area, and the area will in the nature of things be large, soil analyses will be of little value because all differences, chemical or physical, in the nature of the substratum will be overridden by the preponderance of the humus. Such an area, again, will show little relation between the soil and the geology of the country, the soil being practically a drift deposit which has overgrown all the underlying formations alike. In the United Kingdom we must regard ourselves as living almost entirely within one only of these large climatic zones, but one which does not superimpose a soil type on all the various strata to be found there, so that a great diversity of soils may occur within a very small area. We do see the climatic divisions in the peaty soils which develop in all parts of the country above a certain elevation, for though some differences may be traced in the vegetation carried by the moorlands, in the main the character of the soils is alike and has been determined by the elevation and the rainfall and not by the nature of the underlying formation. As a rule, however, in the United Kingdom the soil is derived from and shares the character of the rock or drift material below; even where there might have once been a common forest or steppe soil over a considerable area the processes of cultivation carried on for so long have obliterated the excess

* A. D. HALL and E. T. RUSSELL, Soil Surveys and Soil Analyses, *Journ. Ag. Sci.*, vol. 4, 1911, p. 182.

of organic matter and given the underlying differences full play. The character of our climatic zone is such as to accentuate variety of soils, the humidity is considerable and carries the degradation of the rock material so far that there is an enormous range in the sizes of the particles making up the soil, from coarse sand grains down to clay particles of the order of colloids; there has also been sufficient accumulation of humus to modify the texture of the mass and make it work as a unit and not as a loose aggregate of powdered rock. Chemically also our soils lie between the semi-arid soils, with their richness in unleached salts derived from the decayed rock, and the 'podzols' from which all soluble material has been washed away."

The first method, the geologico-petrographical classification, and the second method, the chemico-petrographical classification, may conveniently be considered together, since they have usually been employed in conjunction with one another in Great Britain, where the adoption of the combination by Hall and Russell in their *Agriculture and Soils of Kent, Surrey, and Sussex** has firmly established it. The authors "have assumed that each [geological] formation represented in the district will give rise to a soil type which can be characterized both by its mechanical analysis and by special features in the farming which prevails over its outcrop. The justification for these cardinal assumptions was obtained in the early stages of the work by following the dividing-line representing the outcrop of two formations, and finding (1) that the dividing-line held for the soils as well as for the underlying formations; (2) that the soils from any formation (with one or two exceptions) did show on analysis certain common features which marked them off from the other soils. These conclusions have been strengthened as our work proceeded; all our experience in the field goes to show that each formation in the area under consideration gives rise to a distinct soil type, the characteristic composition of which can further be recognized by making up an average from the mechanical analyses of the samples taken from the formation. Even in such a case as that afforded by the Lower Wealden soils, which vary from something near a sand to a heavy clay, there still exists but one type of soil, possessing very marked and special characters, though subject to a considerable range of variation from light to heavy."

Since the publication of this work surveys of various counties have been completed or taken in hand in Great Britain. Practically all of this work, especially that done in England, follows consistently the methods of Hall and Russell. Thus in that most recently published—namely, a paper by Rigg†—we read, "The writer has followed Hall and Russell in using the geological formation to mark the extent of a series of soils which have a somewhat similar mineral structure. These series of soils have, however, then been separated into soil formations having different agricultural properties, and the extent of each has been mapped."

As one of the objects of the present paper is to show that in general, and more particularly in New Zealand, the geological map is not the best basis of a soil survey (in other words, that the geologico-chemico-petrographical method is not the best method of soil-classification), a detailed consideration of some of the British work is necessary.

* Published by the Board of Agriculture and Fisheries, 1911.

† T. Rigg, The Soils and Crops of the Market-garden District of Biggleswade, *Journ. Ag. Sci.*, vol. 7, 1916, p. 385.

In the first place, if what has been said above be borne in mind—namely, (*a*) that the objects of a soil survey are not merely to provide a scientific classification of soils, but to provide such a classification as will enable us the more readily to appreciate the agricultural potentialities of each soil type; and (*b*) that the fertility of a soil depends not so much on its chemical composition as on its texture, its climate, and the environment generally that it provides for the plant—then it must at once be conceded that the geologico-petrographical classification is inefficient, since it is based fundamentally on the nature of the rock from which the soil is derived. For the character of the parent rock can affect only the chemical composition (and in some few exceptional cases mechanical composition) of the soil, but it cannot affect climate, water-supply, texture, &c., which are by far the most important fertility factors.

Proceeding from this general statement to the consideration of specific cases, we shall deal first with Rigg's paper mentioned above. Rigg examined the following geological formations, and the series of soils occurring on them were divided into soil formations which had different agricultural properties:—

(1.) Oxford clay, giving rise to two soil formations—
- (*a.*) Pure-clay soil;
- (*b.*) A clay loam, probably resulting from an alluvial wash on to the clay soil.

(2.) Greensand, giving rise to two soil formations—
- (*a.*) Dark sands;
- (*b.*) Brown sands.

(3.) Gault, giving rise to two soil formations—
- (*a.*) Pure-clay soil;
- (*b.*) A sandy loam, locally known as "redland," occurring as a narrow strip between greensand and the pure Gault clay soil (*a*).

(4.) Boulder clay, giving rise to three soil formations—
- (*a.*) Pure boulder-clay soil;
- (*b.*) Heavy loam produced by wash on boulder clay;
- (*c.*) Sandy loam produced by a thin capping of boulder clay on greensand.

(5.) Brick-earths, giving rise to only one soil formation.

(6.) Glacial, giving rise to one soil formation, which, however, is not quite so uniform as the brick-earth formation.

(7.) Valley gravels, giving rise to three soil formations—
- (*a.*) A brown-soil formation (referred to as "Old Brown");
- (*b.*) A heavy brown-soil formation;
- (*c.*) A more recent dark-soil formation (referred to as "New Dark").

Samples of soil from each formation were collected and submitted to chemical and mechanical analysis; and by this means it is claimed that not only were field observations verified, but analysis differentiated between the various soil formations and showed an extraordinary uniformity between the samples taken from any soil formation. The greensand soils are given as an illustration of this. This series of soils is said to be "differentiated from any other by the low percentage of potash and mineral salts and an almost entire absence of calcium carbonate. The coarse-sand fraction is particularly high, and this fact alone would be almost sufficient to distinguish it from any other series." When, however, we turn to the analytical results in the appendix we find (1) that a low percentage of potash is characteristic also of the "Old Brown" formation of the valley-gravel series, so also a low percentage of CaO and MgO; (2) that $P_2O_5$ is not phenomenally low—average for greensands, 0·21 per cent.; average for other formations, 0·20 per cent.

It is further stated that "The dark sand seems to be differentiated by a much lower content of potash and phosphoric acid." This statement, however, is not justified by the analyses of the four soils given, for the figures for potash are 0·24, 0·13, 0·18, and 0·23, two of these being quite up to the average of the brown sands; while the figures for phosphoric acid are 0·43, 0·11, 0·19, and 0·16, one of these being exceptionally high and at least one other not exceptionally low.

The percentage of $CaCO_3$ is admittedly phenomenally low (average 0·08 per cent.); but the Old Brown valley-gravel soils have only 0·11 per cent., the Oxford clay formation only 0·12 per cent., and a Gault formation only 0·15 per cent. Moreover, in the discussion of the "characteristic properties and agriculture" of the various soil formations there is no mention of the necessity for liming or of an excessive use of artificial manures. On the contrary, it is stated that, though "the dark sand formation is characterized by very low percentages of phosphoric acid, potash, and calcium carbonate," it is nevertheless "reported by market-gardeners as being not quite so 'hungry' as the brown sand formation." Again, the table of distribution of crops shows that the main crop is early potatoes, which are "associated with brown and dark greensand and valley-gravel soil formations," while it is stated also that the success of the crops depends to a large extent on the rainfall.

The present writer therefore submits—(1) that a unique chemical composition does not characterize this soil formation; (2) that the chemical composition of the soils of the formation does not in any way affect their agricultural utilization or treatment; (3) that the only agricultural feature of the formation apparently connected with geological origin is the high percentage of coarse sand; but that (4) this is not an invariable feature of greensand-derived soils, for Hall and Russell find that "the soils [of the Upper Greensand in Kent, Surrey, and Sussex] are well balanced and contain all the fractions suitably developed . . . the soils always show a sufficiency of carbonate of lime." The Folkestone sand, however, is "coarse-grained and devoid of carbonate of lime."

Rigg's next illustration is the Oxford clay series. This is divided into two soil formations—(*a*) pure-clay soils, (*b*) clay loams. "The results of chemical analysis," he says, "are sufficient to distinguish the Oxford clay series from all the other clay formations dealt with in this paper, for the percentage of calcium carbonate and phosphoric acid is extremely low in all the samples taken from this series."

The analyses submitted, however, in no wise support the assertion, for the percentage of phosphoric acid for the clay loam formation averages 0·13 per cent., which compares with the average for the dark greensands (0·15 per cent.), the heavy valley gravels (0·17 per cent.), the boulder clays (0·17 per cent. and 0·15 per cent.), and the brick-earths (0·14 per cent.), while the $CaCO_3$ for the samples given is 0·47 per cent., 0·70 per cent., and 0·06 per cent. As for the pure-clay soils in this series, it is scarcely fair to generalize, seeing that the analysis of only a single sample is given. Moreover, one of the three samples of clay loam analysed shows only 0·06 per cent. of $CaCO_3$, a feature which has been cited as characteristic of the greensand series. Lastly, we may refer to Foreman's paper,* which shows that the Oxford clays of Cambridgeshire are phenomenally rich in $CaCO_3$.

"Again," says Rigg, "mechanical analysis at once reveals the necessity for a subdivision into two soil formations, since there is a constant difference of 9 per cent. in the percentage of clay found in the two soil formations mapped from field observations." This is true, and it shows that this clay loam formation, though derived from the Oxford clay, is, as judged by the mechanical analyses given in the appendix, really quite like the clay loam formation of the boulder clay series and the glacial clay; while the pure Oxford clay is quite similar to the pure Gault clay.

The table showing the distribution of crops (abridged below) brings to light the same fact: the clay soils, *of whatever geological formation*, mainly carry legumes and cereals, while the clay loams, of whatever geological formations, are characterized by a greater variety of crops.

DISTRIBUTION OF PRINCIPAL CROPS, MARKET-GARDEN DISTRICT OF BIGGLESWADE.
(After T. Rigg. Figures give percentage of total area occupied by crop.)

| Crop. | Pure-clay Soils. | | | Clay Loams. | | | |
|---|---|---|---|---|---|---|---|
| | Oxford. | Gault. | Boulder. | Oxford. | Boulder. | Brick-earths. | Glacial. |
| Cereals .. .. | 72·5 | 63·5 | 62·5 | 25·0 | 31·9 | 40·0 | 36·5 |
| Legumes .. .. | 14·3 | 14·4 | 10·3 | 6·3 | 4·7 | 1·3 | 4·2 |
| Potatoes .. .. | 2·2 | 2·4 | 5·5 | 14·2 | 16·3 | 20·7 | 21·0 |
| Brussels sprouts .. | 1·9 | 4·9 | 8·3 | 23·5 | 21·3 | 16·9 | 19·8 |

Rigg's account of the "characteristic properties and agriculture" of the soils emphasizes the same facts—that agriculturally clay soils, of whatever geological origin, are alike; and the same applies to loams.

Referring to the Gault clay, Rigg says that the "content of calcium carbonate distinguishes it from the Oxford clay formation." To prove this, however, he cites only one analysis of each. It may also be noted that two soils of the three analysed from the "redlands" formation (Gault clay series) have only 0·05 per cent. and 0·09 per cent. of $CaCO_3$. Moreover, Hall and Russell's analyses show that the Gault clay soils of their district are by no means rich in $CaCO_3$—one has as little as 0·01 per cent. —so that Rigg's generalization from the analysis seems totally unjustified. Finally, Rigg concedes that in other respects the Oxford clay "resembles the Gault clay very closely."

After a careful review of Rigg's paper the present writer concludes that in classifying for agricultural purposes the soils therein described—

(1.) Geological origin is relatively unimportant.

(2.) Mechanical analysis and physical structure are all-important.

(3.) The clays of all three geological formations resemble one another in more numerous and in more important points than they differ from one another; and the same statement applies to the loams and to the lighter soils.

(4.) A simple classification showing three series only—clays, clay loams, sandy loams—would be more useful from the agricultural standpoint. Subdivision of these series into "facies," determined by geological origin, might follow if desired for detailed description.

* F. W. FOREMAN, Soils of Cambridgeshire, *Journ. Ag. Sci.*, vol, 2, 1907, p. 161.

We shall turn now to another example of soil classification by similar methods—"Soils of Cambridgeshire," by F. W. Foreman.* In an introductory note Professor T. H. Middleton says, *inter alia,* "We were anxious to ascertain whether there exists any close connection between local soils and the underlying rock formation"; and he comes to the conclusion that "the majority of the mechanical analyses do show a relationship between all the soils on the one formation."

The soils are treated in the following order:—

| *Clay Soils*— | *Sandy Soils* |
|---|---|
| Boulder clay. | River gravel. |
| Gault. | Lower greensand. |
| Kimeridge clay. | |
| Ampthill clay. | |

In the following table the more important analytical results for the soils of the various clay formations are averaged and summarized for convenience of comparison:—

SUMMARY OF FOREMAN'S ANALYTICAL RESULTS.

| —— | Boulder Clay. | Gault. | Kimeridge and Ampthill Clays.* | Oxford Clay. |
|---|---|---|---|---|
| Coarse fractions† .. .. | 30·58 | 18·0 | 29·93 | 24·90 |
| Silt .. .. .. | 12·97 | 9·54 | 13·77 | 12·76 |
| Fine fractions‡ .. .. | 38·77 | 50·03 | 40·60 | 42·17 |
| Clay .. .. .. | 25·77 | 33·12 | 26·84 | 29·25 |
| Loss on ignition .. .. | 9·03 | 10·62 | 9·13 | 9·15 |
| $CaCO_3$ .. .. .. | 2·16 | 5·23 | 0·184 | 4·07 |
| $P_2O_5$ .. .. .. | 0·115 | 0·121 | 0·108 | 0·134 |
| $K_2O$ .. .. .. | 0·922 | 1·194 | 1·091 | 1·09 |

* Foreman says, "Ampthill clay very closely resembles Kimeridge clay, and the soil derived from it was similar to those from the Kimeridge in every respect."
† Fine gravel, coarse sand, and fine sand.
‡ Fine silt and clay.

The only outstanding features revealed by this table are (1) the markedly high clay content of the Gault, which admittedly distinguishes it from the rest; (2) the markedly low $CaCO_3$ content of the Kimeridge and Ampthill clays.

The boulder clay differs from the Kimeridge clay only in having a higher content of $CaCO_3$, though itself in need of lime, we are told. The Gault differs from the Oxford clay only in having a rather greater percentage of the finer fractions. If, however, we take into consideration the analyses given by Rigg of soils from the same geological formation in the adjoining County of Bedfordshire, we find some of these discrepancies completely removed. Thus the average percentage of clay in the pure Gault is 29·3, in good agreement with 29·5 in the Oxford clay soils. We note also that Rigg cites as characteristic of the Oxford clay that "the percentage of calcium carbonate and phosphoric acid is extremely low in all samples taken from this series"—a conclusion in total disagreement with the results of Foreman shown in the table above.

Both Rigg and Foreman claim that their results show that each geological formation gives rise to soils possessing certain characteristic

* *Journ. Ag. Sci.*, vol. 2, 1907, p. 160.

properties. The characteristic properties cited by each for the same formation are, however, frequently the exact opposites of one another, although the soils examined were in adjoining counties. Thus Rigg shows that Oxford clay soils are poor in calcium carbonate, while Foreman proves that they are rich in that substance. Both quote the Gault clay as extremely rich in $CaCO_3$, while Hall and Russell say, "The most typical Gault soil is deficient in calcium carbonate: all the samples analysed show less than 0·05 per cent. of calcium carbonate, except No. 30."

These results certainly do not furnish convincing proof that a given geological formation gives rise to a soil differing consistently from the soil derived from another geological formation. In Cambridgeshire, for example, there are clay soils from five different geological formations, but these soils do not differ in really important characters, and such differences as do occur are frequently not carried consistently even into the adjoining county.

Foreman will now be followed in his account of the other properties of these soils described by him. For convenience of comparison these are brought together into a concise summary.

### A. *Soils of the Boulder Clay.*

1. Colour: "Brownish."
2. Texture: "Extremely tenacious." Almost impossible to obtain a satisfactory tilth, except in very good seasons.
3. Crops: Barley, oats, wheat, clover, beans, or mangolds—fair to moderate. Undrained land carries very poor pasture; greatly benefited by basic slag.
4. Weeds: Abundant—(1) *Avena fatua,* (2) *Ranunculus repens,* (3) *Brassica sinapis,* (4) *Sonchus arvensis,* (5) *Carduus arvensis,* (6) *Carduus acaulis,* (7) *Rumex crispus,* (8) *Galium Aparine,* (9) *Agrostis stolonifera.* In small quantity—(11) *Stellaria media,* (12) *Senecio vulgaris.*

### B. *Soils of the Gault.*

1. Colour: Light ("thus readily distinguished from those of boulder clay").
2. Texture: "Very stiff and sticky"; "difficult to till, a bare fallow is absolutely necessary at frequent intervals."
3. Crops: Wheat, clover, barley, oats—fair crops in favourable seasons.
4. Weeds: Abundant—(13) *Taraxacum dens-leonis,* (14) *Tussilago farfara,* and (2), (5), (7), (3), above. In small quantity—(15) *Euphorbia Peplus,* (16) *Geranium molle,* (17) *Veronica agrostis,* (18) *Potentilla reptans,* (11), (12), above.

### C. *Soils of the Kimeridge and Ampthill Clays.*

"Ampthill clay very closely resembles Kimeridge clay, and the soil derived from it was similar to those from the Kimeridge in every respect."

1. Colour: Dark brown.
2. Texture: "Very stiff, sticky, and troublesome, necessitating a frequent bare summer fallow."
3. Crops: Wheat, oats, clover, beans—fair to moderate.
4. Weeds: Abundant—(1), (14), (3), (5), (6), (7), above. Fairly prevalent —(13), (11), (8), (16), (17), above.

D. *Soils of the Oxford Clay.*

1. Colour: Shade darker than Gault.
2. Texture: "The soils are not quite so sticky as those of a typical Gault, but in all other respects they are much the same"; "bare fallow is necessary."
3. Crops: Clover, beans, wheat, barley, oats—fair crops in good seasons; basic slag a profitable manure.
4. Weeds: Abundant — (14), (3), (2), (5), (7), (16), *Anthemis Cotula, Sherardia arvensis.*

Discussion: This summary makes it perfectly clear that all these clay soils resemble one another closely so far as their agricultural properties are concerned. Their textures are the same, their crops, and their weeds. Bearing in mind, therefore, the purposes of a soil survey it would be much more useful to group them all together in one series. Thus we arrive at the following conclusions:—

1. The generalization that each geological formation produces a unique soil type is not justified.

2. On the contrary, clays from all formations resemble one another as closely as possible in all essential agricultural characteristics—namely, in texture, in cropping-capacity, and in methods of farming; and the same remarks apply to loams.

3. The rigid application of the geologico-chemico-petrographical method of classification used in recent British work leads only to a needless multiplication of soil series and formations. (Rigg finds seven series in the Biggleswade district, subdivided into fourteen formations.)

4. In exceptional cases a geological formation may consistently give rise to a unique type of soil—for example, it appears that soils on the greensand always have an exceptionally high percentage of coarse sand.

Returning now to Tulaikoff's summary of scientific classifications (p. 476), there still remain—(3) the *physical*, according to the mechanical composition and the physical characteristics derived from it; and (4) the *combined classification*, by which soils are divided into groups—for example, according to mechanical composition—and subdivided according to either their chemical composition or other features. The fourth method embodies the principle of the third, and we may conveniently discuss them together.

It will be seen at once that mechanical composition, on which soil-fertility so much depends, is given due prominence; while that misleading feature, chemical composition, is properly suppressed. This is the method of classification adopted by the United States Bureau of Soils. With them the series is the central term. A series is a group of soils having a common origin, and agreeing in such physical characteristics as colour, and differing only in texture. The units of which the series is composed are called "types." Thus the Miami series includes the Miami gravelly loam, the Miami fine sand, the Miami silt loam, &c. Altogether there had been recognized, in 1909, 715 different types of soil, classified into eighty-six series, which again are grouped into thirteen great soil provinces. The broader grouping into soil provinces "depends upon certain similarities in the soil, due in part to the character of the original material and in part to dominant agencies operating in the formation of the soils," such as climate, heat metamorphism, oceans, rivers, volcanoes, topography.

Any one studying Milton Whitney's bulletin* on the soils of the United States with a view to getting clear ideas as to their criteria of differentiation will be disappointed in the rather rambling, not to say ambiguous, way in which the information is given. It is believed, however, that the following is an accurate summary of the more important of their criteria of differentiation within the various divisions:—

Soil province: Climate, and mode of formation (distinct from geological origin).

Soil series: Colour†; mode of origin; structure(?) as distinct from texture; nature of subsoil to depth of 3 ft. to 6 ft.

Soil type: Texture.

It will be observed that this scheme is less likely to create distinctions where there is little or no difference, being based on those properties which play the largest part in creating differences in the agricultural characters of soils.

The present writer proposes for this Dominion a method of soil-classification similar in principle to the above, but differing in the significance of the terms "series" and "type" (formation) in ways that will presently be explained. Arguments in its favour which are of general application have been brought forward already; and in the next section arguments that apply more particularly to our special New Zealand conditions will be submitted to the reader.

## II. METHOD OF SOIL SURVEY FOR NEW ZEALAND.

It has been shown in the preceding section that the application of the geologico-petrographical method of classification in England has resulted in a multiplication of soil formations even within small areas, many of these formations being exactly similar so far as concerns their agricultural potentialities. As it has been proposed to apply this method to a soil survey of New Zealand, it is necessary to add one or two arguments that, in the writer's opinion, totally discount the applicability of this method to the soils of this Dominion.

In the first place, even assuming the success of the method in England, we must draw attention to the very different conditions here. England is a country roughly triangular in shape, of relatively low elevation, and covered to a considerable extent with soils formed *in situ*. New Zealand is a long and narrow country ranging through a thousand miles in latitude, dominated by a mountain axis of great altitude, and bordered on either flank by plains formed from the material carried down from these mountains by rivers and streams. These plains comprise a great portion of the agricultural land of the country. Many of them in both Islands are formed from the detritus of the main axis, which, throughout a great part of its length, is of tolerably uniform geological structure. The plains so formed should therefore, in a geologico-petrographical classification, be put into the same soil group.

But it has already been shown that the features chiefly responsible for the productivity of a soil are, in order of their relative importance,‡ (1) climate, internal and external; (2) texture; (3) composition; (4) nature

* U.S. Dept. of Agric., Bureau of Soils, *Bull. No. 55.*

† Colour is considered an important indicator of soil-fertility conditions by the United States Soil Survey, though why this is so is not apparent.

‡ These factors cannot be arranged in a rigid order of importance, as they react on one another.

of subsoil. Now, not only are there found in widely separated districts—*e.g.*, the Wairarapa and Canterbury Plains—soils of similar geological origin but of diverse agricultural properties owing to differences in climate, but the same thing is found even in areas of narrow limits. Thus within a few miles of Lincoln there are three different types of soil: (1) The heavy clay loam on sandy-clay subsoil of Lincoln; (2) the silty loam on fine sandy subsoil of Tai Tapu; (3) the light gravelly soil on gravel beds of Burnham.

All these soils are, of course, derived from the same kind of material (petrologically), and two at least are of similar mode of formation; they experience in general the same climatic conditions; and they are of about the same chemical composition. But because of wide differences in their textures and in the nature of their subsoils the methods of farming them are entirely different.

The writer does not deny, however, that sometimes a geological formation does give rise to a peculiar soil type—as, *e.g.*, the Lower Greensand in England. In the North Island the rhyolites and pumice of the central volcanic plateau seems to be of such a type; while in Otago the mica schists probably produce a type of soil unique physically because of the presence in amount of flat plates of mica.

In a classification of the soils of New Zealand, therefore, it is urged that the great divisions must be decided on by climatic considerations—as, indeed, nature has already indicated in the distribution of her own vegetation—while soil texture must be looked to as the main guide in further subdivision. Geological formations that give rise to soils of peculiar type must, however, be recognized, and this may be done in either of two ways: (1) by throwing such areas outside the general scheme of classification, or (2) by subdividing according to geological structure the primary divisions (see "Soil districts," below) based on climatic differences.

At this stage it will be well to take into consideration some suggestions made by Mr. H. T. Ferrar at the meeting of the Canterbury Philosophical Institute at which the first part of this paper was read. He pointed out that, as the detailed work of soil-surveying is first directed towards a classification of the cultivated land, a preliminary division of the country on soil-utilization lines is useful. He suggested that there should first be marked out: (1) Unproductive areas—*e.g.*, the mountainous region of south-west Otago; (2) areas capable of being made productive—*e.g.*, North Island forests; (3) areas that cannot be other than pasture—*e.g.*, tussock mountain-slopes; (4) areas available for cultivation. To the last two classes of land attention would naturally first be paid: the third class is capable of being made to carry more stock when the most appropriate grasses have been experimentally determined; while the fourth class includes land the productiveness of which can be raised by the discovery of the most suitable systems of cropping and manuring.

*Definition of Terms used in the Proposed Scheme of Classification.*

*Soil districts:* The great divisions based on climatic factors we propose to call "soil districts." The United States Bureau of Soils uses the term "soil province" in this sense, but in our country this term would obviously lead to confusion with the political divisions of that name.

*Subdistricts:* If geological formations occur within a soil district that give rise to soils of peculiar type the district is to be subdivided accordingly.

Such subdivisions are to be called "subdistricts." It must be emphasized, however, that such subdistricts are not to be recognized unless their soils possess unique agricultural properties, and unless such properties are directly due to geological factors.

*Soil formation:* The unit in our proposed scheme is the soil formation. This term is universally employed, though not by any means always in the same sense. We propose the following definition: A "soil formation" is a geographically continuous area covered by a soil uniform throughout as regards mode of origin, climatic conditions, texture, profile, and composition, and therefore as regards all agricultural properties. By "profile" is meant the soil section down to a depth of, say, 4 ft.

If one held rigidly to this definition a soil formation of any considerable size would not be found: every farmer will declare that he has two or three kinds of soils on his farm. Nevertheless, areas of some magnitude, thirty to forty square miles and upwards, do exist in which the exceptional parts are relatively so small as to be negligible, and such areas can conveniently be studied as units.

*Soil series:* A "soil series" is defined as a group of separate formations alike in the aggregate of their agricultural properties. The formations need not necessarily be identical in every respect, but if they agree so far that their agricultural properties and potentialities are the same they are put into the same soil series. To give an illustration: The Lincoln formation differs in some respects from the Methven formation—their subsoils, for instance, are not alike; that at Lincoln is a sandy clay, while that at Methven is more porous. But the smaller capacity of the Methven soils to retain water is compensated by a rather greater rainfall, so that agricultural practice on each formation is very similar. These formations are therefore put (provisionally at least) in the same series.

*Facies:* It has been said that a formation will usually include small areas with exceptional characters. These are not likely to be delineated or described until the individual formations come to be studied in detail, and when this stage is reached the term "facies" may be appropriately applied to them. Thus the typical soil of the Lincoln formation is a clay loam on a deep sandy-clay subsoil; but near Lincoln College there is a strip of gravelly soil in a shallow sandy-clay subsoil, on gravel beds. This exceptional area is more or less clearly marked, and constitutes a "facies."

## *Nomenclature.*

The soil districts may conveniently be described in geographical language, thus: The Canterbury Plains district, the North Otago district, the Wellington East district. and so on. The series-names obviously should not be place-names, as the idea of a series is simply a set of soil formations of like agricultural properties. It is suggested, therefore, that the most suitable form of name is one indicative of the more important characters common to the formations constituting the series—as the Loam-on-clay series; the Alluvial series; the Scrub-lands series; the Downs series. The formation, being a geographical entity, is best named after some local place name. This need not be the most important place politically, but should be that place where the soil is being studied by means of continuous field experiments or otherwise. Thus the experimental farms should give their names to the local forma ion—as, *e.g.*, the Weraroa formation, the Ruakura formation.

*Recapitulation.*

The writer submits the following proposals regarding the proposed soil survey of the Dominion:—

(1.) A combined system of classification is best suited to New Zealand conditions.

(2.) The Dominion should first be divided into soil districts, the critical differences being climatic; and districts may be subdivided into sub-districts if important differences in agriculture due to geological structure so demand.

(3.) Within the soil districts the limits of individual soil formations must be determined by study in field and laboratory, the critical differences being (*a*) mode of origin, (*b*) texture, (*c*) situation with reference to water-supply, (*d*) profile, (*e*) composition.

(4.) Formations alike as regards chief agricultural properties and potentialities should be grouped into series, so that full use may be made of the results of field experiments.

Finally, we may represent our scheme of classification diagramatically as shown below:—

Soils of New Zealand

| | | | |
|---|---|---|---|
| Unproductive. | Capable of being made productive. | Pasture only. | Suitable for cultivation. |

Soil districts.

Soil formations (grouped into soil series).

## III. Application of Principles.

In this section an attempt is made to apply some of the principles advocated above by a consideration of the soils of the South Island.

Following is a provisional list of the soil districts. It is open to revision or even to complete recasting, because it has been shown that the proper demarcation of district boundaries involves a knowledge of the meteorology, the geology, the botany, and the topography of the Dominion—in fact, it is the work of a committee rather than of an individual. In practice a knowledge of the distribution of the native flora should be of first-class importance; when the ecologist has shown us the boundaries of the plant provinces it will probably be found that the same boundaries will serve for the soil districts.

*Soil Districts of the South Island, New Zealand.*

1. South Marlborough District: Bounded on the north by the Wairau Valley (included), on the west by the average limit of the western rainfall, and on the south by the Waipara Valley (excluded). Mean annual rainfall, 25–40 in.

2. Canterbury Plains District: Bounded on the north by the Waipara Valley (included), on the west by the average limit of the western rainfall, and on the south by the Waitaki Valley (included). Mean annual rainfall, 18–26 in. on the coastal margin, 25–40 in. inland.

3. Banks Peninsula District: Banks Peninsula. Mean annual rainfall, 30–50 in.

4. Central and North Otago District: Bounded on the north by the Waitaki Valley (excluded), on the west by the limit of western rainfall, and on the south by a line joining Queenstown and Palmerston. Mean annual rainfall, 15–30 in. (Note: A subdivision of this district will probably prove necessary.)

5. South Otago District: Bounded on the north by a line from Palmerston to Queenstown, thence to Manapouri, thence (including the Mossburn, Five Rivers, and Waimea Plains) along the Mataura Valley (excluded) to the sea.

6. Southland District: Bounded on the east by the Mataura Valley (included), on the north by the South Otago District, on the west by the Waiau Valley (included). Mean annual rainfall, 40–60 in.

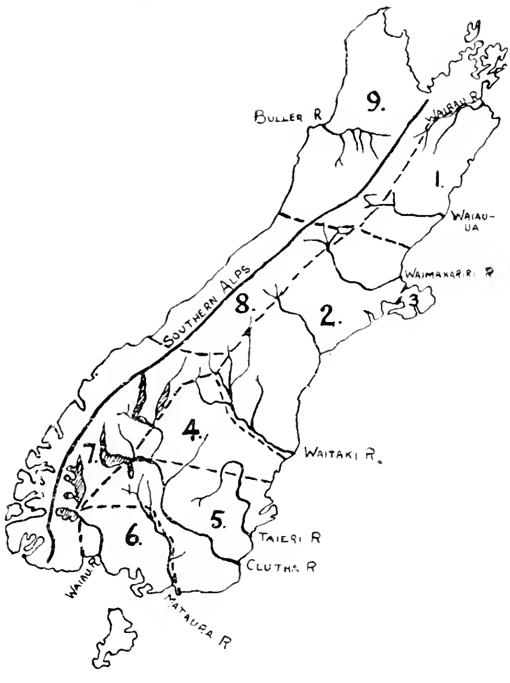



FIG. 1.—Soil districts of the South Island, New Zealand.

1. South Marlborough. 2. Canterbury Plains. 3. Banks Peninsula. 4. Central and North Otago. 5. South Otago. 6. Southland. 7. Sounds. 8. Westland. 9. Nelson.

7. Sounds District: Bounded on the east by the Southland and South Otago Districts to Queenstown, thence by the limit of western rainfall to the Haast River. Mean annual rainfall, 100–200 in.

8. Westland District: Bounded on the south by the Haast River, on the east by the limit of western rainfall, and on the north by the Taramakau River. Mean annual rainfall, 100–150 in.

9. Nelson District: Bounded on the south by the Taramakau River, on the east by the limit of western rainfall as far north as the Wairau Valley, thence along the Wairau Valley (excluded). Mean annual rainfall, 30–100 in. (Note: A subdivision of this district will probably prove necessary.)

Fig. 1 shows the approximate boundaries of these districts.

We further suggest a standard method for the description of a soil formation. One advantage of the methods of soil survey proposed in this article is that the whole is built up from small units. It will be possible for the qualified teachers of agricultural science in the schools and colleges throughout the Dominion to describe the soil formation on which they are located; so that gradually, as information accumulates, the formations may be grouped into series, and practical conclusions of some importance may be expected.

*Scheme for Description of Soil Formation.*

1. Boundaries: Roads or railways will usually be found most suitable until the exact boundaries can be determined in detail. Rivers and hills will usually be unsuitable, as lying wholly within or wholly without the formation.

2. Physiography and topography: A general account of the more important physiographical features, such as rivers, hills, &c.

3. Mode of formation of soil, whether sedentary or transported; water-supply, surface and subsurface.

4. Meteorological statistics so far as available: Rainfall, average annual fall, and seasonal distribution; mean monthly temperature, maximum and minimum; amount of bright sunshine; quality and quantity of wind.

5. Mechanical analyses of samples taken on an average of one per square mile: Soil should as a rule be taken 6 in. deep; subsoil (the next layer) 6 in. deep.

6. Chemical analyses of composite samples representing uniform areas of ten or twelve square miles: The chief determinations should be of lime, magnesia, phosphoric acid, and potash soluble in strong hydrochloric acid. Organic matter may be determined as loss on ignition. The amount of calcium carbonate will often be a matter of importance. A lookout should always be kept for any connection between the amounts of the minerals and the manurial requirements of the soils.

7. Profile: This can usually best be represented by a sketch, the various materials being conventionally represented as shown in fig. 2.

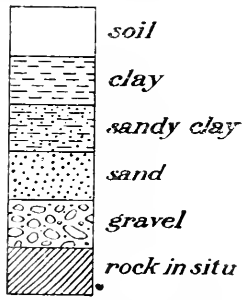



Fig. 2.—Conventional sketch of a soil profile.

8. Information from experienced farmers on the formation regarding crops, manures, and cultivation best suited to the soil.

9. Results of any reliable manurial or varietal experiments that have been made.

10. Lists of prominent weeds, especially those of untended land.

It should be clearly understood that the primary object of the preliminary local work is not an attempt to discover the "philosopher's stone" of the local agriculturist. The first aim is descripton; then comes correlation—an attempt to connect the practical field observations with analytical and other results obtained in the laboratory; finally, when sufficient results have been collected and compared, will come inference—the laying-down of such rules of practice the proof of which has been found in the previous systematic study.

## Art. XLII.—*Fluctuations in the Water-level of some Artesian Wells in the Christchurch Area.*

By F. W. Hilgendorf, D.Sc.

[*Read before the Canterbury Philosophical Institute, 6th September, 1916; received by Editors, 30th December, 1916; issued separately, 10th December, 1917.*]

In 1896 Hutton recorded the fluctuations of two artesian wells at the Christchurch Museum.* Speight continued the observations on one of the wells in 1910,† and since then has taken occasional readings, copies of which he has kindly given me for the purposes of this paper. In 1911 I took a series of readings on a 340 ft. well at Lincoln College, fourteen miles south-west of Christchurch,‡ and have taken monthly readings ever since. From 1912 till the present time Mr. A. D. Dobson, Christchurch City Surveyor, has taken observations on a 217 ft. well at Merivale, a mile and a quarter north-west of the Cathedral, and has given me his readings. In 1914 Mr. Symes and I, aided by a grant from the Hutton Fund, erected a continuous-record machine on a well of uncertain depth on Papanui Road, about three miles north-west of the Cathedral (see this volume, p. 493), and the readings of this well have been used here. The graph shows the fluctuations in the static level of the water in these four wells. The comparatively small variation in the three Christchurch wells as contrasted with the large variation of the Lincoln well affords conclusive proof that the wells in the neighbourhood of Christchurch have a relatively constant source of supply, while the well at Lincoln has a relatively intermittent one. The most reasonable explanation of this feature of the graph is that the main supply of the Christchurch artesian wells comes from the Waimakariri River, while the Lincoln well is supplied chiefly by the rainfall direct, or by percolation from the Selwyn River, which in its middle course flows only during or after heavy rains.

There are two facts that might be used to controvert this explanation were the evidence of the present graph not so overwhelming.

(1.) The Christchurch wells do, as was pointed out by Hutton and Speight, respond very rapidly to a day's rain, but that the rainfall is their chief source of supply is rendered improbable by their relative steadiness during the dry years 1914–16. There can be no influence of either the rainfall or the Selwyn River that would not be more distinctly felt at Lincoln than at Christchurch, as will be shown by a glance at the map in *Trans. N.Z. Inst.*, vol. 44, 1912, p. 146. If either of these influences, then, kept the Christchurch wells steady, they should have kept the Lincoln well steady too, and therefore we are driven to conclude that percolation from the Waimakariri is the chief source of the Christchurch supply.

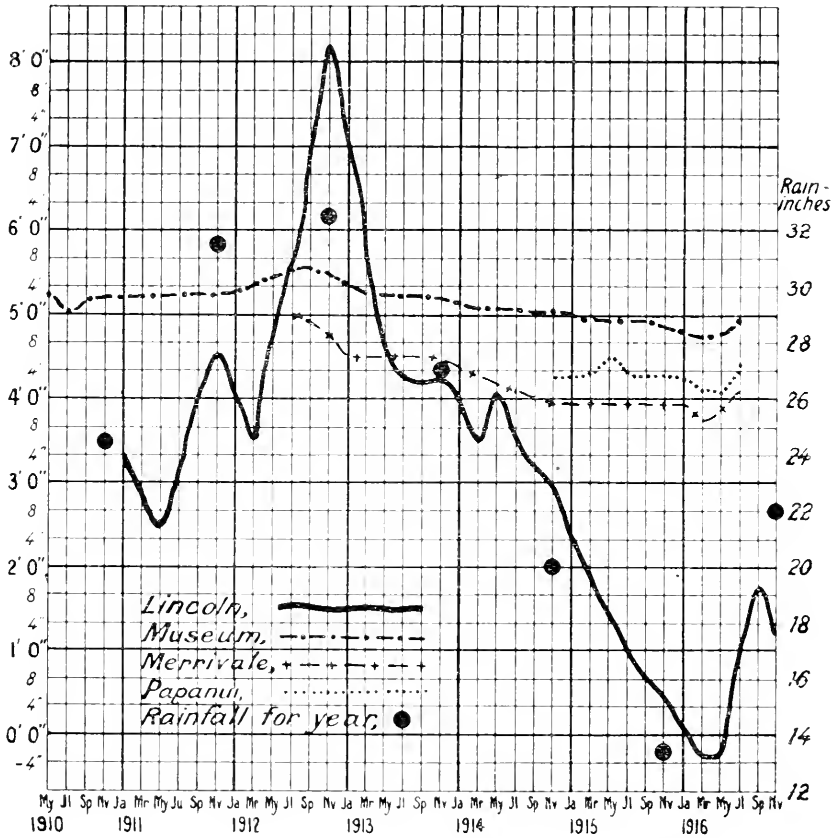
(2.) The second observation that does not support this supposition is that floods in the Waimakariri do not influence the level or the flow of the

* F. W. Hutton, On the Behaviour of Two Artesian Wells at the Canterbury Museum, *Trans. N.Z. Inst.*, vol. 28, 1896, p. 654.

† R. Speight, A Preliminary Account of the Geological Features of the Christchurch Artesian Area, *Trans. N.Z. Inst.*, vol. 43, 1911, p. 420.

‡ F. W. Hilgendorf, Fluctuations in the Level of the Water in some Artesian Wells in the Christchurch Area, *Trans. N.Z. Inst.*, vol. 44, 1912, p. 142.

Christchurch wells, as has again been noted by Hutton. But, since the Waimakariri is flowing always, it is probably losing water by percolation always, and not only during floods; and the rise of water-level may be so toned down by passage through miles of gravel as to be unrecognizable by the time it reaches Christchurch. This is rendered probable by the behaviour of the well at Belfast, six miles from Christchurch, as described by me,* where a river rise of 8 ft. gave a well rise of 5 in. The absence




Graph showing fluctuations in static level of four artesian wells in or near Christchurch.

of response of Christchurch wells to Waimakariri floods, then, is not necessarily at variance with the evidence of the graph, that the Waimakariri is the chief source of the Christchurch artesian water-supply.

In 1862 or 1863, at R. Taylor's brewery, on the site of the present Normal School, some pipes were driven into the ground to form a staging. After a time water was found flowing from these pipes, which thus formed the first artesian well in Christchurch. The City Council then sank a 2 in. pipe at the corner of Tuam Street and Ferry Road to a depth of 81 ft., and

* *Loc. cit.*, p. 158.

a good flow resulted. This well was completed on the 10th February, 1864, and on the 15th February, 1864, the Council started another well, this time in Cathedral Square. For the above information I am indebted to Mr. J. Lothian Wilson, of Kaiapoi. From this date onwards for about fifty years thousands of private wells were sunk in the Christchurch area, and it was soon found that the earlier ones, sunk to depths of 40 ft. and 80 ft., suffered a serious and continuous fall in their static level. Deeper and deeper wells were then sunk, tapping various water-bearing strata down to 400 ft. in depth. The fall in the static level of large numbers of wells was viewed very seriously, as indicating a possible failure of the water-supply; but the evidence of Hutton and Speight's long-period observations on the Museum well shows that the fall has been checked, if not arrested. The static level of the 190 ft. well above Hutton's datum was, in

| | | |
|---|---|---|
| 1894 .. .. | 9 ft. 8 in. | Average fall per year, 3·5 in. |
| 1910 .. .. | 5 ft. 3 in. | |
| 1916 .. .. | 5 ft. 0 in. | Average fall per year, 0·5 in. |

At the time Hutton made his observations he estimated the yearly fall at 5·5 in., so that its rate has been greatly reduced during the last twenty-two years.

Why the wells have ceased to fall is not certain. There are good grounds for believing that it is due to natural causes connected with the supply of water from the Waimakariri and the under-drainage to the sea. But in 1909 the City Council sank, within the area of an acre or two, four wells, 8 in. in diameter, to the 80 ft. stratum, and from these and three similar wells sunk in 1912 water is pumped to supply nearly the whole town. From this date, then, the sinking of private wells almost entirely ceased, and this fact may have so important a bearing on the static level of the pre-existing wells that the matter is not suitable for discussion until a new series of long-period observations have been made.

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## ART. XLIII.—*Note on the Fluctuation of Water-level in a Christchurch Artesian Well.*

By L. P. SYMES.

[*Read before the Philosophical Institute of Canterbury, 2nd August, 1916; received by Editors, 30th December, 1916; issued separately, 10th December, 1917.*]

MANY writers, notably Hutton, Speight, and Hilgendorf, have discussed the Christchurch artesian system, and have shown that the water-level rises every evening, that it rises with rain, and that the Waimakariri River has no apparent influence. Hutton also described a "Sunday rise." These results were founded on intermittent observations made at hourly or less frequent intervals. To obtain more definite knowledge the writer, in conjunction with Dr. Hilgendorf, set up an instrument to make continuous records of the fluctuations in water-level. An isolated well at Papanui, not in use, was selected, though unfortunately its depth is not yet ascertained. This note deals with some of the results obtained through the records of twenty months. The records give a fairly accurate tracing of the movements of the water-level, but owing to a lag in rise and fall of about $\frac{1}{8}$ in. the curve is slightly flattened. The error in timing sometimes amounts to three hours. The records show three distinct classes of fluctuation—a daily fall and rise, a rise with rain, and erratic fluctuations without recognized causes.

*The Daily Fluctuation.*—Except when rain interferes, the well traces a daily curve of fairly constant form with a maximum height between 6 a.m.

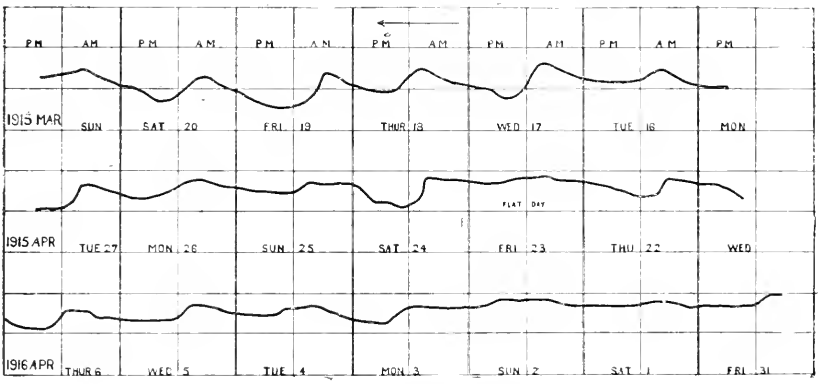



FIG. 1.—Three typical weeks.

and 9 a.m., and the lowest point at about 4 p.m. Fig. 1 shows three typical weeks with the daily curves well marked. The daily curve is gradually modified day by day, and the amount of fall varies between $\frac{1}{4}$ in. and $1\frac{1}{2}$ in. At times "flat days," of which an example is given, appear in a series of well-marked curves. No marked difference between Sundays and week-days has been detected. The modifications of the daily curve do not appear

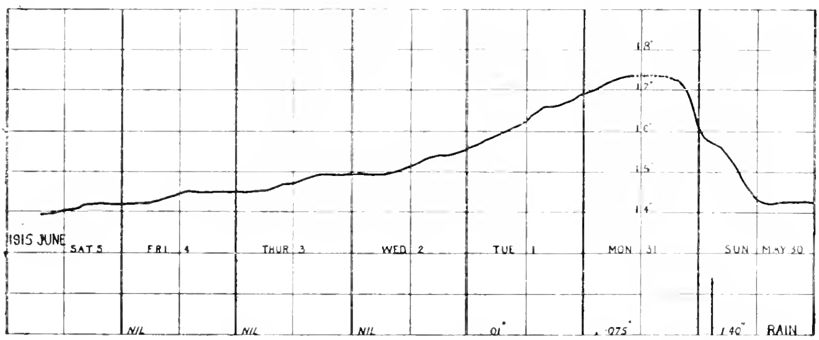



FIG. 2.—Rise and fall after rain.

to be seasonable, though the boldest curves usually appear in spring and autumn. Displacement of the time at which the daily fall commences is apparently associated with rain. While the causes of the daily tide are still obscure, the writer believes it to be a natural phenomenon, and not due to human interference with the water system.

*The Rise after Rain.*—As was expected, rain causes a rise of level, the well responding with remarkable rapidity, and on certain observed occasions a rise has commenced within an hour of the rain commencing. With a heavy rain the rate of rise may amount to 1 in. in three hours and a half. Shortly after the rain stops the level falls rapidly for a period—about four or five times as long as the rising period. In this fall the greater part, sometimes the whole, of the gain disappears. Fig. 2 is a record of a heavy-rain

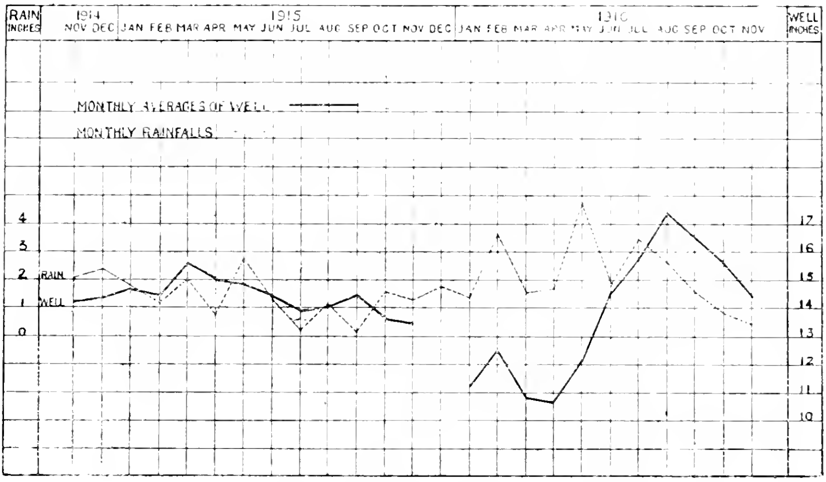



Fig. 3.—Comparison of monthly average heights of well with monthly rainfalls at Christchurch.

rise in which the whole gain was lost. Fig. 3 is a comparison of the monthly average heights of the well with the monthly rainfalls at Christchurch, and shows how they fluctuate in sympathy.

The years 1914 and 1915 were very dry, and 1916 is about normal in rainfall. The similarity of the 1916 portion of this well graph to that of the Lincoln well obtained in 1910 by Hilgendorf* is remarkable.

It was noted that the well rises with very light rains, and on one particular occasion responded to a rain which, terminating a long dry period, wet garden soil to a depth of only ½ in.

*Other Fluctuations.*—There are occasionally other rises without apparent cause: none could be attributed to the influence of the Waimakariri River. Heavy traffic on the tram-line passing about 30 ft. distant causes a distinct wave-like oscillation in the well.

The writer's thanks are due to Dr. F. W. Hilgendorf for assistance and advice, and to Mr. H. F. Skey for rainfall data.

* F. W. Hilgendorf, Fluctuations of the Level of the Water in some Artesian Wells in the Christchurch Area, *Trans. N.Z. Inst.*, vol 44, 1912, p. 143.

Art. XLIV.—*Apparatus for the Determination of the Magnitude of Small Forces, especially useful in connection with Hydraulic Experiments.*

By Professor R. J. Scott, M.Inst.C.E., M.I.Mech.E., F.A.I.E.E.

[*Read before the Philosophical Institute of Canterbury, 6th Septeember, 1916; received by Editors, 30th December, 1916; issued separately, 10th December, 1917.*]

Being desirous of conducting some experiments on surface friction, on the resistance of ship-shaped models, and on the impact and reaction of jets, the author devised a piece of apparatus for use in the experimental tilting-tank at Canterbury College, the construction and action of which will be made clear by a description of the surface-friction experiments.

For these, a ballasted plank, with shaped ends, is suspended on a bifilar suspension in a channel, through which a steady stream of water flows. The plank has fixed upon it a knife-edge, which engages with a suspended lever provided with a pointer and angular scale. A second knife-edge is clamped to a fine oiled silk line, which is strained over four aluminium pulleys, running on centres, and kept taut by equal weights in scale-pans attached to its ends.

The pulleys are situated two at either end of the tank, the axes of each pair being in a vertical plane, at right angles to the stream and above it. The lower pulley is in each case adjustable vertically. The oiled silk line is thus strained in the medial plane of the stream and slightly above its surface. The down-stream set of pulleys acts simply as a locating and straining mechanism. The up-stream set is mounted on a carriage capable of travelling along the stream, and constitutes both a straining and measuring arrangement.

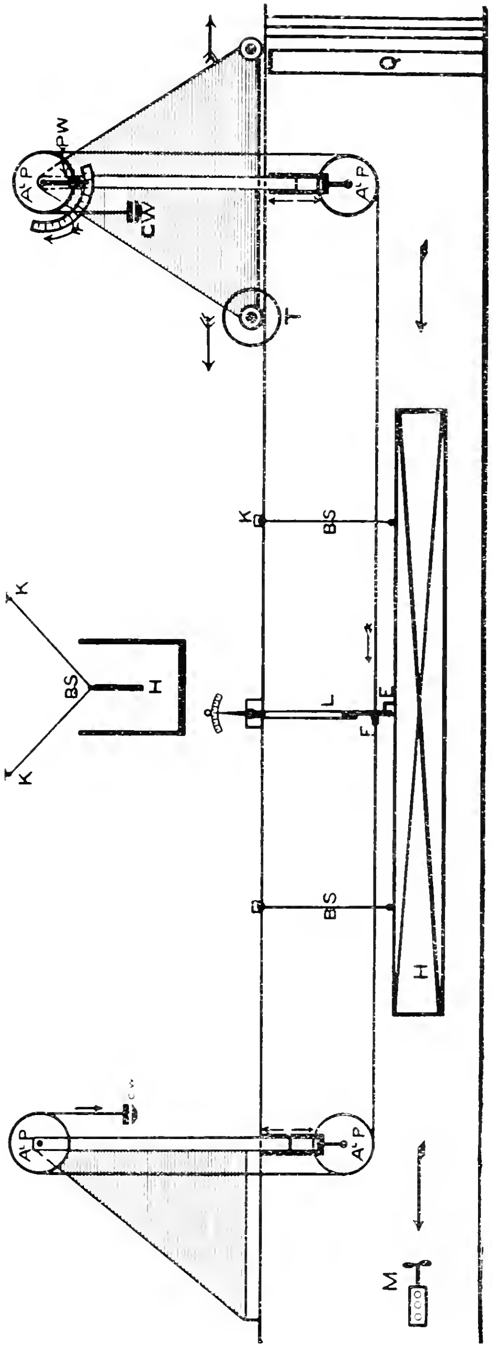
Measuring is effected by the silk line passing completely round the upper pulley, to the axis of which is fixed a pendulum, which is lifted to a degree proportionate to the torque exercised by the pull on the string, the angle being read off by means of a pointer and scale. When in use the action of the water on the plank drives it down-stream until the tangential force is balanced by its weight and that of the suspended lever.

The carriage supporting the weighing mechanism is then advanced, thus exercising a pull on the silk line, until the pointer attached to the suspended lever at the plank reaches zero. The angle to which the pendulum on the carriage has been lifted is then noted, and the pull readily obtained from a calibration table.

The fact that the taking of a reading requires a general displacement of the system eliminates the friction of rest, and adds greatly to the accuracy of the observation.

For experiments on impact, the various vane forms are bolted directly to the lever and the weights on the measuring-pendulum are increased.

Since the resistance torque is proportioned to $W\ r \sin \theta$, it is evident that by choosing a suitable weight of pendulum the sensitiveness and capacity of the apparatus can be varied over a wide range. It can be adjusted to measure a variation in pull of 1 gramme, whilst its adaptability is evident from the fact that for a continuation at higher velocities of the surface-friction experiments it is intended to suspend the *channel* and measure directly the tangential pull of the water on its sides, thus eliminating the wave-making due to the plank-ends.




APPARATUS FOR THE MEASUREMENT OF SMALL HYDRAULIC FORCES.

## Art. XLV.—*An Arrangement for quieting the Flow of a Stream of Disturbed Water.*

By Professor R. J. Scott, M.Inst.C.E., M.I.Mech.E., F.A.I.E.E.

[*Read before the Philosophical Institute of Canterbury, 6th September, 1916; received by Editors, 30th December, 1916; issued separately, 10th December, 1917.*]

In order to measure with reasonable accuracy the discharge of water over a notch or weir it is necessary to first destroy the waves and eddies present in the stream—in fact, to approximate as closely as possible the conditions of stream-line flow. In practice the following methods have been adopted :—

(1.) The use of a pond above the notch.
(2.) The use of deflector plates.
(3.) The use of perforated plates.
(4.) The use of wire-gauze screens.

The use of a pond above the notch is an efficient and simple method of dealing with the discharge of small streams. The pond is easily constructed; the water is brought nearly to rest and eddies are damped out. It is, however, ineffective in windy weather, and evidently cannot be adopted for flows of any magnitude, nor in the laboratory.

Deflector plates reduce surface-disturbances, but the presence of the plates gives rise to a new series of eddies (fig. 1). For this reason deflector plates are often combined with the perforated plates or wire-gauze screens.

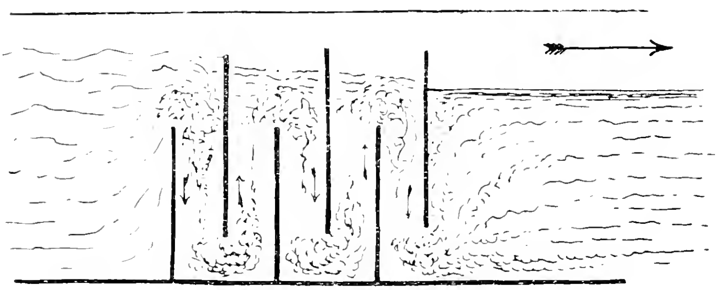


Fig. 1.—Action of deflectors.

With perforated plates the dead-water behind the unperforated portion of the plate gives rise to eddies; surface-disturbance also occurs owing to the drop of a number of small streams (fig. 2).

These disturbances are smaller in the case of wire-gauze screens, which, however, are difficult to keep in a sufficiently clean condition to permit of the necessary freedom of flow.

None of these methods being sufficiently effective to quiet the flow to the degree required for some experiments on surface friction, the author devised the following arrangement :—

After being roughly quieted by ordinary methods, the water is passed through a vertical screen (fig. 3) consisting of bars of fish-shaped section, the up-stream end of each being convex and one-third of the total length, the down-stream end being concave and terminating in a knife-edge. There

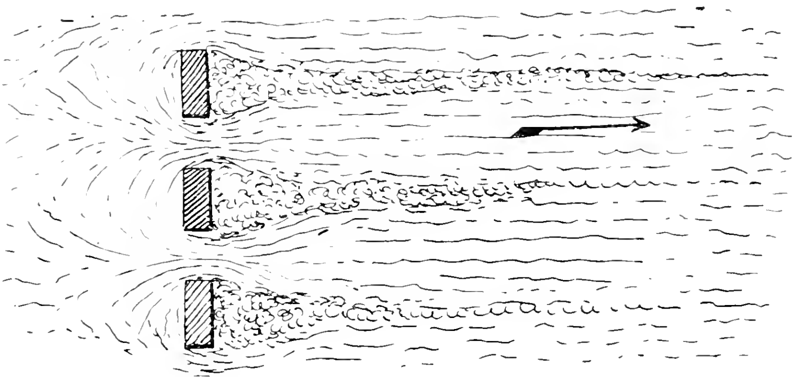


FIG. 2.—Action of perforations.

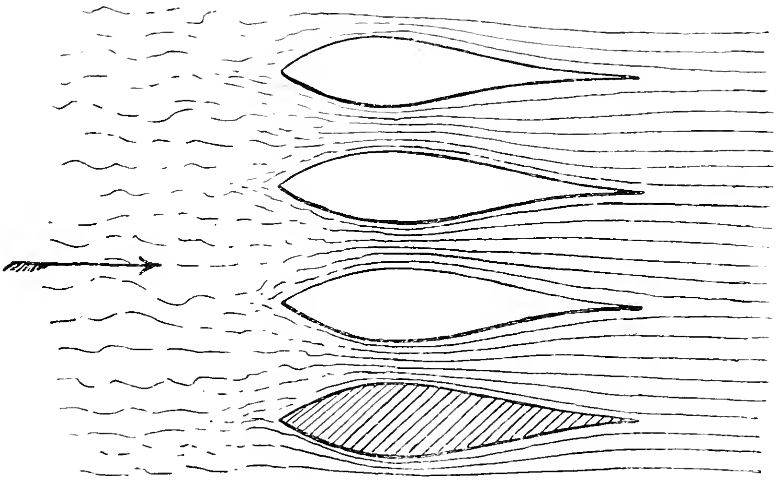


FIG. 3.—Action of improved grating.

is thus no dead-water, and the formation of eddies from this source is prevented, whilst eddies previously existent are destroyed by the water being streamed through cross-sections which first gradually decrease and then gradually increase.

One such screen has proved sufficient for the author's purposes, but in some cases it is possible that the addition of a second screen at right angles to the first might be desirable.

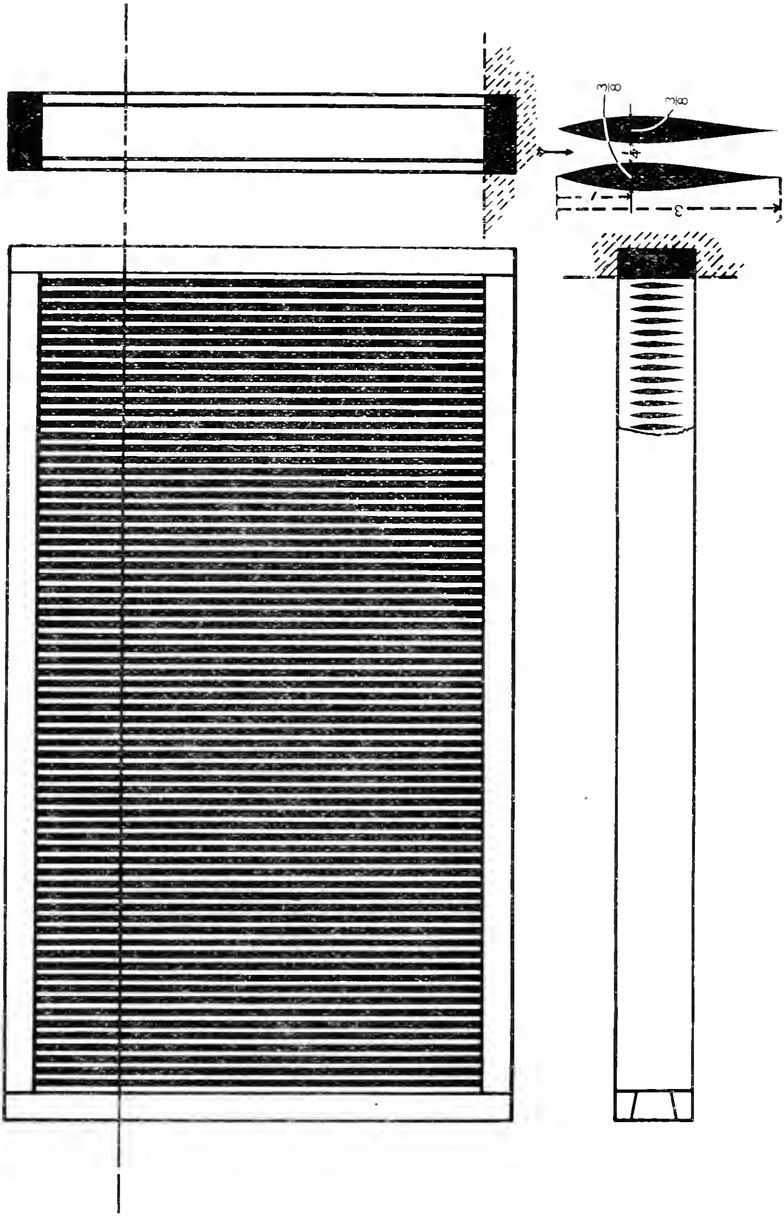


FIG. 4.—General view of screen.

# ART. XLVI.—*A Study of the Electrical Deposition of Nickel in the Presence of Nitrate.*

By JAMES G. ANDERSON, M.Sc., Collegiate School, Wanganui.

Communicated by Mr. L. J. Wild.

[*Read before the Philosophical Institute of Canterbury, 6th December, 1916; received by Editors, 30th December, 1916; issued separately, 10th December, 1917.*]

THE modern method usually employed in the electrical separation of nickel originated in the use of the double sulphate of nickel and ammonium first suggested by Professor Boettger in 1843. The deposition, however, was very slow, and the conductivity of the electrolyte was extremely small. To remedy this latter defect a number of substances were suggested, ammonium sulphate being most frequently used for the purpose. Under suitable conditions a good coherent deposit can be obtained, and the process, though lengthy, admits of a quantitative estimation of the amount of nickel present in a solution.

Numerous experimenters have observed that nitrates exert a most disturbing effect on such estimations. In recent years Thiel* found that the presence of nitrites yields high results owing to deposition of nickel oxide on the cathode. The present investigation was undertaken to study the effect of the addition of known amounts of nitrate on the deposition of the metal, and to eliminate the disturbing products of the electrolysis.

## EXPERIMENTAL DETAILS.

The apparatus used consisted of a glass beaker containing the solution to be electrolyzed, in which were suspended the electrodes. These were of iridio-platinum, and were of the form devised by Perkin.† The cathode was made of gauze, and possessed a total surface of 50 sq. cm.; the anode is opposed to both sides of the cathode during electrolysis, and consequently an even current-density is obtained on all parts of the cathode.

The conditions under which the investigations were conducted were those recommended by Marshall,‡ viz.,—

| | |
|---|---|
| Amount of nickel to be deposited (approx.) .. | 0·3 grm. |
| Volume of solution .. .. .. .. | 150 c.c. |
| Ammonium sulphate .. .. .. .. | 5 grm. |
| Ammonia .. .. .. .. .. | 5 grm. |

The experiments were made at the ordinary temperature, and about four hours was found necessary to complete the electrolysis.

The solution of nickel sulphate to be used in the subsequent course of the work was carefully standardized; a large number of determinations were made under precisely similar conditions, and the results showed close

* A. THIEL, *Zeitsch. Elektrochem*, vol. 14, 1908, pp. 201–8.

† W. PERKIN, A New Form of Electrode, *Journ. Faraday Soc.*, vol. 1, 1903.

‡ A. MARSHALL, Some Polarisation Phenomena, *Proc. Roy. Soc. Edin.*, 1899.

agreement, as the following figures indicate: Amount deposited after four hours, 0·3088 grm., 0·3087 grm., 0·3090 grm., 0·3084 grm., 0·3069 grm., 0·3085 grm.; yielding a mean value of 0·3084 grm. when 5 c.c. of the standard solution with the ammonia and ammonium sulphate (to increase the conductivity) added was electrolyzed.

## Series 1.

(Solution containing no nitrate.)

The first series of experiments was conducted with the solution as indicated above, in the absence of nitrate, with the object of obtaining a curve showing the rate of deposition of the metal. This was effected by interrupting the electrolysis after it had proceeded a definite time, and then washing, drying, and weighing the cathode in the usual manner. At the same time, during the course of the electrolysis, readings were taken continuously of (i) ammeter, (ii) P.D. across the terminals of the electrolytic cell, (iii) P.D. at the cathode.

*Ammeter Readings.*—These were noticed to exhibit slight variations, though they remained practically constant throughout each experiment. A small initial rise was invariably noticeable, due probably to increase in temperature as a result of the ohmic resistance encountered, and towards the conclusion of an experiment a diminution was always observable. The extent of these fluctuations never exceeded 0·1–0·15 amp., and to facilitate subsequent investigations it was decided to maintain the current at a constant value by inserting an adjustable resistance in the circuit. It did not seem possible to deduce anything of importance from a study of these small variations.

*Voltmeter Readings.*—The readings of the voltmeter were found to exhibit a much more marked fluctuation. A considerable number of experiments were conducted so as to confirm the unusual nature of the variations, and it was found that they could be divided into three stages: (*a*) Very slight rise during the first hour, followed by a return to the initial value; (*b*) period during which the voltmeter remained approximately constant; (*c*) towards the end of an experiment a distinct rise in P.D. could be detected, amounting to 0·2–0·4 volt. These stages were not always clearly defined, though the final rise was almost invariably observed. This would correspond to increased resistance between the electrodes, and, on account of the presence of the ammonium sulphate, it could not be explained by a diminution in the conductivity of the solution. Further, it is noticed after almost all the nickel has been deposited and only traces remain in solution. The removal, then, of these last traces of the metal must involve the expenditure of more electrical energy and indicate the presence of polarization phenomena. Marshall (*loc. cit.*) suggests that "a film of some other substance is deposited giving a higher polarization effect. At first this is replaced more or less by nickel, and occasionally breaks down, as shown by the lapses to the original potential, possibly on account of the richer solution being brought against it by convection currents, but it ultimately becomes permanent when the nickel deposition is completed." In the case of this investigation, as in that of Marshall, the final rise appears to be an indication that the deposition is complete.

*Potential Difference at the Cathode.*—To study the changes in P.D. at the cathode the arrangement depicted in fig. 1 was employed.

The composite cell consisted of calomel electrode, Ni–$NiSO_4$ (ammon.).

From the known value of the E.M.F. of the Weston standard cell that of the composite cell could be calculated; and, taking 0·613 as the P.D. at the calomel electrode, it was possible to deduce the variation in the single P.D. Ni–$NiSO_4$ at the cathode as deposition continued (figs. 2 and 3) in the absence and in the presence of ammonium nitrate.

*Rate of Deposition.*—It was noticed that when using the sulphate in the ordinary manner 80 per cent. of the nickel was deposited during the first hour of the electrolysis. The quantity of electricity and the time

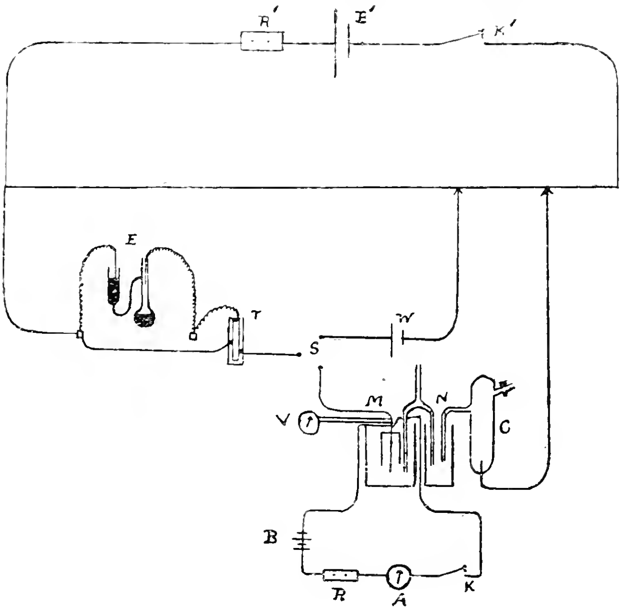



FIG. 1.

B′—storage cells, giving a uniform fall of potential along the bridge wire XY: R′—adjustable resistance; K′—key.
B—battery connected to terminals of electrolytic cell M. By means of R, an adjustable rheostat, the current as indicated by the ammeter A is maintained at a constant value. K—key.
C—calomel electrode (N/10 KCl) dipping into connecting vessel N, containing ammonium sulphate. A siphon, also containing ammonium sulphate, serves to connect N and the electrolytic cell M, one arm being placed in the immediate vicinity of the cathode.
V—voltmeter placed across the terminals of the electrolytic cell M.
E—Lippmann capillary electrometer; T—short-circuiting key; S—switch.
W—Weston standard cadmium cell.

necessary to remove the final traces of nickel from the solution are out of all proportion to the amount of metal actually present.

On the basis of Faraday's quantitative law, $W = \gamma\eta t$ (where W = weight in grammes of metal deposited, $\gamma$ = current in amperes, $\eta$ = electrochemical equivalent of metal, $t$ = time in seconds), the theoretical amount of nickel was computed on the assumption of perfect efficiency, and on comparison with the experimental values the working efficiency was found to be 25–30 per cent.

*Results.*

Each experiment of the series was repeated a number of times, and the agreement between the sets of values was found very satisfactory, and sufficient to confirm the general nature of the results. Typical series of values and curves are given below :—

| | Time. Hours. | P.D. Volts. |
|---|---|---|
| 1. Variation of P.D. between terminals .. | 0 | 3·6 |
| | ½ | 3·65 |
| | ¾ | 3·6 |
| | 1½ | 3·7 |
| | 2 | 3·8 |
| | 3½ | 3·87 |
| 2. Variation of P.D., cathode solution (fig. 2, *a*) | 0 | 0·878 |
| | ½ | 0·874 |
| | 1 | 0·870 |
| | 1½ | 0·865 |
| | 2 | 0·860 |

| | Time. Hours. | Amount in Grammes. |
|---|---|---|
| 3. Rate of deposition of nickel (fig. 4, *b*) .. | 1 | 0·2680 |
| | 2 | 0·3050 |
| | 3 | 0·3077 |
| | 4 | 0·3087 |

SERIES 2.

In this series of experiments varying amounts of ammonium nitrate were added to the solution, and the observations repeated as in the preceding series. The conditions were precisely similar, but in this case the current was kept at a constant value.

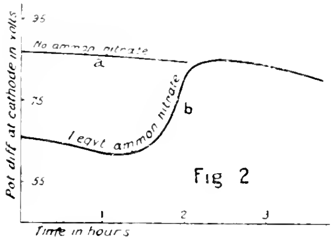
*Results.*

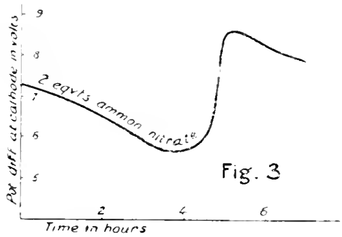
1. P.D. across terminals : The variations were not so general and definite as in the former series. During the larger part of an experiment the P.D. remained practically constant, and towards the end a fall, and not a rise, was observed. Whatever the explanation may be, the presence of the nitrate appears to have the effect of removing the polarization by destroying the film deposited on the cathode, which, as Marshall suggests, is the cause of the increased resistance observed in the previous case.

2. P.D. cathode solution : Here an interesting periodicity was found to be quite general. The curves indicating the variation of the P.D. with time are appended, and it will be seen that they consist of three distinct portions : (*a.*) At first a gradual diminution is observed, the extent of the diminution and the period during which it persists depending upon the actual amount of nitrate present in the solution. (*b.*) This is in every case followed by a sudden rise—very pronounced. (*c.*) After the maximum value of (*b*) is attained, the P.D. gradually diminishes as time proceeds.

| | Time. Hours. | P.D. Volts. |
|---|---|---|
| Values— (*a.*) One equivalent of ammonium nitrate (fig. 2, *b*) | 0 | 0·660 |
| | 1 | 0·635 |
| | 1½ | 0·646 |
| | 2 | 0·820 |
| | 2¼ | 0·851 |
| | 3 | 0·837 |
| | 3½ | 0·815 |
| | 4 | 0·793 |

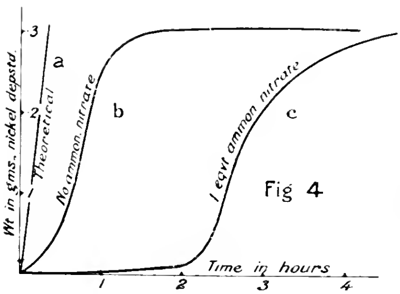
| | Time. Hours. | P.D. Volts. |
|---|---|---|
| (*b*.) Two equivalents of ammonium nitrate (fig. 3) | 0 | 0·726 |
| | 2 | 0·655 |
| | 2½ | 0·615 |
| | 3 | 0·585 |
| | 4 | 0·579 |
| | 4½ | 0·616 |
| | 5 | 0·859 |
| | 6 | 0·825 |

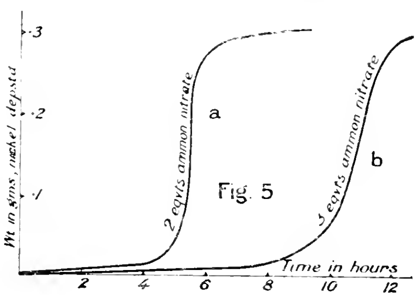



3. Rate of deposition : The rate of deposition of the nickel was found to be enormously affected by the addition of ammonium nitrate. The following typical values may be given from a number of closely agreeing experiments where one, two, and three equivalents of nitrate were added to the solution :—

| | Time. Hours. | Amount deposited. Grammes. |
|---|---|---|
| (*a*.) One equivalent of ammonium nitrate (fig. 4, *c*) | 1 | 0·0065 |
| | 2 | 0·0382 |
| | 3 | 0·2234 |
| | 4 | 0·2861 |
| | 5 | 0·3050 |
| (*b*.) Two equivalents of ammonium nitrate (fig. 5, *a*) | 2 | 0·0061 |
| | 4 | 0·0153 |
| | 5 | 0·0813 |
| | 6 | 0·2748 |
| (*c*.) Three equivalents of ammonium nitrate (fig. 5, *b*) | 3 | 0·0055 |
| | 4 | 0·0063 |
| | 11 | 0·1469 |
| | 12 | 0·2738 |



*Discussion.*

From the results obtained it was evident that the electrical energy was utilized in effecting some reaction other than the separation of the metal from the solution. Accordingly a series of experiments was undertaken in order to ascertain the way in which the energy was used up.

Now, on comparing the sets of values showing the variation in the P.D. at the cathode and the rate of deposition of the metal, it will be noticed that a sudden rise in P.D. appears to occur when the metal is beginning to be separated in quantity. This was investigated, and from a number of experiments this rise in P.D. appeared to be an infallible criterion that deposition had commenced. Furthermore, during the course of the deposition subsequent to this sudden rise in the P.D. at the cathode the values for the latter exhibited a gradual diminution, as was previously observed in the absence of nitrate.

Series 3.

The preceding series of experiments was repeated, using a greater current-density, but similar results were obtained.

Series 4.

The most probable manner in which the energy would be utilized would be in effecting the reduction of the ammonium nitrate. This reduction may lead to a variety of products, according to the extent to which the reduction has taken place—*e.g.*, nitrous acid, hydroxylamine, or ammonia may result.

In the case where one equivalent amount of ammonium nitrate (0·85 grm.) was added, the amounts of hydrogen necessary to effect the reduction to the three stages were calculated from Faraday's law to be 0·0212 grm., 0·0637 grm., and 0·0849 grm. respectively.

The amounts of hydrogen liberated during the electrolysis, deducting the equivalent of the amount of nickel deposited, were calculated to be—At end of one hour, 0·037 grm.; at end of two hours, 0·075 grm.; at end of three hours, 0·1045 grm.; at end of four hours, 0·1398 grm.

This series of experiments, then, was performed in the hope of isolating hydroxylamine, which one might reasonably expect to be one of the products of the reduction.

*Estimation of Hydroxylamine.*

At the end of a definite interval of time the electrolysis was interrupted and the solution evaporated to dryness. From the mixture of salts so obtained the hydroxylamine was extracted by trituration with absolute alcohol; on evaporation of the latter the salt crystallized out. The hydroxylamine so obtained was dissolved in carefully distilled water, and estimated in the usual way by the reduction of boiling Fehling's solution,* which proceeds according to the following equation: $2NH_2OH + 4CuO = 2Cu_2O + N_2O + 3H_2O$. The cuprous oxide was filtered through a Gooch crucible, dried carefully, and weighed, and hence the corresponding amount of hydroxylamine could be readily computed.

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* H. O. Jones and F. W. Carpenter, The Estimation of Hydroxlyamine, *Journ. Chem. Soc.*, vol. 83, 1903, pp. 1394–1400.

*Results.*

| | Time. Hours. | Amount Hydroxylamine. Grammes. |
|---|---|---|
| (*a.*) One equivalent of ammonium nitrate | 1 | 0·059 |
| | 2 | 0·033 |
| | 3 | 0·008 |
| (*b.*) Two equivalents of ammonium nitrate | 1 | 0·050 |
| | 2 | 0·023 |
| | 3 | 0·007 |
| (*c.*) Experiment with ammonium nitrate alone | 1 | 0·093 |
| | 2 | 0·035 |

SERIES 5.

The preceding series of observations indicates that though hydroxylamine is undoubtedly a product of the reduction, yet it undergoes further change subsequent to its formation—probably being reduced to ammonia. The formation of hydroxylamine, however, can only be ascribed to reduction taking place at the cathode ; and in order to study more closely this action it was decided to conduct a series of experiments in a divided cell where the anode and cathode compartments were kept separate, so that the solutions could be analysed separately.

*Apparatus.*

The apparatus consisted of a Grove porous pot and outer vessel ; the inner compartment contained the same solution as in the previous cases—one-third quantities being used—and in it was placed the cathode. The outer vessel contained ammonia and ammonium sulphate solution.

*Results.*

| | Time. Hours. | Amount deposited. Grammes. |
|---|---|---|
| (*a.*) No nitrate present .. .. .. | $\frac{1}{2}$ | 0·0540 |
| | 1 | 0·0686 |
| (*b.*) One equivalent ammonium nitrate .. | 1 | 0·056 |
| | 2 | 0·068 |
| (*c.*) Two equivalents ammonium nitrate .. | 1 | 0·054 |
| | 2 | 0·066 |
| (*d.*) Three equivalents ammonium nitrate | 1 | 0·053 |
| | 2 | 0·063 |

| | Time. Hours. | Amount formed. Grammes |
|---|---|---|
| Amount of hydroxylamine .. .. | 1 | 0·037 |
| | 2 | 0·008 |

*Discussion.*

The results obtained with the divided cell were certainly more satisfactory in the presence of the nitrate, and seemed to indicate that increasing amounts of the nitrate did not produce such a decided effect on the rate of deposition as when the undivided cell was used. This would seem to suggest that perhaps some product formed at the anode had the effect of retarding the progress of the electrolysis.

There appears to be no doubt that the hydroxylamine undergoes a further change. An experiment was performed as follows to test this :—

*Experiment.*

To the solution in the cathode compartment, containing no nitrate, were added successive quantities of hydroxylamine so as to produce conditions as nearly comparable as possible to those that would be expected to obtain from the basis of Faraday's law. Suppose, for instance, one equivalent of ammonium nitrate were present ; then the amounts of hydroxylamine present in the solution at various times—*e.g.*, $\frac{1}{4}$ hour, $\frac{1}{2}$ hour, &c. —can be approximately computed. At intervals, then, such amounts of hydroxylamine were slowly added. It is at once apparent that the conditions in the two cases are by no means identical, for in one a certain amount of energy is expended in producing the hydroxylamine prior to its transformation, while in the other such an expenditure of energy is not involved. Hence, while one would expect to be able to isolate a greater amount of hydroxylamine in the latter case, yet a comparison of the results in the two cases was considered likely to prove instructive. This was repeated, and good agreement in each case was found. The results of one set of this experiment may be given as typical :—

| | Nitrate present. | Hydroxylamine added. |
|---|---|---|
| | Grammes. | Grammes. |
| Nickel deposited .. .. .. | 0·056 | 0·056 |
| Hydroxylamine .. .. .. | 0·037 | 0·041 |

SERIES 6.

The results of the previous experiments indicated that energy was primarily utilized in the formation of hydroxylamine. It was, however, considered possible that nitrous acid might be formed as an intermediate substance according to equation 1, *supra*. Were this the case it was thought that some substance might be introduced which by chemical interaction would destroy the nitrous acid and convert it into harmless products, without otherwise interfering with the course of the electrolysis. This would tend to accelerate the removal of the nitrate, and would enable the electrical energy to be utilized more completely in effecting the deposition of the nickel.

The obvious desirability of introducing a substance that would not exert an effect upon the electrolyte and at the same time interact with the nitrous acid (if formed) suggested the use of urea.

*Result.*

The solution in the cathode compartment then was rendered faintly acid and the experiments conducted as before. The mean of a number of closely agreeing values gave at the end of one hour—

| | No Urea. | Urea added—Acid Solution. |
|---|---|---|
| | Grammes. | Grammes. |
| Amount nickel .. .. .. | 0·056 | 0·055 |
| Amount hydroxylamine .. .. | 0·037 | 0·038 |

This apparently indicated that nitrous acid is not formed as an intermediate product.

RÉSUMÉ.

The main results of this investigation may be summarized thus :—

1. In the electrical deposition of nickel from ammoniacal solution the efficiency is remarkably low. This may possibly be due to polarization effects. The nickel is perhaps present as $Ni(NH_3)_x$ ions and a small proportion as Ni. Oxidation appears to take place at the anode with the formation of $Ni(OH)_3$, for on removal of the anode it was often found to be practically coated with a black deposit, presumably of nickel hydroxide, On being allowed to stand in the solution it dissolved, forming $Ni(NH_3)_x$. Periodic phenomena are also to be observed at the anode.

2. In the presence of ammonium nitrate the rate of deposition is greatly diminished. The electrical energy appears to be utilized primarily in the reduction of the nitrate, and only when that has reached an advanced stage does deposition of the metal appear to take place in any quantity.

3. Periodic phenomena are observable at the cathode ; and if the P.D. cathode solution is studied a sudden rise in the P.D. seems to be a safe criterion that electrical separation of the metal has begun.

4. The reduction of the nitrate appears to be first to hydroxylamine and finally to ammonia. The hydroxylamine undergoes some subsequent change, and nitrous acid does not seem to be formed.

5. Even in the presence of nitrate the use of the divided cell yielded distinctly better results. The deposit of metal was much more even than when the undivided cell was used. The writer hopes at a future date to investigate more fully the application of the divided cell to the separation of nickel ; and the results thus far obtained seem to justify the possibility that conditions may be devised under which the deposition of the metal may be a commercial success.

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## ART. XLVII.—*Notes on an Artesian Trial Bore, Westshore, Napier.*

By R. W. HOLMES, M.Inst.C.E., Engineer-in-Chief, Public Works Department.

[*Read before the Wellington Philosophical Society, 19th July, 1916 ; received by Editors, 30th December, 1916 ; issued separately, 10th December, 1917.*]

THE construction of the railway northward from Napier requires the building of a long bridge across a part of the Inner Harbour, while the proposed extension of the Inner Harbour works necessitates the removal of the present road bridge ; and, as decay has rendered it unsafe, it has been decided to erect a combined road and railway bridge, and to build the structure of reinforced concrete. The length of the bridge is 1,232 ft. ; the width, 41 ft.

In the mixing of the concrete a large quantity of fresh water is necessary, salt or brackish water not being permissible where concrete has to be reinforced with iron or steel. A large quantity of fresh water will also be required to supply the boilers of the machines used in the construction of the bridge, and of the locomotives which will be working on the construction of the line as far as the River Esk, the first source of supply after leaving Napier.

"Westshore" is an extension of the "Spit." It consists of a number of dwellings, a meat-works, and ship-repair yards, &c., all of which require fresh water. The village, and also the railway, is situated on a ong

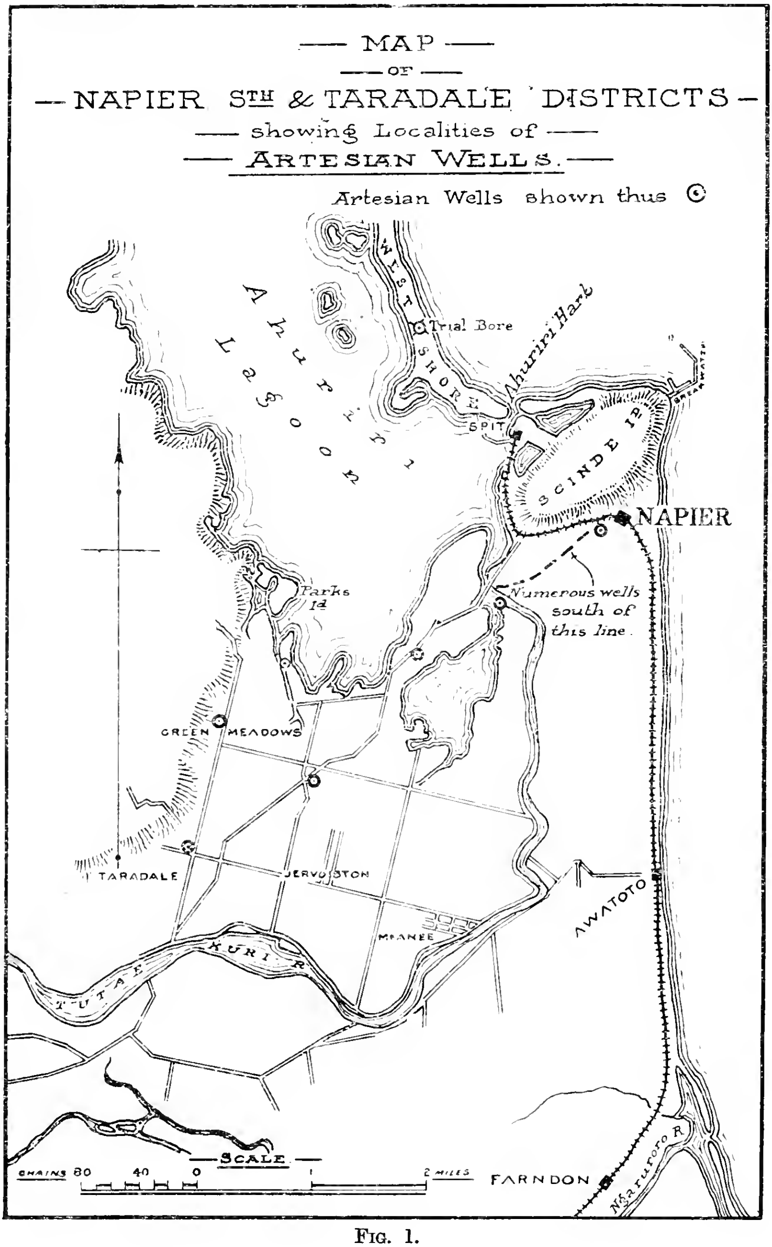



Fig. 1.

shingle spit extending from the entrance to the Inner Harbour to the valley of the River Esk. It is bounded on the east side by the sea (Hawke Bay), and on the west by the Inner Harbour (salt) and the low-river channel of the Esk River. During low river the proper mouth of the Esk

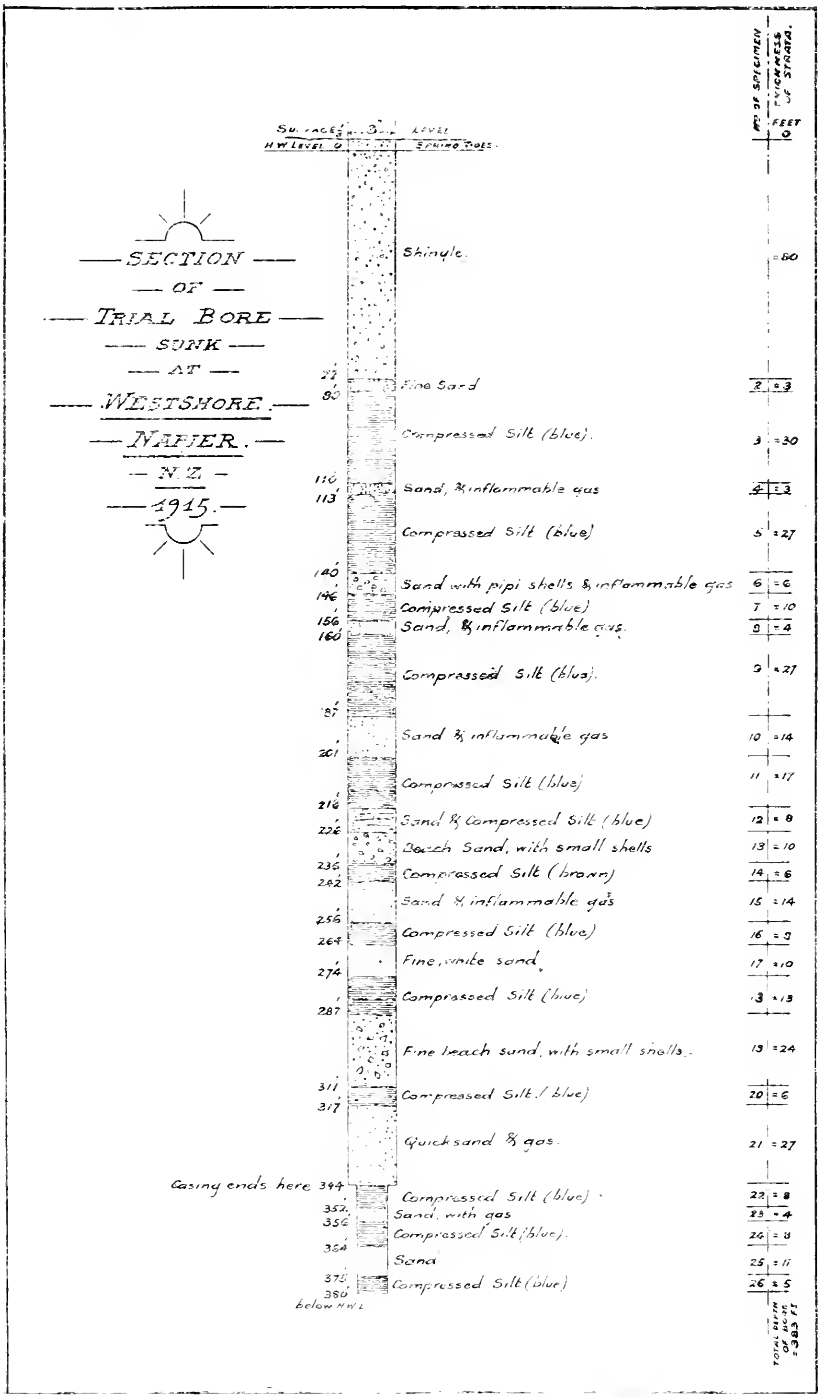

SECTION
OF
TRIAL BORE
SUNK
AT
WESTSHORE
NAPIER.
N.Z.
1915.
No. of SPECIMEN
THICKNESS OF STRATA.
FEET
Surface 3 Level
H.W. Level 0 Spring Tides.
Shingle.
Fine Sand
Compressed Silt (blue).
Sand, & inflammable gas
Compressed Silt (blue)
Sand with pipi shells & inflammable gas
Compressed Silt (blue)
Sand, & inflammable gas.
Compressed Silt (blue).
Sand & inflammable gas
Compressed Silt (blue)
Sand & Compressed Silt (blue)
Beach Sand, with small shells
Compressed Silt (brown)
Sand & inflammable gas
Compressed Silt (blue)
Fine, white sand
Compressed Silt (blue)
Fine beach sand, with small shells.
Compressed Silt (blue)
Quicksand & gas.
Casing ends here 344
Compressed Silt (blue)
Sand, with gas
Compressed Silt (blue).
Sand
Compressed Silt (blue)
below H.W.L.
TOTAL DEPTH OF BORE = 383 Ft

FIG. 2

is usually blocked up with shingle thrown up by the sea. On the occurrence of a flood of sufficient volume the shingle bank is broken through, when the greater part of the water flows directly out to sea, the remainder finding its way into the Inner Harbour. Pure salt water thus occurs on both sides of the Spit for more than three miles.

Much consideration was given to the question of obtaining sufficient fresh water for the works, only two sources apparently being available—viz., from the Napier Borough supply or from an artesian well. On the accompanying map are indicated a number of existing artesian wells, which are situated to the south and west of Scinde Island, a hill consisting principally of limestone and marl, on which the residential part of Napier is built. These wells are apparently supplied from the Tutaekuri River. This river rises in the clay-slate ranges westward of Napier, and thence carries shingle down to, or within a short distance of, Taradale. From the point where shingle ceases the course of the river is a meandering one across an alluvial plain or delta formed of mud, which provides the necessary watertight covering over some shingle or sand strata to produce artesian water. The same conditions exist in the case of the Waimakariri River and its relation to Banks Peninsula, where artesian water is obtainable below the tidal estuary of the Heathcote River, and within a short distance of the sea. The resemblance of the two places is so close that it seemed reasonable to expect that artesian water could be obtained at Westshore. It was therefore decided to sink a trial bore before undertaking the more expensive alternative of laying a main to convey water from the Spit. The result of the bore was, however, a disappointment, no water being obtained down to a depth of 380 ft. Unfortunately the casing became bound at a depth of 344 ft., otherwise the sinking would have been continued to at least 500 ft.

The bore is being preserved by casting a block of concrete over the top, so as to be available if it should be decided at some future time to continue an exploratory bore by inserting a smaller interior casing. A careful record was kept of the strata passed through, which are indicated on the accompanying section. The strata marked "Compressed silt" are very tight, and of a pug-like consistency; otherwise the country below the first bed of shingle was wholly sand.

Nearly all the sand beds from 110 ft. below high-water mark carried an inflammable gas. This gas when lighted burned quietly at the mouth of the pipe, with a flame about 12 in. high, which was easily put out by dropping the hammer over it. At levels 110 ft., 140 ft., and 156 ft., however, the gas was under considerable pressure—sufficient to throw mud and water 10 ft. out of the pipe.

The quicksand at 317 ft. caused considerable trouble; three lengths of the cleaning-out rods were caught as it forced its way up the casing, and were lost for a time, but were eventually picked up again.

As information of a negative character is quite as valuable as, and often more so than, that of a positive description, the results obtained by this bore should be placed on record in a manner easily accessible, for the information at some future time of those who may be again considering the question of artesian water at Westshore.

The *Transactions of the New Zealand Institute* affords a well-known and accessible means of placing on record valuable information, such as has been obtained by this bore; hence my decision to place this paper before the Geological Section of the Wellington Philosophical Society, in the hope that it may be accepted for publication.

The exact location of the bore is 140 links to the right of 1 mile 7860 links on the original railway-survey mileage.

## ART. XLVIII.—*Night Marching by the Stars.*

By GEORGE HOGBEN, M.A., F.G.S., C.M.G.

[*Read before the Wellington Philosophical Society, 1st November, 1916; received by Editors, 30th December, 1916; issued separately, 10th December, 1917.*]

MARCHING or sailing the ocean by the stars is, of course, no new thing; in fact, owing to the use of the compass the method is less used in modern times than it was of old. But there are many occasions on which the compass is out of order, or not available; besides, only a few officers can be provided with compasses, and oftentimes it falls to the lot of the individual non-commissioned officer or private to determine his direction for himself. It is then that a little star knowledge may be most useful.

The first method described below is that recommended to the members of the New Zealand Expeditionary Forces, who have been provided with copies of star maps 1 and 2, with brief directions for their use. Star map No. 1 is familiar to every one; the diagram called star map No. 2 is, I believe, new. What it enables any one to do, on any clear night, is to find the south approximately at any hour on any day of the year.

I am well aware that other methods have been used or recommended for use. The chief of these were discussed in connection with a paper read before the Royal Geographical Society of London by Mr. E. A. Reeves, on the 13th April, 1916.* The two most important are (i) by the use of Colonel Tilney's tables, which give the bearings of certain selected conspicuous stars for the local mean time; (ii) by the finding of the altitude of a known star above the horizon, and hence inferring its bearing east or west of the meridian—this method being independent of the date or hour.

My second method, described below, is a modification of Colonel Tilney's, as will be seen. The first method I have described is subject to an important error due to the varying value of the equation of time at different periods of the year. Accordingly, in Table I, to be used in connection with my second method, the approximate time of meridian transit given for the first day of each month is calculated according to the average value of the equation of time for the month. The error is thus greatly reduced.

The simplest way in which I can explain the methods now presented is to give the description as it would be given to an officer who wished to use these methods in the field.

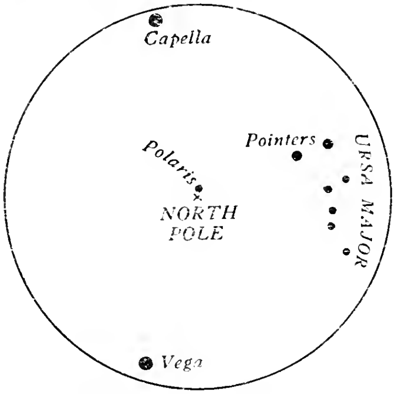
### STAR MAP NO. 1 (LOOKING NORTH).

*To find the North at any Time when the Stars are Visible.*

The two "Pointers" in the Great Bear (Ursa Major) point very nearly to the North Pole of the sky, which is always due north of you. The distance of the nearer "Pointer" from the North Pole is about five times the distance between the two "Pointers." (There is a small star, Polaris, near the Pole.) The two bright stars, Vega and Capella, nearly on opposite

* *Geog. Journ.*, vol. xlvii, June 1916, pp. 440–60.

sides of the Pole, give a check as to its direction, if the star map be turned round so as to make the position of the Great Bear on it agree with its position in the sky when you are looking north and leaning half back.




STAR MAP NO. 1 (LOOKING NORTH).

STAR MAP NO. 2 (LOOKING SOUTH).

1. Note that the diagram is made for 50° north latitude.

2. Note that the time to be used is the local time of the place of observation.

3. Note that, owing to the daily rotation of the earth about its axis and to its yearly revolution round the sun, the stars appear to have two motions, the daily motion and the annual motion : *i.e.*,—

(*a.*) On any given day a star moves across the sky, parallel to the Equator, at the rate of 15° an hour, from east to west ;*

(*b.*) During the year, besides the daily motion, every star has an apparent motion (parallel to the Equator) towards the west of about 30° a month, or nearly 1° a day* ; that is, any star is in the meridian (due south) about two hours earlier to-day than it was on the same day last month, or nearly four minutes earlier to-day than it was yesterday.

4. During your voyage to the seat of war you should make yourself familiar, by looking at the sky every clear evening, with the stars shown on the diagram, especially with Aldebaran, Sirius, Regulus, Spica, Antares, Altair, Markab, and perhaps $\alpha$ Arietis.

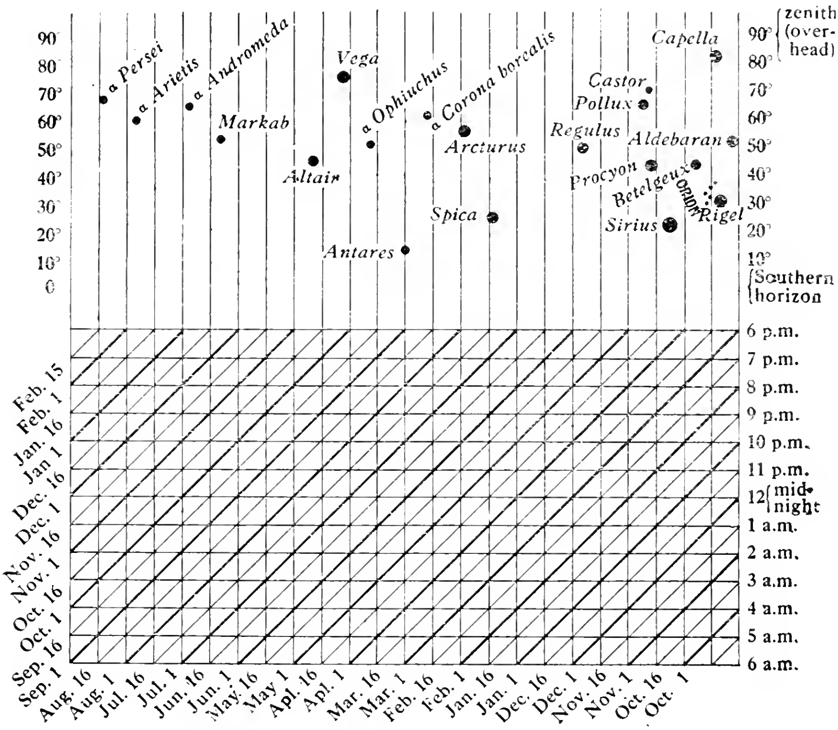
A. *First Method.*—To find the south approximately for any day and hour (local time). Follow the date-line *diagonally* up to the right until you come to the *horizontal* hour-line ; the stars on or near the *vertical* line through that point are on or near the meridian—*i.e.*, due south or nearly due south of you. Check this by the north as found by the Great Bear (star map No. 1).

Example on the 1st October, at 8 p.m. The south is somewhat to the left or east of Altair ; at 11 p.m. on the same evening the south will

* It does not follow that the bearing of a star—east or west, parallel to the horizon—varies on account of (*a*) by 15° an hour, or on account of (*b*) by 1° a day.

be on the left or east of Markab. On the 8th or 9th October the stars named will be in the position just referred to at about 7.30 p.m. and 10.30 p.m. respectively. (See note 3 (*b*) above).

B. *Second Method.*—The direction may be found somewhat more exactly by using Tables I and II below in conjunction with the diagram. For instance, supposing a night march is fixed to take place between 8.30 p.m. and midnight on the 24th April. From the diagram (star map No. 2) we see that the stars nearly south during that time are, first, Regulus, and afterwards Spica. Table I shows us that Regulus on the 1st May will be




STAR MAP No. 2 (LOOKING SOUTH). (For latitude 50° N.)

on the meridian about 7.30 p.m.; therefore, on the 24th April (or seven days earlier) it was on the meridian twenty-eight minutes later, say at 8 p.m. Similarly, Spica is on the meridian about 11.15 p.m. on the 24th April.

At 8.30 p.m., or thirty minutes after its meridian transit, Regulus (as we see from Table II) is 12° west of south; at 9 p.m., 23° west of south; at 10 p.m., 44° west, or nearly south-west; and so on. In other words, each five minutes it alters its bearing towards the west by nearly 2°.

At 8.30 p.m. Spica will have two hours and three-quarters to go before its meridian transit, and its bearing will be about 43° or 44° east of south, or nearly south-east; at 9.15 it will be 32° east of south; at 10.15, 17° east; and so on. In each quarter-hour it alters its bearing about 4°.

We should write beforehand, say on a small card, for use if necessary during the march, the bearings of these stars at quarter-hour or half-hour intervals. Such a card would show entries somewhat as follows:—

*From South.*

| | Regulus. | Spica. |
|---|---|---|
| 8.30 p.m. .. .. .. .. | 12° W. | 44° E. |
| 9.0 ,, .. .. .. .. | 23° W. | 36° E. |
| 9.30 ,, .. .. .. .. | 34° W. | 29° E. |
| 10.0 ,, .. .. .. .. | 44° W. | 21° E. |
| 10.30 ,, .. .. .. .. | 53° W. | 13° E. |
| 11.0 ,, .. .. .. .. | 60° W. | 4° E. |

*From South.*

| | Spica. | Antares. |
|---|---|---|
| 11.30 p.m. .. .. .. | 4° W. | 36° E. |
| 12 (midnight) .. .. .. | 13° W. | 30° E. |
| 12.30 a.m. .. .. .. | 21° W. | 24° E. |
| 1.0 ,, .. .. .. .. | 29° W. | 17° E. |
| 1.30 ,, .. .. .. .. | 36° W. | 11° E. |
| 2.0 ,, .. .. .. .. | 44° W. | 4° E. |
| 2.30 ,, .. .. .. .. | .. | 4° W. |
| 3.0 ,, .. .. .. .. | .. | 11° W. |
| 3.30 ,, .. .. .. .. | .. | 17° W. |
| 4.0 ,, .. .. .. .. | .. | 24° W. |
| 4.30 ,, .. .. .. .. | .. | 30° W. |

The bearings of Antares are added to our card as a precaution, in case the march takes longer than was expected.

Let us suppose that at 9.30 p.m. we have reached a point whence our map shows that we have to advance in a direction 20° west of south. Regulus is then 34° west of south; so that we are to take the direction 14° on the east or left side of Regulus. This angle can be taken off beforehand on our small card, and found on the field by three pins stuck in the card so as to show the angle—the card being held horizontally.*

But, generally speaking, it is well for every man, or, at all events, every officer and non-commissioned officer, to be able to ascertain the general direction; therefore the most important thing is to find the north-and-south line first, and to determine the line of march from that—which may be easily done by placing the map or plan flat on the ground in its true position.

In conclusion, I may say that officers at the front have borne testimony to the practical value of the first method described; I trust that the second method (perhaps in conjunction with the first) may prove as useful. If it saves one man's life, I shall feel myself a thousandfold repaid for all the thought spent upon it.

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* 14 is very nearly the angle subtended by the line joining the tip of the thumb and the tip of the middle finger of the left hand stretched at full length (palm outwards) when looked at with the right eye. Other bodily measurements may be similarly used for determining angles roughly; or even distances between points on the rifle, &c.

TABLE I.

Showing the Approximate (local) Times at which certain Stars are on the Meridian (due South) on the Dates named.

| Star. | 1 Jan. | 1 Feb. | 3 March. | 2 April. | 1 May. | 1 June. | 1 July. | 2 Aug. | 2 Sept. | 1 Oct. | 1 Nov. | 1 Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aldebaran .. | p.m. 9.50 | p.m. 7.50 | p.m. 5.50 | .. | .. | .. | .. | .. | a.m. 5.45 | a.m. 3.50 | a.m. 1.50 | p.m. 11.50 |
| Betelgeux .. | 11.10 | 9.10 | 7.10 | .. | .. | .. | .. | .. | .. | 5.10 | 3.10 | a.m. 1.10 |
| Sirius .. | a.m. 12.0 | 10.0 | 8.0 | p.m. 6.0 | .. | .. | .. | .. | .. | 6.0 | 4.5 | 2.0 |
| Regulus .. | 3.25 | a.m. 1.25 | 11.25 | 9.25 | p.m. 7.30 | .. | .. | .. | .. | .. | 7.25 | 5.25 |
| Spica .. | 6.40 | 4.40 | a.m. 2.40 | a.m. 12.40 | 10.45 | p.m. 8.45 | p.m. 6.45 | .. | .. | .. | .. | 8.40 |
| Arcturus .. | 7.30 | 5.30 | 3.30 | 1.30 | 11.35 | 9.35 | 7.35 | .. | .. | .. | .. | .. |
| Antares .. | .. | 7.40 | 5.40 | 3.40 | a.m. 1.45 | 11.45 | 9.45 | p.m. 7.40 | .. | .. | .. | .. |
| Altair .. | .. | .. | .. | .. | 5.10 | a.m. 3.10 | a.m. 1.10 | 11.5 | p.m. 9.0 | p.m. 7.5 | p.m. 5.5 | .. |
| Markab .. | .. | .. | .. | .. | .. | .. | 4.25 | a.m. 2.20 | a.m. 12.15 | 10.20 | 8.20 | p.m. 6.20 |
| *At London.* | | | | | | | | | | | | |
| Sunrise (a.m.) | 8·8 | 7·42 | 6·48 | 5·35 | 4·34 | 3·50 | 3·49 | 4·25 | 5·14 | 6·2 | 6·55 | 7·45 |
| Sunset (p.m.) | 3.58 | 4.45 | 5.38 | 6.32 | 7.20 | 8.5 | 8.19 | 7.47 | 6.46 | 5.38 | 4.33 | 3.53 |

NOTE.—Each star is on the meridian about four minutes earlier on any night than it was the night before.

TABLE II.

Showing the Approximate Bearing of certain Stars in Degrees
{East from South at Intervals named before / West from South at Intervals named after} the Time when on the Meridian (due South); also Meridian Altitudes of the same Stars.

| Star. | Bearing in Degrees East or West of South at Times named before or after Meridian Transit. | | | | | | Altitude of Star when on Meridian. |
|---|---|---|---|---|---|---|---|
| | 30 min. | 1 hr. | 1 hr. 30 m. | 2 hr. | 2 hr. 30 m. | 3 hr. | |
| Aldebaran .. | 13 | 25 | 36 | 45 | 55 | 63 | 56° |
| Betelgeux .. | 11 | 22 | 31 | 41 | 49 | 57 | 47° |
| Sirius .. | 8 | 16 | 24 | 31 | 38 | 45 | 23° |
| Regulus .. | 12 | 23 | 34 | 44 | 53 | 60 | 52° |
| Spica .. | 8 | 17 | 25 | 32 | 40 | 47 | 29° |
| Arcturus .. | 14 | 27 | 39 | 49 | 58 | 66 | 60° |
| Antares .. | 7 | 14 | 20 | 27 | 33 | 39 | 14° |
| Altair .. | 11 | 22 | 32 | 41 | 50 | 58 | 49° |
| Markab .. | 12 | 24 | 35 | 45 | 54 | 62 | 55° |

# Art. XLIX.—*Effects of the Snowstorm of the 6th September, 1916, on the Vegetation of Stewart Island.*

By Walter Traill.

Communicated by Dr. Charles Chilton, C.M.Z.S.

[*Read before the Philosophical Institute of Canterbury, 6th December, 1916; received by Editors, 30th December, 1916; issued separately, 10th December, 1917.*]

On the 6th September, 1916, there occurred a particularly heavy snowstorm in Stewart Island, which caused considerable damage to many of the indigenous trees and shrubs, and the following particulars are perhaps worthy of being placed on record.

The weather of Stewart Island on the 6th September was very unusual. The first part of the day there was heavy rain for about seven hours, with little wind. About 10 p.m. the rain stopped, and a calm followed, with a dense fall of snow. The temperature was then about 50° F., and during the night it kept comparatively mild and warm, but towards dawn the sky cleared, and although still and absolutely calm it became bitterly cold. During this cold spell there could be heard, in the forest, trees and branches crashing down. As the sun appeared the sky again became cloudy; a light W.N.W. wind sprang up; the temperature rose to about 53° F., and the snow, which was about 5 in. deep, began to melt very fast—*i.e.*, near the sea-coast and on beaches. By the evening about 2 in. of snow was left on the open land. The rainfall, including the snow, for the 6th was 3·68 in.

In the coastal scrub the tree most affected was *Senecio rotundifolius*; then, much less so, *Dracophyllum longifolium*, *Coprosma* spp., *Nothopanax Colensoi*, and large-sized manukas (*Leptospermum scoparium* var.). *Olearia Colensoi*, *O. arborescens*, and *O. angustifolia* do not appear to have suffered at all, nor the veronicas (*V. elliptica*, *V. salicifolia* var. *communis*); but fuchsias (*Fuchsia excorticata*), although bare of leaves, suffered a good deal.

Of the trees and shrubs from other places planted on the section at my residence on Ulva Island, *Senecio Huntii*, *Olearia Traversii*, *Coprosma robusta*, *C. grandifolia*, and *Arbutus unedo* suffered badly; but the pines (*Pinus radiata*), larches, spruces, yew, &c., were not damaged at all. The six specimens of *Brachyglottis repanda* planted here, and now of large size, also escaped damage, a remarkable circumstance considering the great size of its leaves and its brittle twigs. In the forest the miro (*Podocarpus ferrugineus*) lost far the most branches, but few whole trees were down. Rimu (*Dacrydium cupressinum*) comes next: quite a number were uprooted, and branches were hanging from others in all directions. Rata (*Metrosideros lucida*) and kamahi (*Weinmannia racemosa*) did not suffer so badly as the rimu, and totara (*Podocarpus Hallii*) seemed to stand the weight of snow fairly well; but a number of all the larger trees in the forest on Ulva were uprooted. In some instances flood-water covered the ground around their roots. The cabbage-tree (*Cordyline australis*) had all the outside leaves bent down: but this will not matter, as new leaves will soon form.

The Government tracks on Ulva are now cleared, and I got one of the men to help me on the section. We removed nearly a cord of firewood from branches on the tracks within a radius of about 5 chains, and this should give an idea of the average fall of branches, whole trees being omitted.

The old Natives here say there is no record among them of such damage to the trees by snow as the present one. I may mention that a few days before the snowstorm thousands of kakas and pigeons arrived at Ulva, and many are still here.

## Art. L.—*New Zealand Bird-song: Further Notes.*

By Johannes C. Andersen.

[*Read before the Wellington Philosophical Society, 25th October, 1916; received by Editors, 30th December, 1916; issued separately 10th December, 1917.*]

It has often been questioned whether any similarity exists between the song of birds and the song of human beings: whether birds modulate their voice in intervals agreeing with those that build up the scale of the octave. That it is possible for them to do so is evident, since they are able to slur from one note into another, through the full octave, in the same way that the human voice is able to do. Yet most writers, if they theorize at all upon the subject of bird-song, contend that birds do not sing with regular or constant intervals, and "would not deign to be fettered with a scale."* Writers are, however, inconsistent among themselves. It is commonly admitted that the cuckoo sings a minor third at the commencement of the season, increasing the interval regularly through a major third, a fourth, and a fifth, as the season advances; and so constant and well known is the common cry of the bird that it is reproduced mechanically in whistles and clocks. Witchell† states that the calls of the redstart, nightingale, chiff-chaff, willow-warbler, and white-throat are in upward fifths; and he has, further, recorded‡ the singing by starlings of a phrase consisting of three fifths of different pitch. The rise of a fifth appears to be a natural one, for the tendency of the human voice to rise a fifth has often been noted.§ It is admitted|| that occasionally the notes do agree with our notes, and the intervals with our intervals; and a reluctant admission seems to be made that birds may occasionally, and as it were accidentally, stumble on the same scale of sounds that the professional musician uses.

But a little reflection must compel something more than a reluctant admission. Fowler, himself a musician, maintains¶ that birds do not dwell definitely on any note, but modify it by slightly raising or lowering the pitch, and sliding insensibly into another note, forsaking that for a subdued chuckle or trill, descending or ascending through fractions of a tone. Surely the most casual listener knows that birds do dwell on single notes, and repeat single notes of different pitch clearly and in succession. And in human singing, is it not the finished singer who, besides singing single notes of even pitch clear and true, also blends notes in slurs and trills, until we say she sings "like a bird"—implying a decided compliment? When a singer is out of tune, there is a failure to pay due regard to exact intervals: how often is a bird heard singing out of tune, despite its raising and lowering of pitch, its chuckles and its trills, and its sliding insensibly from one note into another? Moreover, standards of taste in human song differ: to most European ears the song of the Maori is monotonous and unmusical

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* W. W. Fowler, *A Year with the Birds*, ed. 3. 1889, p. 149.

† C. A. Witchell, *The Evolution of Bird-song*, 1896, pp. 113, 116.

‡ Witchell, *loc. cit.*, pp. 83. 84.

§ *Encyclopaedia Britannica*, 1911, vol. 25, under "Song." col. 2.

|| Witchell, *loc. cit.*, pp. 231, 232; Fowler, *loc. cit.*, pp. 257, 258.

¶ Fowler, *loc. cit.*. pp. 257, 258.

in the extreme. Yet the Maori thoroughly appreciates his own music, and appreciates in addition the music of the European, singing it, as well as his own, with facility, fidelity, and undoubted art. Birds, too, are able to learn human tunes; and the powers of natural mocking-birds are too well known to need remark. Do not such powers prove the receptivity of birds to be akin to that of man, and their discrimination to be as keen as his—for do not human beings, too, first learn by imitation?

In Maori music, it is not the apparently small compass of the song that makes it distasteful to many ears, but the free use of quarter-tones.* Then why is not the song of birds with small compass distasteful? Again, if failure to adhere to the recognized pitch of notes and recognized intervals cause a song to be out of tune, why do not the songs of birds sound out of tune? The very fact that they are tuneful and pleasing to practically every human ear is surely fact sufficient to give one pause before stating that their notes do not conform to the scale accepted by musicians. Did they not conform, their sound would be found intolerable, simply because they would be different from the standard to which we are accustomed. They are, of course, full of slurs, trills, vocalizations, changes of timbre, to an extent quite beyond the human voice or any single musical instrument; but the basis on which they are built is none other than that on which the music of the human voice and of musical instruments is built, and the one notation serves for recording them all.

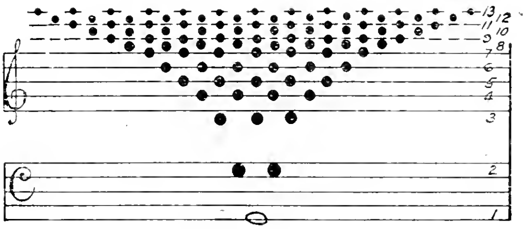
The scale in music is usually held to be an artificial subdivision of a range of sound lying between two notes, one of which is composed of twice the number of vibrations per second that composes the other. This range is called an octave, and it comprises seven different notes, rising in pitch in a definite series from the lowest to the highest. The eighth note has a difference in pitch from the lowest, and a certain difference in sound; though if the two are sounded together a single appreciable sound results: their vibrations coincide, and, in addition to the coinciding vibrations, the higher note has an additional vibration midway between each coinciding pair; so that whilst one sound results when both notes are sounded together, the ear is easily able to detect its composite quality.

When, then, two notes, one an octave higher than the other, are sounded together, the singleness of the sound is apparent only. It is quite evident that there must be two sounds in the resultant note, and the ear is easily able to detect both. Furthermore, if the lower note be sounded alone, the ear is still able to detect the upper, though with much greater difficulty than when both are sounded together. Nor is this imagination only. The motion of every resonant vibrating body is more or less complex. It vibrates as a whole; and this, the principal vibration, gives the principal and predominant note. At the same time, it vibrates in two equal parts, each part vibrating with twice the frequency of the whole, and producing accordingly a note an octave higher, but very much fainter, than the principal note. Nor is this all. The wire or string, supposing it to be a piano or violoncello in question, is subdivided into quite a number of portions, all vibrating with different frequencies from the whole string, and so producing different sounds. All are normally, however, vibrating in definite and comparatively fixed proportions. The string is, as it were, divided first into two portions; then into three, four, five, six, and so on. Where the division is into two the vibrating parts give a sound an octave above the

* Sir G. Grey, *Polynesian Mythology*, 1885. Appendix, pp. 225 *et seq.*

principal note, their rates of vibration being double that of the full string; where the division is into three, the vibrating parts give a sound a twelfth above the principal note, or a fifth above the first octave; where the division is into four, the vibrating portions give a sound two octaves above the principal note, as their rates of vibration are four times that of the full string; where it is into five, a sound a seventeenth above the principal note, or a third above the second octave; and so on. The full note is, in fact, composed of quite a number of different sounds, called harmonics or partial tones. Whilst they are present they are exceedingly faint, the smaller the subdivision producing them being the fainter being the sound emitted, and the less distinguishable from the much fuller body of the principal note. The ordinary unaided ear is able to detect the first four or five partial tones only; yet the presence or absence of these and the higher partials determines the richness and quality of the resultant sound. The vibration of different materials produces different partials, or produces them in different degrees of intensity: the human voice is rich in the lower partials; in cymbals and like "noisy" instruments the upper partials predominate. The nasal quality of the oboe and clarionet is caused by the absence of the even partials—the second, fourth, sixth—and the presence of the odd—the first, third, fifth, seventh.

The harmonics or partial tones of the open G string of the violoncello are represented in the subjoined diagram:—*



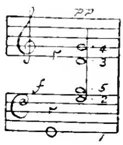

The first partial tone is the principal note: the second is produced by the string dividing into two parts: the third by its dividing into three; and so on to the thirteenth partial here shown.

It seems hardly credible that such a number of notes should all be sounding when the G string is set in motion, yet the fact is, by mechanical means, quite demonstrable. It is easy for the ordinary unassisted ear to detect at least the lower partials. If the G be struck on the piano, and the sound be allowed to die away by keeping the damper from the wire, as the principal note becomes fainter the third and fifth partials, D and B, are heard, faintly but clearly. The second and fourth partials, being the first and second octaves of the principal note, whilst heard as clearly as the third and fifth, are not so readily distinguished, as they do not differ in actual sound, but in pitch only. They may be heard in this way: Hold down the key of the principal note, G, without striking the wire: then strike the G above it—the second partial—and after a second or two release the key, still holding down the lower G. The sound of the G struck, and of the G an octave above it—the second and fourth partials—will now be

* From MOMIGNY, *Grove's Dictionary of Music*, Harmonics.

heard most clearly; and that they are heard in the string of the lower G, which has been set in vibration by the string struck, is made evident by the sounds ceasing immediately the key of the lower G is released. Thus it is evident that the unassisted ear is able to detect the first five partials, or four besides the first partial, the principal note: some ears are able to detect more than these.

The result of this is far-reaching. Lower the fifth harmonic one octave; then strike the principal note G firmly, and immediately afterwards the second, third, fourth, and the fifth lowered an octave, together, lightly, as in the diagram. The sounds of the second to fifth partials, heard faintly when the principal note was struck, are now accentuated, and the common chord of G has resulted. This means that whenever a note is sounded the common chord of that note is also sounded, *and is heard by the listener*, though he may not be conscious that he hears it, as he may hear the ticking of a clock and not be conscious that he hears it until it stops, or until he consciously directs his attention towards it. He is conscious of the change in *quality* of a note, and this change is caused by a subduing, or an accentuating, of certain partials. The four partials heard with the lower G as above are the principal notes of the scale; the intermediate notes are derived from the higher partials.



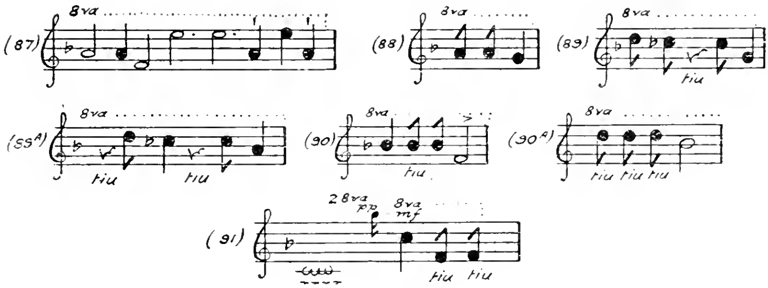
Whilst, then, the scale, as a scale, may be an artificial production, the notes of which it is composed are natural productions, all sounding, in varying degrees of intensity, every time a musical note is produced. Science did not invent the scale; it merely explains the manner in which the scale came to be used unconsciously by singers from time immemorial. It must be remembered that until music came to be written in harmony—that is, about the seventeenth century—there was no need for the term "scale." Mankind had been singing its melodies for hundreds of years without knowing such a term, and without feeling any need for it. Their ear was probably as true as the ear of the most skilled musician of the present day; certainly their melodies were equal to his in beauty. Not that the melodies themselves were fixed: they were common property, and singers varied them as the mood inspired, and as the ear allowed. It cannot be said of any particular melody that its preserved form was the form in which it was sung; all that can be said is that that is how it was sung at least by some. "Scales" were unknown, and "bars" also; and that it is possible to confine the old wild-song melodies within modern scales and bars is proof that the ancient artless music and the modern art of music have a common basis. All that is claimed for birds is that this common basis is the one on which their song, too, is built.

The figures accompanying this article contain the new notes observed since publication of the paper in the *Transactions* of 1914 (*Trans. N.Z. Inst.*, vol. 47, p. 593). As before, for convenience of reference, the variations in the notes of each species of bird have been numbered consecutively from (1) onwards, the earlier numbers appearing in *Trans. N.Z. Inst.*, vol. 41, p. 422; vol. 43, p. 656; vol. 45, p. 387; vol. 47, p. 593. Reference is at times made to these earlier-numbered variations.

## The Tui.

The few new notes were heard at Pangatotara, Motueka Valley, in January, 1916. The theme of (87) was heard on the 7th at early morning, in the grey dawn before the thrushes started their song. The notes, occupying about three seconds, were very musical, clear, and flute-like, inclining to a bell-sound. On the 8th at twilight, when almost dark, the notes of (88) were repeated: time occupied by the phrase, one second. On the 9th (89) and (89A) were noted. The sound vocalized *tiu* was on G, but being uttered, apparently, with a wider aperture than the accompanying flute-notes, the sound differed in quality: the final G, though of the same pitch, was perfectly flute-like. Besides the *tiu* there were other little breaks or catches heard when the bird was near at hand, the high notes of the bubbling song, sounding very softly, appearing to escape amongst the others. The song was not, therefore, clear and sharp unless heard at some distance, when the intruding notes were lost; and when yet greater distance subdued the *tiu* also, (89) sounded simply as D, C flat, G, C flat, G. Time taken, little over a second.

On the 17th, two tuis began their song at a quarter to 4 in the morning, when grey, but too dark to read print. The thrushes, and other English birds, began at 4, and all, tuis, thrushes, &c., stopped at half past 4. The first tui to begin sang (90), repeating it over and over with but slight pause between the repetitions, the phrase taking about a second. Another tui broke in now and again with the variant (90A), but with notes of quite a




different quality from (90), being hoarse, almost unmusical. Later the second bird, judging from the direction of the sound, changed to (91). The *rrrr* had no musical quality, but was merely a vibrating sound exactly imitated, except in intensity, by vibrating the uvula without emission of breath. One, sometimes two or more, bubbling notes followed the *rrrr*, then a bell-note, and lastly two half-vocalized bell-notes. The bubbling notes were barely audible when audible at all, and I surmised, by the pause that often occurred between the *rrrr* and the C, that many times the notes were inaudible to me where I lay in my tent.

Referring to the note in *Transactions* of 1914, vol. 47, p. 598, regarding tuis singing in harmony, Mr. C. Howard Tripp has forwarded further letters on the subject, extracts from which follow:—

Mr. B. M. Moorhouse, Timaru, writes: "I have several times heard the 'morning chorus,' principally in Peel Forest, twenty or thirty years ago, and have often been struck by the immense volume of sound, and not a discordant note that I could distinguish. I am not an authority on musical matters, but believe I could distinguish an harmonious combination from a medley of musical sounds, and the music I have heard was always such as to make one leave off any work or occupation to listen and be enthralled. I have only, so far as I can remember, heard it at sunrise, and then only for a short time. You mention tuis only, but it was my impression that the bell-birds also joined in, but I am not sure. So far as I remember, one bird used to start, and then all the birds within earshot joined in. In any case, I remember it as one of the finest pieces of orchestral music I ever listened to. I have lately spoken to two or three others, who agree with me in most of the above remarks."

Mr. W. H. S. Moorhouse, Wellington, writes: "I was on a boat at anchor in the harbour [at Port Hardy, north of D'Urville Island], and just before daylight a single bell-bird started a few notes, and almost immediately afterwards thousands of birds from every side of the harbour started a most glorious chorus, which continued for three or four minutes and then as suddenly ceased. It was not possible to determine the notes of the different birds, any more than an amateur could say what instruments composed a huge band. The chief songsters in the harbour at other times were tui, bell-bird, and lark; also the smaller birds were in great numbers—ground-robins, fantails, white-eyes, &c.—but probably these would not join in the chorus. At the time I speak of the whole harbour-sides were clothed with dense bush, which I find on my last visit has almost entirely gone to give place to sheep. The year was 1902, December."

## The Fantail.

The song (14) was heard at Khandallah (near Wellington) on the 24th October, 1915. The sound was almost a whistle, but half-vocalized as noted. The song was made up of the theme, shown between the double bars, repeated several times without break, the theme taking about two seconds, so that if repeated five times the song lasted, say, ten seconds. The very soft

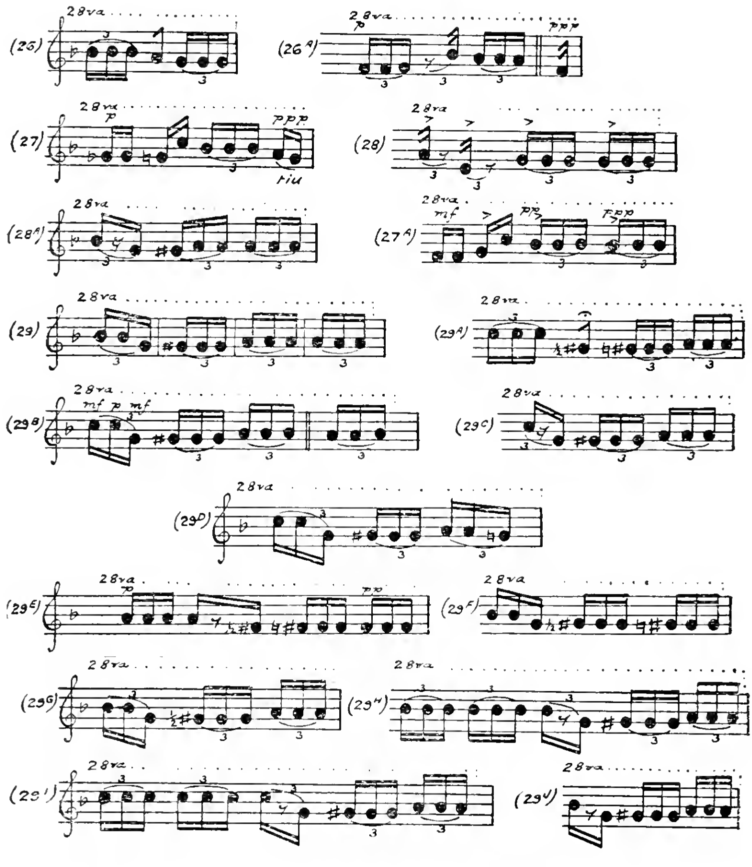

introductory note was not repeated with the theme; only at the opening of the song. The two pairs of slurred notes were at times three pairs. The most characteristic song heard in the scrubs, shrubberies, and clumps of native bush about Wellington is that of (15), varied as in (15A) and (15B). The notes, which may be twenty or more in number, arranged in pairs, are sharp whistles, unslurred and unvocalized. The eight pairs of (15) were uttered in about four seconds, and were heard in Tinakori Road on the 26th October, 1915, the ten pairs of (15A) being heard in the Botanical Gardens on the 3rd November, 1915: their pitch was G A, G A, on the 1st December. The notes are more deliberate than those of (14). They are at times whistled as the prelude of the tweeting song, and may themselves be preceded by *tweet-tweet, tweet-a-tweet*: they are, however, more often whistled alone. On the 1st December the *tweet-a-tweet* was a fifth lower in pitch than the lower note of the pair. No notes were heard in February, and occasional notes only in March; but through the rest of the year 1916 these whistling notes were heard more or less every day. They are monotonously regular, their chief variation being in pitch and interval. On the 10th April, 1916, they were B C, B C, and on the 12th the B was slightly raised—less than a semitone. On the 27th April the interval was very small, as in (15B), and probably the interval was even less; the opening C was little more than half-flat. In singing this theme the whole, including the two introductory vocalized notes, was repeated four times or more. Usually the accent is decidedly on the first note of the pair; at times the accent is absent, and the sequence of the notes of the pair can be gathered only from the opening or close of the theme; at times the accent is on the upper note, when the interval, instead of sounding an upward one, sounds downwards, as in (18). On this occasion (12th September, 1916) the bird sat quietly on a bough whilst singing these notes, variously vocalized as indicated, following them with a faint tweeting. Another, singing the common high whistle, also falling instead of rising, sat on the bough with beak wide open, slightly closing it at each drop of the sound. It was never still whilst singing, facing first in one direction, then flitting round and facing in another. On the 29th August, 1916, the common upward whistling notes, half-converted to *tweeting*, were sung by a bird whilst flying with another in playful evolutions.

On the 21st May, 1916, a sunny, dewy morning, with thrushes singing freely, the song (16) was heard, sung by a black fantail. Two birds were together, and the song, with its *tweety* introduction followed by whistled triplets, was very characteristic and charming. It is usually the pied birds that are observed singing; but as the number of these is, in this district, much greater than the number of black birds, no inference may be drawn from this fact. The notes of (11A) are probably call-notes. They were uttered, some five notes in two seconds, by a pied bird, another answering, and the two gradually approaching. The notes differ in vocalization only from those of (11) (*Trans.*, vol. 45), being vocalized *chit, chit*, instead of *ti, ti*, the vowel sound being the same. The triplets of (17) were very quickly sung, on the 24th August, 1916, the nine notes being uttered in little over a second, and the whole repeated several times. The effect of these triplets, with their curious vocalization *tweedle-a*, was quite different from the vocalized triplets of (14), or the whistled triplets of (13) and (16). The notes of (19) may perhaps be considered a variation of the common whistling song: it is in pairs; the high notes are preceded by a vocalized pair *tweet-a* or *tweet-tweet*; but the high notes are here also vocalized rather than whistled, and the song is broken into short repeated phrases. When not otherwise specified, these variations were noted in the Botanical Gardens, Wellington.

## THE GREY WARBLER.

The more I hear of the warbler the higher is my estimation of its gentle song. The characteristic nature of the song, rising or falling triplets, soon becomes familiar, and may be heard almost every day in the environs of Wellington. The whole of the variations noted below were heard in the

Botanical Gardens unless otherwise specified. The varied phrase (26) was heard in Crieff Street on the 25th August, 1915; (26A) was there repeated many times, and again in various parts of the Kaiwarra Valley on the 7th and 8th September of that year. In (26A) the triplets rise instead of falling, and the place of the middle quaver is taken by a pause and semiquaver. When at a distance the theme ended at the double bar; but when near the bird a faint note followed, so that it is probable the faint note always followed when the phrase was repeated. When at a distance, too, the triplets often sounded like a single note. No. (27) is a variant of (26A), heard on the 4th October, 1915, in the Botanical Gardens. The opening notes were here




pairs instead of triplets, and the final soft note was a slur, vocalized *tiu* (*tee-oo*). The phrase was often repeated many times in succession. The pitch and the final note were varied as in (27A) on the 29th October, 1915; and, again, these opening pairs were at times triplets. The pairs often sounded when the bird was close at hand, and there was then no intermediate faint note: the value of the notes was rigidly observed by the bird. The phrase (28), heard on the 23rd October, 1915, usually opened with a few indeterminate notes, the phrase itself being several times repeated with these opening notes omitted. It was varied on the same day as in (28A).

No. (29), with its many variants, was the most characteristic song heard about Wellington during the year. The type of this song may be taken as (29) or (29B), and the typical variation as (29C). In these the intervals are true to scale, and the "time" is also perfect, the phrase making a complete four bars of two-eight time, as indicated in (29). The last triplet,


as in (29B), was at times absent, when its place was taken by a pause, or it was very faintly uttered: in fact, it occurred in all gradations between complete silence and the ordinary loudness of the rest of the melody. This curious variation of the loudness of adjoining notes is best exemplified in other of the warbler songs, such as (30). It is in variations of the type song that intervals other than those of the scale occur, as in (29A, E, F, and G).

No warbler was heard during February; on the 2nd and 3rd March the song was heard once, and again on the 10th, 11th, and 12th. On the 18th the variation (29A) was heard—the first time the half-sharp was heard during the year; but again on the 13th July (29E) was heard, and (29F) and (29G) on the 19th July. The differences in pitch were most noticeable: (29F) was heard in the Botanical Gardens, (29G) in the Sydney Street Cemetery.

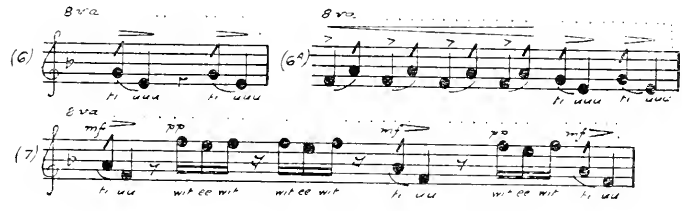
These differences in the type song, and in others, cannot at present be explained by me, if any explanation be necessary. I think it very evident that individual birds have individual songs; and, again, that different localities, and perhaps even different years, have different songs. The difference in individual birds is comparable with a like characteristic in human beings: in songs not sung from music all sorts of variations distinguish the rendering by various people of the same song; and some, in addition to other differences, sing flat or sharp. The type song is often opened with a rambling theme of uncertain notes, which is not repeated with the theme, and apparently forms no part of the song itself: this is unhesitant and confident and clear. Such a rambling theme is given in (30); and when the soft intermediate notes are so soft as to be inaudible the effect is very much as the rambling notes of (1). No. (30) was noted on the 28th April, 1916. Following an opening similar to (29A), the theme (31) was sung on the 10th April, 1916, the rests being occasionally filled with faint notes as in (31A). These faintly sounded notes produced another result in (32), heard on the 18th April, 1916. At a distance this sounded as written—a long note followed by a higher soft staccato note. On nearing the bird, however, the long note, which should perhaps be a dotted crotchet rather than a dotted minim, was resolved into triplets, as in (32A). The high staccato note formed the third note of the second triplet, though it *sounded* like the introductory note of the following triplet. They were very quickly uttered, the whole of (32) taking under two seconds—perhaps nearer a second and a half. Another quickly uttered song is the unusual one of (33), heard on the 1st June, 1916. The burden of this sounded very like *cheerily oh, ye oh;* but the " *i* " in the first *ti ri* are short, like the " *i* " in "hit," the others like "*ee*," the Continental "*i*." The first eight notes, including rest, occupied about a second, and the rest were taken at like speed. It was an almost continuous strain, repeated, after the staccato slur *tiu*, in irregular order, sometimes one of the pairs following the six opening notes, sometimes two. It may be the vocalization of the staccato slur that caused the apparent drop of an octave. It should be noted that this drop at the finish is characteristic of Maori songs. The warbler notes are often *near* vocalization, but this theme was exceptionally distinct.

Another departure from the song common during the year was (34), heard in Crieff Street on the 9th June, 1916. The theme, up to the double bar, was repeated two or three times the first time sung, then once at intervals, each time occupying about a second and a half. The bird was alone, busily searching in a tree-lucerne for insects as it sang. The vocalization of the deep note was distinct; the others were softly warbled. No. (35) was heard on the 28th October, 1915, the song being several repetitions of this phrase; (36) was heard at Pangatotara, Motueka Valley, on the 9th January, 1916, the theme taking about two seconds, and being repeated three times or more in succession. The descending triplets of (37) and its variants were like a rapid vibrato, twelve notes in perhaps two seconds. In (37) there were two birds, the male, presumably, singing. He was darker than his mate, who flittered from branch to branch, lower in the tree, with wings quivering as if to the vibrato of the song. She was pale dove-grey on the breast—a beautiful soft colour—and darker on the back. This pair, seen at Khandallah on the 27th August, 1916, was the first to give an indication of spring. The song was varied as in (37B), descending in semitones. The variant (37C) was heard in Wilton's Bush on the 23rd September, 1916.

A variant of the rambling song is (38). This consists of two parts—the opening and the part between the double bars, the repetition of the latter, twice or more, constituting the main part of the song: heard on the 27th August, 1916. It was varied as in (38A), heard in Wilton's Bush on the 23rd September, 1916—a theme very quickly sung, all in about a second, repeated three or four times. It was still further varied as in (38B); and this, too, is a lovely variant of the type song, rising and falling instead of falling and rising, in the manner of (27) and (27A). The song was heard in the distance on the 10th October, 1916; and, judging by songs of like nature, it would sound as (38C) if close at hand. No. (39), a theme repeated three or four times, is another curious vocalization, heard in Wilton's Valley on the 23rd September, 1916. At a distance the theme ended with a rest, but near at hand the rest was filled with a soft slur, and this was repeated each time with the other notes.

## THE SHINING CUCKOO.

In the summer of 1915 I first heard the cuckoo, in the Botanical Gardens, on the 6th October. The two upward notes were repeated four or five times, but no down slur. It was heard again on the day following, and on most days thereafter until the end of the year. I did not hear it after my return from the Motueka Valley at the end of January. The down slur was first heard on the 22nd November, when the first notes were



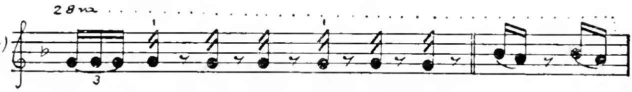

G A, and the slur G F. The day was sunny and warm, after cold weather, and all the birds were lively. The down slur was F to B three times repeated on the 11th December, after upward slur G to A six times repeated, and after a pause F B, F B, a pause, and again F B. The opening notes were also G A at Pangatotara, Motueka Valley, on the 16th January, 1916.

In the summer of 1916 I first heard the cuckoo on the 25th September. I was in Wilton's Bush, and, hearing the down slurs, took them for the notes of a practising thrush. But I was undeceived when the ordinary upward slurs sounded, followed by the down slurs. I had been attracted by a beautiful pendulet of white clematis looped in the upper branches of a graceful putaputaweta (*Carpodetus serratus*), and was seated under this tree when the cry sounded. I did not, however, see the bird until it flew off, though it had been sitting on the high bare branch of a dead tree just above me. It had probably been perched, cuckoo-wise, along instead of across the branch. The notes were those of (6). I have not been able to note that there is an increase in the interval between the notes of the slurs as the season advances: such increase of interval does take place in the well-known cry of the European cuckoo. I did not hear it in the Botanical Gardens until the 17th October, a warm day following cloudy and rainy weather. On the 19th a new element was introduced into the song. In the pauses between the down slurs an indefinite number of triplets, one, two, or three, were sung very softly, vocalized as in (7).

### The Blight-bird (Silver-eye).

On the 21st April, 1915, I was seated indoors near an open window, at twenty minutes past 9 in the evening, when I heard a twittering, almost singing, that lasted one or two minutes. I was in Armagh Street, Christchurch, near the old Provincial Government Buildings, and thought the birds were in the shrubberies opposite, and went out to investigate; but the sound then seemed in the air, and passed away, apparently to the south-east. It sounded like scores of birds, all twittering the two notes of (*a*) in (5), or (*b*), or (*c*), or (*a*) and (*b*) combined, now one, now the other

(5) 


(6) 


—a medley—individuals could not be distinguished. The interval of the slur was hardly a semitone. The night was chilly, dark, and overcast, and perfectly still—no breath of wind. The note had the characteristic plaintive sound of that of the blight-bird; and I remembered Mr. J. Hardcastle, of Timaru, saying that he had one night heard what he thought to be the twittering of small birds passing overhead, and the twittering was as the cry of the blight-bird. On the 22nd May, 1916, (6) was noted in the Botanical Gardens—a quick, soft-toned whistle, followed after a pause by the usual slurred cry: the part to the double bar occupied about a second and a half.

### The Morepork.

The cry commonly heard in Crieff Street is as in (9): (9) 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## Art. LI.—*The Blepharoceridae (Diptera) of New Zealand (in Part a Translation of the Work of Professor Mario Bezzi).*

By David Miller.

[*Read before the Philosophical Institute of Canterbury, 6th December, 1916.*]

(The manuscript of this article has been placed in the library of the New Zealand Institute.)

# PROCEEDINGS.

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OF THE

# NEW ZEALAND INSTITUTE,

# 1916.

## FOURTEENTH ANNUAL MEETING.

WELLINGTON, 30TH JANUARY, 1917.

THE annual meeting of the Board of Governors of the New Zealand Institute was held in the Dominion Museum Library, Wellington, on Tuesday, the 30th January, 1917, at 10 a.m.

Present: Professor Benham, President (in the chair); Professors Chilton, Easterfield, Kirk, Marshall, Segar; Drs. Cockayne, Hatherly, Hilgendorf, Allan Thomson; Messrs. C. A. Ewen, H. Hill, D. Petrie, J. W. Poynton, G. M. Thomson, and B. C. Aston.

The Secretary announced that the appointments of Government representatives in December had made no change in the representation, Dr. Chilton* and Mr. C. A. Ewen having been re-elected. Dr. Hilgendorf apologized for the absence of Mr. A. M. Wright, absent on active service in the war-zone.

*Presidential Address.*—The President then read his presidential address (see p. 543). On the motion of Mr. Hill, a hearty vote of thanks was carried to the President for his address, which was ordered to be printed in the Proceedings.

*Standing Committee's Report.*—The Standing Committee's report, which had been circulated, was considered clause by clause and adopted.

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* See Standing Committee's Report.

## Report of the Standing Committee.

Ten meetings of the Standing Committee have been held during the past year, the attendance being as follows: Mr. Petrie, 1; Mr. G. M. Thomson, 2; Professor Kirk, 7; Professor Easterfield, 6; Dr. Cockayne, 10; Professor Marshall, 1; Professor Segar, 2; Dr. Allan Thomson, 9; Mr. C. A. Ewen, 6; Mr. B. C. Aston, 10; Professor Benham, 1; Professor Chilton, 1.

*Hector Memorial Fund Award to Sir E. Rutherford.*—A medal has been suitably inscribed and sent to the High Commissioner in London, through the Department of Internal Affairs, for presentation to Sir E. Rutherford, but details of the presentation have not yet been received.

*Hutton Memorial Fund.*—Grants for research work were made at the last annual meeting of the Board to the Portobello Fish-hatchery (£25), which was duly paid, and to Major Broun (£50), towards the cost of publishing his scientific papers by the Institute. (Reports on the progress of the investigations supported by these grants have been received, and a further report on a grant to Mr. W. R. B. Oliver made in 1915 has been also received.)

*Hutton Award Committee for 1917.*—Professor David, of Sydney, having enlisted, this Committee has appointed Mr. W. H. Twelvetrees, Government Geologist, Launceston, Tasmania, to the vacancy.

*Publications.*—The first six copies of volume 48 of the *Transactions of the New Zealand Institute*, of which 1,750 were ordered by the Committee, were received from the Government Printer on the 6th November, the delivery of the issue being completed on the 28th November. As Parliament was not sitting when the volume was published, the presentation to Parliament has been delayed until next session. Owing to the necessity of keeping the expenses of the Institute within the income, it was decided that the Government Printer should this year distribute the volumes in bulk to the secretaries of the incorporated societies, on whom will devolve the duty of distributing them. As the date of publication of volume 48 (16th October, 1916) conflicts with a decision of the Institute, some action must be taken to put the matter in order. (Minute-book, 1910 annual meeting, p. 186: "That 1st June of each year be the date of publication of *Transactions of New Zealand Institute.*—Dr. Cockayne and Professor Easterfield.")

It has been decided by the Committee that wherever possible the small pamphlets of the Institute should be sold by booksellers, and that applications from the public be referred to booksellers.

*Stock of Transactions.*—In response to this Committee's circular to public and secondary school libraries in New Zealand, 135 replied accepting the Institute's offer. The Government Printer, acting on the instructions of the Minister of Internal Affairs, the Hon. Mr. Russell, accordingly despatched, free of charge to the Institute or to the libraries, a partial set of the *Transactions of the New Zealand Institute*, consisting of volumes 19 to 36, to each of the libraries mentioned below:—

Akaroa Coronation Library.
Anderson's Bay Public Library.
Ashley Public Library.
Apiti Circulating Library.
Ashburton High School.
Brightwater Public Library.
Bombay Public Library.
Bunnythorpe Public Library.
Barr Hill (Rakaia) Public Library.
Brydone Athenæum Public Library.
Clyde Athenæum Public Library.
Collingwood Public Library.
Cromwell Public Library.
Cave Public Library.
Clinton Public Library.
Cust Public Library.
Canterbury Public Library (Christchurch).
Clifton Terrace Public Library.
Christchurch Boys' High School.
Dannevirke Borough Public Library.
Dunrobin Public Library.
Ealing Public Library.
East Takaka Public Library.
Eskdale Public Library.
Fairlie Public Library.
Geraldine Public Library.
Gordon Settlement Public Library.
Gore High School.
Greytown Public Library.
Hawera Technical School.
Hawera Public Library.
Hawke's Bay Education Board.
Hamilton High School.
Hamilton Public Library.
Herbertville Public Library.
Hanmer Springs Sanatorium.
Helensville Public Library.
Heddon Bush Public Library.
Hector Observatory.
Inglewood Public Library.
Invercargill Athenæum.
Kawakawa Public Library.
Kaiapoi Public Library.
Knapville (Gore) Public Library.
Lincoln Public Library.
Loburn Public Library.
Levin Public Library.
Linwood Public Library.
Lyttelton Public Library.
Makino Public Library.
Marlborough High School.
Makara Public Library.

Mangapai Public Library.
Matamata Public Library.
Mataura Public Library.
Merton Public Library.
Millerton Public Library.
Mossburn Public Library.
Marton Public Library.
Maungakaramea Public Library.
Morven Athenæum.
Napier Municipal Library.
Napier Borough Council.
New Plymouth Technical School.
Norsewood Jubilee Library.
Ngaruawahia Public Library.
Nightcaps Public Library.
Oamaru Mechanics' Institute.
Ocean Beach Public Library.
Okuru Library and Institute.
Okain's Bay Public Library.
Onehunga Carnegie Public Library.
Otahuhu Public Library.
Opouriro North Library (Bay of Plenty).
Owaka Public Library.
Otorohanga Public Library.
Otaio Public Library.
Omaha (Leigh) Public Library.
Pahiatua Public Library.
Pahi Public Library.
Palmerston North Technical School.
Paparoa Public Library.
Picton Literary Institute.
Pongakawa Public Library.
Pokeno Public Library.
Portobello Public Library.
Pukekawa Public Library.
Quinton Public Library.
Rangiora Library Institute.
Redcliffs Public Library.
Ross Borough Council.
Seddon Public Library.
Southland Boys' High School.
Southland Girls' High School.
Southland Technical College.
Shannon Public Library.
Sumner Public Library.
Stewart Island Athenæum.
St. Albans Public Library (Christchurch).
Stanley Brook Public Library (Nelson).
Sydenham Public Library.
Tai Tapu Public Library.
Taupo Public Library.
Tauranga Public Library.
Taupiri Public Library.
Tapanui Public Library.
Te Puke Public Library.
Temuka Public Library.
Timaru Boys' High School.
Timaru Borough Council.
Tuapeka Athenæum and Mining Institute.
View Hill Public Library.
Wanganui Technical College.
Waihi Public Library.
Waitaki Boys' High School.
Waerenga Public Library.
Warkworth Town Library.
Waikoikoi Public Library.
Waimahaka Public Library.
Wakefield Public Library.
Waimate Public Library.
Waimana Public Library.
Ward Public Library.
Waipawa Citizens' Public Library.
Wairoa Mechanics' Institute.
Waitara Public Library.
Waipu Public Library.
Warterton (Ashburton) Public Library.
Weber Public Library.
Wellington Technical School Board.
Wellington Girls' College.
Wellington College.
Woolston Public Library.
Woodville Public Library.
Whakatane Public Library.

A large number of appreciative replies have been received from the libraries, thanking the Institute for the valuable gift. This Committee has passed a special vote of thanks to the Hon. the Minister for his kind action in the matter. There still remains a large number of *Transactions* in stock, and this Committee has decided that those volumes of which more than two hundred are in stock may be sold to non-members at 5s. per copy, the price to members having already been fixed by the Board at 2s. per copy. This Committee has further decided that the price of a complete set of the *Transactions* shall be £20. By reducing the price of the numbers of which there is a large excess it is hoped to bring the stock within manageable compass. The volumes remaining are still stored in the General Assembly vaults by the courtesy of the Chief Librarian (Mr. Charles Wilson), to whom the thanks of the Institute are due.

*Resignation.*—Mr. A. H. Turnbull, a Government nominee, resigned his seat on the Board of Governors in March. The appointment of a successor to Mr. Turnbull was referred by the Hon. the Minister (Mr. Russell) to the President, who recommended Dr. Chilton, and the latter was appointed to the vacancy in April, 1916.

*International Catalogue of Scientific Literature.*—The compilation of the index cards for 1915 was referred by this Committee to the Library Committee.

*Panama Exhibit.*—The exhibit of the Institute prepared for the Panama Pacific Exposition was safely returned, but unfortunately, owing to some oversight, had not been exhibited.

*Hamilton's "Maori Art."*—Permission was given by this Committee to the Herbert Spencer Trustees to use portions of *Maori Art* in a work on ethnology to be issued by them.

*Vote of £250 for Research.*—A vote for the encouragement of research was placed on the estimates for 1916–17 by the Hon. the Minister of Internal Affairs, in fulfilment of his promise at the last annual meeting of the Board. (See *Trans. N.Z. Inst.*, vol. 48, p. 530.) The use of the vote was discussed by a deputation which waited on the Hon. Mr. Russell in Dunedin, consisting of the President (Professor Benham), Professor Marshall, and Mr. G. M. Thomson. The Minister inquired—(1) Under what conditions could this money be most profitably spent in the interests of the Dominion? (2) What conditions is it suggested should be attached to the spending of the vote? (3) Would it be desirable to divide the money into, say, five prizes of £50 each or more? (4) What subject should be selected for research? and asked that the matter be considered by the Institute. The subject was duly referred by the President to the Standing Committee, with instructions to formulate proposals of a more or less definite character to govern the expenditure of the vote. The Standing Committee drew up a scheme, and waited in deputation on the Minister on the 20th October, Professors Easterfield and Kirk, Drs. Cockayne and Allan Thomson, and Mr. B. C. Aston being present. The deputation explained the scheme which had been agreed upon, and the Minister gave his general approval. As a result of the meeting it was understood that—

(1.) The Institute would be entrusted with the expenditure of the vote of £250.

(2.) Any surplus unexpended on the 31st March, 1917, need not lapse, but should be carried forward to the succeeding year, the Minister hoping to be able to increase the amount of the total vote for that year.

(3.) Portions of the vote will be paid as occasion arises on the recommendation of the Institute, comparatively large items to receive the Minister's sanction first.

(4.) The Minister is prepared to supply from a separate vote such scientific literature as may be requ.red by research workers.

(5.) The two methods of distributing grants to research workers suggested by the Standing Committee are approved, as follows: Preference to be given in the first instance to investigations which appear to have an economic bearing, purely scientific investigations to be by no means excluded. When the research is one that leads to a direct economic advance the Government shall reserve to itself the right of patenting the discovery and of rewarding the discoverer; but it is to be understood that grants from this vote of £250 are not in the nature of a reward or prize, but for out-of-pocket expenses incurred by the research worker. Plant, books, apparatus, chemicals, &c., purchased for applicants are to remain the property of the Institute, and eventually to form a loan collection of apparatus in the manner practised by the Royal Society of London. First method: Applications shall be invited for grants in aid of research to be specfied by applicants. Second method: The Governors of the Institute to suggest from time to time subjects the investigation of which is desirable, and to ask capable investigators to undertake such researches, the Institute to pay for apparatus, material, and working-expenses, including assistance.

(6.) The Minister was prepared to give some relief in the matter of the Government Printer's bill against the Institute, and to inquire into the method adopted by the Government Printer in making his charges. The Minister was prepared further to reissue certain papers individually or bound together in booklet form.

On the 9th November, 1916, taking advantage of the presence in Wellington of several Governors of the Institute, a meeting of the Standing Committee, attended by the President, Professors Chilton, Easterfield, Kirk, and Segar, Drs. Cockayne and Allan Thomson, and Mr. B. C. Aston, was held. Three applications from the Philosophical Institute of Canterbury received for portions of the above vote were granted. Grants have also been made to applicants through the Otago Institute, the Wellington Philosophical Society, Hawke's Bay Philosophical Institute, and to Mr. D. Petrie. The total vote of £250 has now been all apportioned. The scheme as outlined above has been circulated among the incorporated societies, with the result that several applications have been received.

The matter has been put in order by receipt of a letter dated the 14th December, 1916, from the Under-Secretary, Internal Affairs, confirming the Minister's approval of the above scheme, and stating that the question of granting some relief in the Government Printer's account is receiving attention, and advising that the Philosophical Institute of Canterbury's applications have been approved and the money banked to the New Zealand Institute account. Dr. Cockayne, Professor Easterfield, and Dr. J. Allan Thomson have been deputed to draw up conditions under which portions of the vote shall be paid over to the grantees, to report to the annual meeting.

*Destruction of Fur Seals.*—The Standing Committee has drawn the attention of the Right Hon. the Minister of Lands to the case recently reported in the daily Press of the destruction of fur seals at the Sounds National Park, and urged the prosecution of the offenders.

*Annual Reports and Balance-sheets* of the following incorporated societies have been received, and are now laid on the table:—

Auckland Institute, for year ending 22nd February, 1916.
Hawke's Bay Philosophical Institute, for year ending 1st December, 1916.
Manawatu Philosophical Society, for year ending 30th October, 1916.
Wellington Philosophical Society, for year ending 30th September, 1916.
Nelson Institute, for year ending 22nd December, 1916.
Canterbury Philosophical Institute, for year ending 31st October, 1916.
Otago Institute, for year ending 30th November. 1916.
Wanganui Philosophical Society, for year 1916.

On the motion of Dr. Cockayne, the action of the Standing Committee in appointing Mr. W. H. Twelvetrees to the Hutton Award Committee was confirmed.

On the motion of Dr. Hilgendorf, seconded by Dr. Chilton, it was resolved, That the Standing Committee make arrangements with the Government Printer for the distribution of the copies of the *Transactions*.

On the motion of Dr. Chilton, seconded by Professor Marshall, it was resolved, That the resolution of the year 1910 respecting the date of publication of the *Transactions* be rescinded.

The regulations regarding the expenditure of grants under the research-grants scheme, which were formulated by the sub-committee consisting of Professor Easterfield, Drs. Cockayne and Allan Thomson, appointed by the Standing Committee, were read and approved.

*Destruction of Fur Seals.*—A report from Drs. Cockayne and Thomson was submitted. On the motion of Mr. J. W. Poynton, seconded by Dr. Chilton, the report was amended and adopted in the following form:—

That this Institute learns with regret that the declaration of an area as a national park does not prohibit sealing therein, and urges that a special Act be passed defining the limits of an area for a national park including the southern fiord lands and waters, with protection, under severe penalties, of seals and other animals therein, and that a copy of this motion be sent to the Minister of Lands.

That this Institute learns with regret that the declaration of an area as a sanctuary under the Animals Protection Act does not prevent sealing therein—*e.g.*, in the Sounds National Park—and urges that the amendment of the law necessary to secure such protection for seals be taken in hand by the Government, and that a copy of this motion be sent to the Minister of Internal Affairs.

That it is desirable in the interests of the preservation of the seal that sealing should be permanently prohibited in the Sounds National Park and at Cascade Point, Westland, and that the Minister of Marine be requested to take such steps as will ensure this.

*Research Grants.*—An account of the apportionment by the Standing Committee of the sums of money to research workers was given by the Honorary Secretary and approved. It was resolved to incorporate the details in the Proceedings of the Institute.

*Incorporated Societies' Reports.*—The annual reports of the Auckland Institute, the Wellington Philosophical Society, the Philosophical Institute of Canterbury, the Otago Institute, the Hawke's Bay Philosophical Institute, the Manawatu Philosophical Society, the Nelson Institute, and the Wanganui Philosophical Society, for the last year, were received.

*Honorary Treasurer's Reports.*—The financial statements of the Honorary Treasurer, Mr. C. A. Ewen, comprising those of (*a*) receipts and expenditure; (*b*) assets and liabilities; (*c*) the Carter Bequest, the Hutton Memorial Fund, and the Hector Memorial Fund, all of which were duly audited and certified to by the Auditor-General, were adopted. A minute dated the 17th January, 1917, from the Hon. the Minister, regarding the Carter Bequest, was referred to the Standing Committee.

Statement of Receipts and Expenditure for the Year ending 31st December, 1916.

| *Receipts.* | £ | s. | d. |
|---|---|---|---|
| Balance per last statement | 492 | 7 | 2 |
| Government grant .. | 500 | 0 | 0 |
| Government grant (special) | 110 | 0 | 0 |
| Sales of *Maori Art* .. | 4 | 4 | 6 |
| Sales of *Transactions* .. | 10 | 15 | 9 |
| Sales of Bulletins, Index, reprints .. .. | 1 | 18 | 5 |
| Post Office Savings-bank interest .. .. | 18 | 8 | 6 |
| Canterbury Institute levy .. | 22 | 7 | 6 |
| Otago Institute levy .. | 21 | 7 | 6 |
| Wellington Institute levy .. | 15 | 15 | 0 |
| Manawatu Institute levy .. | 6 | 15 | 6 |
| Auckland Institute levy .. | 37 | 10 | 0 |
| | £1,241 | 9 | 10 |

| *Expenditure.* | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Government Printer .. | | | | 625 | 0 | 6 |
| Government stationery .. | | | | 1 | 16 | 0 |
| Governors' travelling - expenses .. .. | | | | 23 | 10 | 2 |
| West, Newman .. .. | | | | 1 | 1 | 0 |
| McKay (custodian) .. | | | | 5 | 0 | 0 |
| Fire-insurance premium .. | | | | 5 | 0 | 0 |
| Hon. Editor, petty cash .. | | | | 3 | 0 | 0 |
| Bank charge .. .. | | | | 0 | 10 | 0 |
| Hon. Secretary, postages .. | | | | 10 | 6 | 11 |
| Hon. Secretary, cash in hand | | | | 4 | 13 | 1 |
| Stamp duty, Bank of New Zealand .. .. | | | | 0 | 0 | 4 |
| Balance in— | | | | | | |
| Bank of N.Z. | 243 | 3 | 4 | | | |
| P.O. Savings-bank | 318 | 8 | 6 | | | |
| | | | | 561 | 11 | 10 |
| | | | | £1,241 | 9 | 10 |

Statement of Liabilities and Assets at 31st December, 1916.

| | *Liabilities.* £ | s. | d. | *Assets.* £ | s. | d. |
|---|---|---|---|---|---|---|
| By Balance in Bank of New Zealand .. .. .. | .. | | | 243 | 3 | 4 |
| Balance in Post Office Savings-bank .. .. .. | . | | | 318 | 8 | 6 |
| Hawke's Bay Institute levy .. .. .. | .. | | | 6 | 0 | 6 |
| Nelson Institute levy .. .. .. .. | .. | | | 3 | 10 | 0 |
| Wanganui Philosophical Society levy .. .. | .. | | | 6 | 17 | 6 |
| Petty cash in hands of Secretary .. .. .. | .. | | | 4 | 13 | 1 |
| Authors' copies and *Transactions* sold .. .. | .. | | | 30 | 6 | 8 |
| To Special Government grant .. .. .. .. | 110 | 0 | 0 | .. | | |
| Government Printer's account for printing and stationery | 599 | 4 | 6 | .. | | |
| Typewriting and clerical assistance .. .. .. | 5 | 0 | 0 | .. | | |
| Custodian's account .. .. .. .. | 3 | 0 | 0 | .. | | |
| Rent, Town Hall .. .. .. .. .. | 2 | 2 | 0 | .. | | |
| By Balance .. .. .. .. .. .. | .. | | | 106 | 6 | 11 |
| | £719 | 6 | 6 | £719 | 6 | 6 |
| To balance .. .. .. .. | £106 | 6 | 11 | | | |

In addition to the above assets the Institute has a large stock of *Transactions* for sale, and possesses a very valuable library.

Hector Memorial Fund.—Statement of Receipts and Expenditure for the Year ending 31st December, 1916.

| | £ | s. | d. | *Dr.* £ | s. | d. | *Cr.* £ | s. | d. |
|---|---|---|---|---|---|---|---|---|---|
| By Balance brought forward .. .. .. | | | | .. | | | 1,086 | 10 | 0 |
| Public Trust Office— | | | | | | | | | |
| Interest, 31st December, 1915, to 31st December, 1916, at $4\frac{1}{2}$ per cent. .. | 47 | 14 | 7 | | | | | | |
| Bonus for year ended 31st March, 1916 | 4 | 14 | 11 | | | | | | |
| | | | | .. | | | 52 | 9 | 6 |
| To New Zealand Institute's Account: Professor P. Marshall, Hector Prize for 1915 .. .. .. | | | | 45 | 0 | 0 | .. | | |
| Public Trust Office: Postages .. .. .. | | | | 0 | 1 | 6 | .. | | |
| Balance .. .. .. .. .. | | | | 1,093 | 18 | 0 | .. | | |
| | | | | £1,138 | 19 | 6 | £1,138 | 19 | 6 |
| By Balance brought down .. .. .. | | | | .. | | | £1,093 | 18 | 0 |

HUTTON MEMORIAL FUND.—STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDING 31ST DECEMBER, 1916.

| | £ s. d. | *Dr.* £ s. d. | *Cr.* £ s. d. |
|---|---|---|---|
| By Balance brought forward .. .. .. | | .. | 739 13 6 |
| Public Trust Office— | | | |
| Interest, 31st December, 1915, to 31st December, 1916, at 4½ per cent. .. | 32 13 10 | | |
| Bonus for year ended 31st March, 1916 | 3 4 7 | | |
| | | .. | 35 18 5 |
| To New Zealand Institute's Account: Grant to Portobello Fish-hatchery .. .. .. .. | | 25 0 0 | |
| Public Trust Office: Postages .. .. .. | | 0 1 6 | |
| Balance .. .. .. .. .. | | 750 10 5 | |
| | | £775 11 11 | £775 11 11 |
| By Balance .. .. .. .. .. | | .. | £750 10 5 |

CARTER BEQUEST.—STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDING 31ST DECEMBER, 1916.

| | £ s. d. | *Dr.* £ s. d. | *Cr.* £ s. d. |
|---|---|---|---|
| By Balance brought forward .. .. .. | | .. | 3,744 0 5 |
| Debenture stock— | | | |
| A. T. Bate, proceeds of sale of New Zealand Loan and Mercantile stock | 15 10 0 | | |
| Less brokerage .. .. .. | 0 5 0 | | |
| | | .. | 15 5 0 |
| Dividend, New Zealand Loan and Mercantile Company, 30th June, 1914, to 30th June, 1915 .. | | .. | 0 1 4 |
| Public Trust Office— | | | |
| Interest, 31st December, 1915, to 31st December, 1916, at 4½ per cent. .. | 168 19 11 | | |
| Bonus for year ended 31st March, 1916 | 16 5 11 | | |
| | | .. | 185 5 10 |
| To Public Trust Office— | | | |
| Commission, 2½ per cent. on £15 6s. 4d. | 0 7 8 | | |
| Postages .. .. .. | 0 1 6 | | |
| | | 0 9 2 | |
| Balance .. .. .. .. .. | | 3,944 3 5 | |
| | | £3,944 12 7 | £3,944 12 7 |
| By Balance brought down .. .. .. | | .. | £3,944 3 5 |

*Hutton Fund Grants for Research.*—Reports on the progress of the investigations undertaken by Major T. Broun (by the Honorary Editor), by Mr. W. R. B. Oliver, and by the Portobello Fish-hatchery (from Mr. G. M. Thomson) were read and approved. No further applications for grants were received.

*Financial Position.*—On the motion of Dr. Cockayne, seconded by Dr. Thomson, it was resolved, That for every copy of volumne 49 of the *Transactions* received by the incorporated societies a contribution of 2s. 6d. towards the cost of printing shall be made during the current year by such society.

*Hector Award Committee's Report.*—The report of the Committee (Professor Haswell and Sir Baldwin Spencer) was opened by the President, and the recommendation awarding the medal and prize to Professor Charles Chilton was adopted.

*Hutton Award Committee's Report.*—The report of the Committee (Mr. W. H. Twelvetrees, Professor Benham, and Dr. Cockayne) was then opened, and the recommendation that the Hutton Medal be awarded to Professor P. Marshall was adopted. It was resolved that the presentation of these two medals should be made at some public meeting.

*Publication Committee's Report.*—The report of the Publication Committee was discussed by Dr. Cockayne, Honorary Editor, who spoke highly of the assistance rendered by Dr. C. A. Cotton, Joint Honorary Editor, now absent in Europe. The report was adopted on the motion of Dr. Cockayne, seconded by Mr. G. M. Thomson.

### Report of the Publication Committee.

At the end of 1915 the Honorary Editor, Professor C. Chilton, resigned his position, and on the 28th January, 1916, Dr. L. Cockayne was appointed Honorary Editor and Dr. C. A. Cotton, Joint Honorary Editor.

Sixty-nine papers were offered for publication, and of these fifty-six were accepted for the *Transactions* by your Committee, two were recommended to be published as bulletins, and the remainder were withdrawn, held over for the time being, or declined.

Volume 48 of the *Transactions of the New Zealand Institute* was issued on the 16th October, 1916. It contains 598 pages (of which no less than 75 are devoted to the Proceedings), 29 plates, and a great many text-figures.

The late appearance of the above volume was due to the following causes: (1) Urgent work at the Government Printing Office connected with war matters, especially the production of the National Register, taking precedence of all else; (2) Parliament meeting a month earlier than usual; (3) no Editor being appointed after Professor Chilton's resignation until the end of January, 1916.

Besides the annual volume of *Transactions*, the publication of four bulletins was considered by your Committee. One, by Major T. Broun, on "Coleoptera," was ordered to be proceeded with at once, since a grant of £50 from the Hutton Fund had been voted by the Board of Governors for this purpose. Unfortunately, special printing in connection with the war hindered the work being proceeded with, but it is expected to be taken in hand early in 1917. The three other bulletins were held over for the time being on account of lack of sufficient funds for their production, since they would have cost over £150.

*Cost of Printing the Proceedings.*—A proposal that the affiliated societies should be required to pay the cost of printing their respective Proceedings, proposed by Dr. Allan Thomson, seconded by Dr. Hatherly, was lost.

*Notice of Motion.*—Professor Kirk gave notice that he would move that the regulation—5 (*a*), 1—referring to the publication of Proceedings be rescinded, and that the following regulation be agreed to:—

"(*a*.) The publications of the Institute shall consist of: (1.) Such current abstract of the Proceedings of the societies for the time being incorporated with the Institute as the Board of Governors deems desirable."

*Date of Publications.*—On the motion of Dr. Hilgendorf, seconded by Professor Marshall, it was resolved, That the Publication Committee be authorized to arrange for the publication of authors' copies in advance of the publication of the volumes of *Transactions*, and for the printing on the title-page of each paper of the date of receipt by the Editor and the date of issue by the Printer.

*Bulletins.*—On the motion of Mr. D. Petrie, seconded by Dr. Cockayne, it was resolved, That a set of the bulletins published each year be forwarded to all societies on our exchange list.

*Report of the Library Committee.*—The adoption of the report of the Library Committee was moved by Dr. Thomson, Honorary Librarian, and carried.

REPORT OF LIBRARY COMMITTEE.

The usual large number of additions to the library by exchange or donation have been received, registered, and arranged. In spite of the additional shelf-space gained by placing in store old and little-used books during the last two years, the growth of the library is so rapid that accommodation is again being taxed. The question of providing a suitable building for the library is one that demands the serious consideration of the Board of Governors.

The matter of enlarging the exchange list was referred by the Standing Committee to the Library Committee, and a number of institutions with whom an exchange is desirable have been selected, but owing to the pressure of other duties on the members of the committee the necessary correspondence has not yet been carried out.

Your committee has ascertained that copies of the bulletins of the Institute have not been supplied to exchanging institutions, and is of the opinion that this procedure greatly detracts from the value of the bulletins as a means of publication.

J. ALLAN THOMSON,
Hon. Librarian.

*Housing the Library.*—On the motion of Mr. H. Hill, seconded by Mr. D. Petrie, it was resolved, That this Institute, representing the various Philosophical Societies of the Dominion, urge upon the Government the need of a suitable building in which to house the valuable library and records of the Institute, the destruction of which would be an irreparable loss to the country.

*Correspondence.*—Letters from the Wellington Philosophical Society (dated 9th December, 1916, and 16th December, 1916) were read conveying resolutions advocating the formation of a technical library, and an alteration of New Zealand mean time.

*Library.*—On the motion of Professor Kirk, seconded by Mr. Petrie, it was resolved, That this Institute believes that one of the first and most important steps in the direction of encouraging the application of science to industry is the formation of a scientific and technological library in the Dominion, and urges the Government to take immediate steps to provide such a library.

*New Zealand Mean Time.*—It was proposed by Dr. Thomson, and seconded by Professor Easterfield, That the New Zealand Institute endorse the resolution of the Wellington Philosophical Society regarding the alteration of New Zealand mean time. An amendment proposed by Dr. Chilton, That the Institute should proceed to the next business, was carried.

*Co-ordination of Science with Industry.*—Reports from the Auckland Institute (20th November, 1916), Otago Institute (22nd November, 1916), Wellington Philosophical Society (9th December, 1916), and the Philosophical Institute of Canterbury (20th December, 1916) were received, copies having already been circulated amongst members.

On the motion of Professor Chilton, seconded by Dr. Cockayne, it was resolved, That the New Zealand Institute, as the body which for fifty years has persistently encouraged the carrying-out of scientific researches, offer to the Government its services in the interests of national efficiency; and that a deputation be appointed to wait upon the Acting-Premier to present to him a report as to the relations of science and industry, and to urge the necessity of definite action.

It was resolved that a committee, consisting of the President, Professor Easterfield, Dr. Cockayne, Mr. G. M. Thomson, Mr. Petrie, and Sir James G. Wilson, be set up to arrange for the deputation to the Acting-Premier and to draw up a report on the co-ordination of science with industry.

*Reform of the New Zealand Institute.*—Dr. Thomson spoke on the subject of his notice of motion, copies of which had already been circulated. On the motion of Professor Kirk, seconded by Professor Marshall, it was resolved. That this meeting refers the question of reform as outlined by Dr. Thomson to the several incorporated societies for consideration and report.

*Dominion Museum, Wellington.*—On the motion of Professor H. B. Kirk, seconded by Dr. Cockayne, it was resolved, That the attention of the Government be again called to the fact that the Dominion Museum collection, including many valuable records and objects that could by no possibility be replaced, are still housed in an old and highly combustible wooden building.

*New Zealand Fishes.*—On the motion of Mr. G. M. Thomson, seconded by Professor Kirk, it was resolved, That the preparation and publication of a catalogue of New Zealand fishes is a matter of national importance, and that the Government be asked to undertake this work at as early a period as possible.

*New Zealand Science Worthies.*—On the motion of Mr. G. M. Thomson, seconded by Professor Chilton, it was resolved, That this Institute places on record its appreciation of the valuable services to science of Alexander McKay, Henry Suter, and Thomas Broun ; and that a letter be sent to each of them expressing the hope that they may long be spared to enjoy the fruits of their labours in science.

*Proposed Department of Scientific Affairs.*—Mr. G. M. Thomson gave notice of his intention to move at the next meeting of the Institute, That this Institute recommends to the Government that the time has come for the establishment of a Department of Scientific Affairs, in which all the purely scientific departments of the Government be placed, and that an Advisory Council be set up to assist the Minister in charge.

*Hamilton Memorial.*—Professor Easterfield, in reply to a question from Mr. H. Hill, read the report of the Wellington Philosophical Society's Hamilton Memorial Committee.

*Election of Officers and Committees.*—The following officers and committees were elected : *President*—Professor W. B. Benham ; *Hon. Editors*—Dr. L. Cockayne and Dr. C. A. Cotton ; *Hon. Treasurer*—Mr. C. A. Ewen ; *Hon. Secretary*—Mr. B. C. Aston ; *Hon. Librarian*—Dr. J. Allan Thomson. *Publication Committee*—Professor Kirk, Drs. Cockayne, Cotton, and Allan Thomson, and Mr. B. C. Aston ; *Library Committee*—Drs. Cotton, Cockayne, and the Hononary Librarian ; *Hector Award Committee for 1918*—Professors Chilton, Easterfield, and Marshall, and Dr. Cockayne ; *Hutton Award Committee for 1920*—Dr. Cockayne, Professors Benham and Marshall. *Research Grant Committee*—Professor Easterfield, Dr. Thomson and Mr. Aston were appointed a committee to administer regulations in connection with the Government research grants.

*Date and Place of next Annual Meeting.*—It was resolved, That the next annual meeting be held at Wellington on Tuesday, the 29th January, 1918, at 10 a.m.

*Travelling-expenses.*—It was resolved, That the travelling-expenses of the Governors attending this meeting be reimbursed by the Institute.

*Votes of Thanks.*—Votes of thanks to the honorary officers for their services during the past year were passed, Dr. J. Allan Thomson specially acknowledging the assistance he had received from Mr. Macdonald in the library.

31st January, 1917. D. PETRIE, Chairman.

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## PRESIDENTIAL ADDRESS.

The following is the presidential address delivered at the annual meeting of the Board of Governors of the New Zealand Institute, at Wellington, on the 30th January, 1917, by Professor W. B. Benham, F.R.S.:—

GENTLEMEN,—I desire to thank you most sincerely for the honour you did me at the last annual meeting in electing me as your President for the year. I trust that you will overlook the many shortcomings on my part, as they will be counteracted by the good will of the officers of the Board and by the work of the Standing Committee.

In looking through the addresses delivered by the previous occupants of the chair, I feel very diffident of my ability to carry on my duties as efficiently as they have done, and feel rather appalled at my inability to deal adequately in this address with the various matters with which this Institute is concerned.

Although it has been customary to make allusion to those members of the Institute who have died during the year, I find in previous addresses no reference to distinguished men of science of Britain who may have passed away. I propose on this occasion to refer to some of the leaders in the various branches of science whose deaths have had to be recorded during 1916.

Professor Judd, F.R.S., for many years Professor of Geology at the Royal College of Science at South Kensington, was perhaps especially known for his studies of the volcanic districts in Europe.

Elias Metchnikoff, a Russian by birth, was in the earlier part of his life known to zoologists as a student of the structure and embryology of lower invertebrates, in which he made discoveries of great significance. While thus engaged in these microscopic studies, he observed again and again, in animals of widely different character, certain peculiar cells which were highly mobile—moving about in the living tissues in a very active fashion; and in certain of them he discovered that these cells were engaged in feeding upon foreign substances, organic and inorganic, which had obtained access to the tissues. To these cells he gave the name "phagocytes," and he established the fact that they are of universal occurrence. He went further than this: he demonstrated that in the higher animals these phagocytes are of prime importance in the process known as "inflammation," and that they are intimately related to the phenomenon of "immunity" from disease, the proper understanding of which has revolutionized medical theory and practice. This is one instance of a discovery in pure science being of immense value to mankind.

Professor Silvanus P. Thompson, F.R.S., made very important discoveries in electricity, magnetism, and optics.

Sir William Ramsay, F.R.S., the great chemist, passed away at the comparatively early age of sixty-three. He was the discoverer of the peculiar inert gases argon, neon, helium, crypton, and xenon, some of which occur in the atmosphere. Confronted with a type of element entirely devoid of chemical properties, he was forced to rely entirely on their physical properties in order to put them in their proper relation to the other elements, and he solved the problem by aid of molecular and atomic conceptions. He was a pioneer in the work, and exhibited great manipulative skill in designing the apparatus and performing the necessary experiments. A detailed history of these discoveries is one of the romances of modern science. At a later date he pursued the study of radio-active emanations—discovered by Rutherford elsewhere—as exhibited by some of these gases.

Sir Lauder Brunton, F.R.S., gained high distinction by his work on physiological medicine. He was one of the first among practising physicians who used no empirical remedies without first seeking to discover their mode of action—that is, he correlated his clinical knowledge with laboratory work; and by his work pharmacology has become a definite branch of science.

Each of these men has produced vast changes in the science in which he laboured.

Another man, less known, less distinguished perhaps, has an interest for us, since he used his great mathematical knowledge for the benefit of New Zealand. Mr. F. W. Frankland, son of Sir Edward Frankland, came to New Zealand in 1875 to recuperate from a breakdown in health. He entered the Government Insurance Department, ultimately becoming Government Actuary and Registrar of Friendly Societies. Always alive to the possibility of scientific expansion and improvement in life-insurance methods, Frankland originated and introduced into New Zealand the regulation that in the registration of deaths of males the particulars of the family left should also be recorded, and the data so obtained have been found of great value by actuaries all over the world. He was, too, of a philosophical turn of mind, and a paper by him was published in our *Transactions*, entitled "Mind Stuff."

These men died at a ripe age after a life of active research; but I cannot forbear to refer to the many young scientific men who had already shown promise of brilliant attainment whose lives have been cut short abruptly during this pitiless and horrible war. Mention may be made of Dr. Jennings, Lieutenant Athol Hudson, and other New-Zealanders of promise. Amongst them also was a young Oxford zoologist, Geoffrey Smith, thirty-four years of age, who had done some very original experimental work in the endeavour to ascertain the physiological causes of secondary sexual characters. By a masterly association of ideas he showed the analogy between the physiological regulation in parasitized crabs and the phenomenon of regulation which produce immunity in bacterial disease.

But this war is taking a tremendous toll of the younger scientific men, and when we realize the prime importance of science, in peace as well as in war, and the value of their work in industries, it is extremely saddening to read, week after week, in *Nature*, the records of brilliant young scientific men who have been sacrificed to this war. At first these men were allowed to enlist in any capacity, instead of being retained for work for which their scientific training rendered them valuable. It is deplorable that these young scientific men were permitted at the outbreak of the war to enlist in the combatant forces: it is only one of many indications of the neglect to make use of skilled men in work in which they are experts which characterizes the Governments of British countries, and which one is inclined to attribute to their ignorance of science, and especially of the science of organization.

These young scientific men would have been of immense value behind the fighting-line during the war, as well as in the future peace, as we believe that the need of scientific qualifications in the reconstruction of Empire is of prime importance. But, unfortunate as this is, we have no right to differentiate between this deplorable wastage of trained scientific men and the awful decimation of the young manhood of the Empire, for in their loss the Empire is losing the potential fathers of the race. The most vigorous, most unselfish, most intelligent, and bravest representatives of all classes, from the heir to an earldom to the humblest labourer, are the men of the highest eugenic value to the race, and the loss of these men is extremely serious for the future of the race.

It is time that I turned to the activities of our Institute:—

1. The financial position of the New Zealand Institute is a matter for perennial discussion, and I fear that in this the third year of the present war little can be done to better it. It has been pointed out again and again that the statutory grant still stands at the figure it was forty-eight years ago, when the condition of life in the colony (as it was then) was very different from what it was in 1914: when the cost of printing was less and the scientific activity less. Yet in all these years only on two occasions have we had any definite increase of our annual grants of £250. But we cannot look, I presume, for any immediate assistance from Parliament. There will be, when peace is declared, a period of financial stringency, during which, I much fear, all sorts of economy will take place wherever possible. But the half-crown levy on our members will no doubt be of some assistance: it has this year added more than £100 to our income.

It may be that many members of the local branches will prefer to forgo the volume of *Transactions*. It no longer appeals to the general public as it did before it was truly and wholly a scientific publication. In those earlier days, you will remember, it was customary to print *in extenso* the annual reports of the various presidents, popular lectures, curious articles on pseudo-scientific subjects, and other matters. These were all intelligible to and of interest to the non-scientific members. But to-day, when we have succeeded in eliminating everything but what is of scientific value—when the papers, or most of them, are couched in technical terms—and the *Transactions* have thereby become a valuable record of scientific research done in the Dominion, it follows that the volume is lacking in interest to our lay members.

What will be the effect of this levy? Will it reduce the number of members who are willing to pay one guinea to the local branches? Will the branches be able to lower the subscriptions payable to them by those who do not desire to take the volume? It seems likely that the number of volumes to be printed will be reduced, and so relieve somewhat our finances.

We shall have reports as to the disposal of grants made from the Hutton and Hector Funds.

2. The most important piece of work that has fallen to the Standing Committee during the past year relates to a scheme for making use of the grant of £250 provided by Cabinet, at the instance of the Hon. the Minister of Internal Affairs, for the purposes of research. The Minister communicated with me, as your President, outlining his idea as to the way in which this sum should be expended; and when he was in Dunedin he was good enough to receive Dr. Marshall, Mr. G. M. Thomson, and myself, and we put before him a general outline of what we considered desirable. Later your Standing Committee arranged for a deputation of Wellington members to wait on him, and a scheme was submitted to him on behalf of the Governors; and a number of grants have been made, as enumerated in the report of the Standing Committee. It will be our duty to confirm their action.

We are much indebted to the Hon. Mr. Russell for the interest he has taken in the work of the Institute, and appreciate his sympathetic attitude towards science, and his evident desire to encourage scientific research, especially in relation to the industries of the Dominion. We trust that he will be able to obtain a continuance of this grant, and even an increase in the amount, as he has led us to understand is his desire. At the same time it must be borne in mind that making important investigations of a class similar to those already being undertaken may require considerable time and the expenditure of considerable sums of money for their proper solution, and may require co-operation between workers along different lines. It must also be remembered that some of these researches may have a negative result that will not necessarily be a waste of money, for if the researches are properly recorded and published it will save waste of time and money in the future in attempting work along the same lines.

Mention may aptly be made here of the uncoördinated researches in Agricultural and other Departments, the absence of good reports of many of these researches, and the difficulties that lie in front of those who try to find out what has been the result of the investigation of particular problems. These matters were brought before the Philosophical Institute of Canterbury, and I trust that something will be done to remedy the defects in the publications of this and other Government Departments. The publication in full of these researches is a necessary complement to the work, for unless this is done the research is wasted and the money is wasted. It will, I suppose, be for the Government to find money for the proper publication of these reports, in such a form and at such a price that if the results are of value to the industries they may be readily brought under the notice of the industrial community.

3. At the beginning of the war the University colleges placed at the disposal of the Minister of Munitions the scientific apparatus in their laboratories, and the professors expressed their willingness to assist in any way that they could: but, so far as I know, little use has been made of the offer. Certainly, Professor Scott, of the engineering department at Canterbury College, spent a considerable amount of his time and energy in making the numerous gauges necessary for the manufacture of shells and in making shells, but later it was found that these were not required. The Professors of Chemistry, I understand, have been engaged on various works in connection with the war, and Professor Kirk placed his services at the disposal of the Defence Department, and has done useful work in fighting the flies that invaded the camps.

In the address of one of my predecessors in the chair reference was made to the bequest of the late Mr. T. Cawthron, of Nelson, who had intended to leave money to establish an observatory; that, however, now seems unlikely to eventuate. But he left a substantial sum of money to be used in establishing an institute for research. It is the most important bequest of its kind that has been made in New Zealand, and the only one, I believe, with a definite stipulation that research should be carried on. The trustees under the will set up a commission of scientific men to draw up a report as to the best way in which to carry out the wishes of the donor. The report of this commission is not yet completed, so that it is not right that I should say more than this: If the recommendations contained therein are acted upon, an institute will be established in which research into certain agricultural problems will be carried on under a highly trained scientific staff, and I feel sure that the New Zealand Institute will welcome this addition to the opportunities for research in our primary industry.

This leads us naturally to consider the improvement that is in progress in the Home-country and the Dominions towards a closer co-operation between science and industry. New Zealand lags behind the Commonwealth in this matter. As you are aware, the Prime Minister of Australia set aside a quarter of a million sterling for the preliminary work of a conjoint Board on which science and industries are represented, the work of that Board being to investigate various defined and important subjects the solution of which would lead to improvements in manufacture, the utilization of waste products, the destruction of certain weeds which had become a pest, and so forth.

In New Zealand very little progress has been made with the scheme initiated by the Institute. Certain committees have been set up in the four centres, and the Auckland committee have circulated a valuable pamphlet containing their recommendations, which will be seen from the report laid before you. There was formed at Dunedin an "Institute of Science and Industry," which roused a certain amount of enthusiasm amongst the representatives of the local industries, many of whom co-operated with the scientific men.

The Minister of Internal Affairs has expressed his intention of calling a conference, which we may hope will result in some practical steps being taken to bring the results of scientific research and method into closer relation with some of the industries. It is not my intention to discuss the matter here, but, as this Institute is the chief body of scientific opinion in the Dominion, and should be able to exercise greater influence than it does at present in all matters involving scientific principles, I cannot pass the movement by altogether.

The valuable report on the relation of science to industry circulated by the committee of the Auckland Institute contains, as you will have seen, recommendations for increased teaching of science, for increased remuneration of research scholars and an extension of the system, and for the application of science to industry. In the case of the last, it seems to me that the committee have scarcely gone as far as they might. Chemical analyses, bacteriology, and agriculture are mentioned, but no reference is made to other industries. Moreover, I think that the gap between the student who has done academic research and one employed in an industrial research is not bridged by the recommendation.

It has been a complaint, I understand, by manufacturers in England that most of the young graduates, usually chemists, that have come to them from universities are useless, owing to the fact that they have, naturally, no knowledge of doing research on a business scale: they know, and generally can know, nothing of the especial needs of the particular works, or such matters as the most economical way of production, utilization of waste material or by-products. In other words, they lack a business training in connection with their science. It has occurred to me that to get over such a difficulty there should be a central research institute under a competent director with business knowledge—a knowledge of the needs of manufacturers. Here the graduate would be set to work out special problems presented by manufacturers, under the guidance of the director, and thus get some insight into the working of a large concern. It would, of course, need money, but I suppose it would not be impossible to interest the large manufacturers in the matter. Get grants or endowments from individual firms, from business corporations of various kinds, and I believe that such an institute would justify itself in a few years.

It seems to me that this Institute should take a much more active part in urging the importance of a better training in science—or, rather, in scientific methods—in our secondary schools, and in urging, in season and out of season, on the industrial community the need for scientific organization and co-operation. It is to this Institute that the Government should be induced to turn for advice and assistance in any matter in which science is involved. For instance, I understand that important reports from the British Government were received by our Government and referred to a single individual for a report. Now, these reports, it seems to me, should have been referred to the Institute as a body, which, if necessary, should be called together to discuss and advise. It is as true here as in Britain that few of our politicians have any knowledge of science, or what is meant by scientific method; and we ought to see that this is remedied by persistent deputation, if need be, when the present grievous time is passed.

For instance, the matter of scientific afforestation is one that demands immediate attention. It is true that a few years ago the Institute approached the Government with the suggestion that a scientifically trained Forester be appointed, but I believe nothing has been done. The members of the Institute are all busy men, and it is difficult, perhaps, to keep track of the varied needs of the Dominion; but if each of the scientific men on the Board were to bring forward from time to time the matters that occur to them as being in need of reform, a special meeting of the Institute might be held at which such matters might be discussed more fully than is possible at our annual meeting. Committees might be set up to deal with them, and deputations to the Ministers concerned might be arranged, and other steps taken to impress upon the Government the need for taking action.

I must not omit to refer to the first meeting of the Board of Science and Art, a body which has great potentialities in regard to science. The first meeting was called by the Hon. the Minister of Internal Affairs immediately after our last annual meeting. As the President of this Institute is *ex officio* a member, I had to take my place on that Board in the evening, though I was only elected your President in the afternoon. The Board considered at some length a report by the Director of the Museum as to the future of the Museum. It was agreed that the present site is the best one for a museum and art gallery, and a plan of the building was laid before us. It was re olved that a fireproof building should be erected as soon as possible, the building to be part of the completed plan. The Minister was most sympathetic, and gave us reason to hope that the money would be found for its erection; but Cabinet, I presume, was indisposed to make the necessary grant at a time when the Dominion is requiring so much money for other and more pressing purposes. It is a matter for deep regret that former Governments had postponed the erection of so important a structure. It is a standing disgrace to the Dominion that the extremely valuable and irreplaceable collection of Maori objects is housed in the inflammable building in which we sit.

Protection has been accorded to our native birds, to some extent to native plants and insects, by preservation of national reserves, and steps have been taken by Act of Parliament to prevent the removal of Maori antiquities from New Zealand; but there is another set of historical records for which some sort of protection is needed—the early pre-Maori rock paintings of Canterbury and North Otago. These rock paintings, in red and black, occur on the walls of rock shelters, and have received some description at the hands of Mantell, von Haast, and Hamilton — some of whom attempted to give explanations of these extraordinarily varied objects, all of which are totally unlike any of the designs occurring in the carvings of the Maoris. During this last year these rock shelters have been inspected by an American visitor, Mr. James Lee Elmore, who has taken a good deal of interest in similar objects in South Africa and Australia. He has made tracings of all these pictographs in the known shelters, adding a very great deal to what had previously been recorded by Hamilton, and discovered new shelters. Mr. Elmore allowed photographs of these tracings to be made, and from them we have obtained a plan of each such group of pictographs, arranged in true relative position, in case their juxtaposition may have some meaning. There is now in the Otago Museum a complete set of these reproductions. But the Otago Institute went farther: it commissioned Mr. Elmore to remove some of these designs from shelters which are now exposed to weather and so being destroyed. Needless to say, he got permission to do so from the freeholders. But while some of the shelters are on private property, others are on Crown land, or land owned by a County Council, and it is most desirable that some means of protecting these pictographs should be devised, as some of the shelters are in danger of being destroyed. I think a small committee might, if you think it desirable, be set up to consider what steps, if any, can be taken to protect these extremely interesting records of the earliest inhabitants who have left permanent traces of their existence in these Islands. I hope, too, that a detailed and well-illustrated account of these extensive and varied pictographs will be published.

# WELLINGTON PHILOSOPHICAL SOCIETY.

At the Council meeting held in March, 1916, to fill the vacancy caused by the death of Mr. Thomas King, Dr. C. Monro Hector was elected President, Mr. A. C. Gifford was elected Vice-President, and Dr. C. E. Adams Secretary and Treasurer.

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First General Meeting: *24th May, 1916.*

The President, Dr. Hector, in his introductory remarks, made sympathetic reference to the death of the late President, Mr. Thomas King. Dr. Hector announced that Miss Jessie King, sister of the late Mr. King, had presented to the society, for the use of the Astronomical Section, the $5\frac{1}{2}$ in. equatorial telescope, made by Sir H. Grubb, Dublin, and the astronomical books of her brother, as a memorial to him, and that the Council had accepted these valuable gifts on behalf of the society.

*Life Member.*—Mr. C. W. Adams was elected a life member of the society.

*New Rules.*—The new rules of the society were adopted.

*Address.*—Dr. Hector delivered an interesting address on "National Efficiency."

*Exhibit.*—Dr. J. A. Thomson exhibited a model of the Piltdown skull.

*Lecture.*—Mr. J. L. Elmore delivered an address on the "Pictorial Art of the Australian Blacks and the South African Bushmen," illustrated by tracings of rock drawings and carvings in their natural size and colours.

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Second General Meeting: *28th June, 1916.*

*Exhibit.*—Mr. P. W. Burbidge, M.Sc., exhibited and described a new X-ray bulb—the Coolidge type.

*Lecture.*—Professor Kirk delivered a lecture on "Fly-control in Camps and Cities."

Third General Meeting: *26th July, 1916.*

*Discussion.*—Professor Easterfield introduced a discussion on the organization of scientific and industrial research. Many members of the society took part in an interesting discussion, and a committee, consisting of Mr. W. Ferguson, Mr. G. Hogben, Mr. E. Parry, Dr. L. Cockayne, Professor Easterfield, and Mr. S. H. Jenkinson, with power to add to their number, was appointed to consider the best means of organizing scientific and industrial research, and the study of science within New Zealand, and to confer with similar bodies in order that action may be taken.

### Fourth General Meeting: *23rd August, 1916.*

The President announced that the society had applied for £150 of war bonds.

On the motion of Dr. L. Cockayne, F.R.S., the society resolved to protest to the Minister of Lands against the killing of fur seals, as reported in the *New Zealand Times* of the 23rd August, and to ask the assistance of the New Zealand Institute in preventing the killing of the fur seals.

*Lecture.*—Mr. W. S. La Trobe, M.A., delivered a lecture on "Big Guns and Big-gun Shooting," illustrated by lantern-slides.

*Paper.*—A paper, "Notes on Floristic Botany of New Zealand, Part II," by Dr. L. Cockayne, F.R.S., was taken as read.

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### Fifth General Meeting: *27th September, 1916.*

*Lectures.*—Mr. C. W. Adams, a life member of the society, delivered a lecture on "Daylight-saving."

Dr. J. Allan Thomson delivered an address on "The Distribution of Brachiopods in the Southern Hemisphere," with exhibits and lantern-slides.

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### Forty-ninth Annual General Meeting: *25th October, 1916.*

The following officers and Council were elected for the year 1917: *President*—G. Hogben, M.A., F.G.S., C.M.G. *Vice-Presidents*—C. Monro Hector, M.D., B.Sc., F.R.A.S.; R. W. Holmes, M.Inst.C.E. *Council*—J. Allan Thomson, M.A., D.Sc., F.G.S.; A. C. Gifford, M.A., F.R.A.S.; W. S. La Trobe, M.A. (Chairman of Astronomical Section); F. W. Furkert, A.M.Inst.C.E. (Chairman of Technological Section); C. A. Cotton, D.Sc., F.G.S. (Chairman of Geological Section); T. H. Easterfield, M.A., Ph.D.; Evan Parry, B.Sc., A.M.Inst.C.E.; H. B. Kirk, M.A.; L. Cockayne, Ph.D., F.R.S.; D. M. Y. Sommerville, M.A., D.Sc. *Secretary and Treasurer*—C. E. Adams, D.Sc., F.R.A.S. *Auditor*—E. R. Dymock, F.I.A.N.Z. *Representatives on the New Zealand Institute*—T. H. Easterfield, M.A., Ph.D.; H. B. Kirk, M.A.

*Film.*—By the courtesy of the Tourist Department, a fine film of "A Tour of the Southern Alps" was shown by Mr. Taylor.

*Papers read.*—1. H. Hamilton, "Notes on the Occurrence of the Crab-eating Seal *Lobodon carcinophaga* in New Zealand Waters."

2. J. C. Andersen, "Further Notes on New Zealand Bird-song."

*Papers taken as read.*—C. E. Adams, "Harmonic Tidal Constants of New Zealand Ports," and "Harmonic Analysis of Tidal Observations."

*King Observatory.*—The President exhibited a plan, by Mr. W. S. La Trobe, of the proposed King Observatory, and stated that a deputation of the Astronomical Section would wait on the City Council on the 26th October to make application for a site in the Botanical Gardens on which to erect the Observatory.

*Meteorological Returns.*—On the motion of Dr. Thomson, seconded by Mr. Holmes, the society resolved to urge upon the Government the im portance, both from the educational and the economic standpoint, of the more extensive publication of the meteorological observations of a larger number of stations in New Zealand.

### Annual Report of the Council.

*Death of President.*—Before the opening of the 1916 session the society suffered a severe loss in the death of its President, Mr. Thomas King, F.R.A.S., and at a special meeting of the Council the following resolution was passed: "The Council, on behalf of the Wellington Philosophical Society, desires to place on record its deepest sympathy with the family of its late President, Mr. Thomas King, F.R.A.S., in their bereavement, and at the same time to express its highest appreciation of the valuable services which he rendered for so many years to the Wellington Philosophical Society, as Secretary and member of the Council."

*Roll of Honour.*—The following members of the society have volunteered for active service: Mr. E. H. Atkinson, Dr. C. M. Begg, Mr. Val. Blake, Mr. F. K. Broadgate, Mr. C. Freyberg, Mr. J. Fulton, Mr. G. W. King, Mr. C. C. Johnston, Professor E. Marsden, Mr. D. McKenzie, Mr. H. M. Miller, Dr. J. M. Mason, Mr. W. L. Moore, Dr. T. D. M. Stout, Mr. H. S. Tily, Mr. H. Vickerman, Mr. C. J. Westland. Lieutenant Val. Blake was killed in action at Gallipoli on the 9th December, 1915.

*The Sections.*—The Astronomical, Technological, and Geological Sections have been very active during the session, and a number of important papers have been read before them.

*Membership.*—Since the last report two members of the society have died, and five have resigned their membership. Eighteen new members have been elected. The roll at present contains 169 names, including those of sixteen members on active service, nine life members, and one life member of the Otago Institute.

*The Hamilton Memorial.*—The committee appointed to provide a memorial to the late Mr. Augustus Hamilton reports that arrangements are now well forward for the erection of a suitable monolith and tablets over the grave at Russell, Bay of Islands.

*Statement of Receipts and Payments.*—A statement, duly audited, of receipts and payments for the year ended 30th September, 1916, is presented with this report. The total receipts were £128 4s. 6d., and the total payments were £101 17s. 5d. The balances at the end of the year were—Bank of New Zealand, £34 8s. 6d.; Savings-bank, £137 10s. 3d.; war bonds, £150 (including Research Fund, £49 13s. 1d., and Life Subscription Fund, £80 7s. 1s.); Hamilton Memorial Fund, £123 13s. 4d.: total, £445 12s. 1d. The liabilities were—Library Account, £48 8s. 2d.; Hamilton Memorial Fund, £123 14s.: total, £172 1s. 6d.: leaving a balance in favour of the society of £273 10s. 7d.

*Library Account.*—In accordance with the rules of the New Zealand Institute, one-third of the revenue of the society is devoted to the upkeep of the library. The amount so available this year is £42 14s. 9d.: this with the balance carried forward from last year makes £78 4s. 2d. available for the library. The payments on the library have been £29 16s., leaving a balance of £48 8s. 2d. to be spent on the library.

*Interim Report of the Committee on Organization of Scientific and Industrial Research.*—The committee appointed at the July meeting of the society has held several meetings, and has got into touch with the Philosophical Societies in the other large centres, and also with various industrial bodies. By invitation of the Philosophical Institute of Canterbury, the chairman of the committee visited Christchurch on the 4th October, and delivered a lecture on the importance of scientific research to industries and commerce.

## ASTRONOMICAL SECTION.

The following papers were read during the year: (6th October, 1915) "Some Points in the Theory of Optical Instruments," Professor E. Marsden, D.Sc.; (3rd November, 1915) "Tidal Waves of the Earth's Crust," Mr. G. Hogben, M.A.; (7th June, 1916) "Notes on Californian Observatories," Dr. C. E. Adams; (2nd October, 1916) "Facts and Fancies of the Fourth Dimension," Professor D. M. Y. Sommerville; "Methods of calculating Moonrise," Mr. C. J. Westland, F.R.A.S.; (6th September, 1916) "Circular Errors in Pendulums," Mr. W. S. La Trobe, M.A.; "Novae," Mr. A. C. Gifford, M.A.; "Wireless Time Signals, and Notes on Recent Eclipse of Sun," Dr. C. E. Adams.

*Members.*—The total number of members of the Astronomical Section is about fifty-one.

*Committee and Officers for 1917.*—*Hon. Member*: Miss Mary Proctor, F.R.A.S.: *Chairman*: Mr. W. S. La Trobe, M.A.: *Vice-Chairmen*: Mr. C. P. Powles, Professor D. M. Y. Sommerville, Dr. C. E. Adams: *Committee* —Mr. W. E. Spencer, Mr. G. Hogben, Mr. E. Parry, Mr. A. C. Gifford, Dr. C. M. Hector, Captain G. Hooper, Miss C. Helyer: *Director and Curator of Instruments*: Dr. C. E. Adams: *Hon. Treasurer*: Mr. C. P. Powles: *Hon. Secretary*: Mr. C. G. G. Berry.

## GEOLOGICAL SECTION.

During the year seven meetings have been held, with an average attendance of fourteen. The papers read have dealt with widely different aspects of geology, and, together with the numerous exhibits, have combined to maintain interest in the meetings, and to mark the year as one of steady progress.

The following papers have been read: J. A. Bartrum, "A Phase of Shore-line Erosion": S. S. Buckman, "Terminology for Foraminal Development in Terebratuloids": C. A. Cotton, "The Continental Shelf": W. Gibson and M. Ongley, "The Geology of Petroleum": J. Henderson, "The Structure of the Paparoa Range": R. W. Holmes, "An Artesian Trial Bore at Westshore, Napier"; P. G. Morgan, "Notes of a Visit to Marlborough and North Canterbury, with Especial Reference to Unconformities post-dating the Amuri Limestone": J. A. Thomson, "Stage Names applicable to the Divisions of the Tertiary in New Zealand": G. H. Uttley, "The Volcanic Rocks of Oamaru."

*Election of Officers for 1917.*—*Chairman*: C. A. Cotton, D.Sc., F.G.S.; *Vice-Chairman*: J. Henderson, M.A., D.Sc., B.Sc. (Eng.): *Hon. Secretary*—E. K. Lomas, M.A., M.Sc.: *Committee*—The above and Messrs. Holmes, Morgan, Ongley, Dr. Thomson, and Mr. Uttley.

## TECHNOLOGICAL SECTION.

Papers were read during the year as follows: (31st May) "Electricity in the Smelting and Refining of Iron," E. Parry, B.Sc., A.M.Inst.C.E.: (14th June) "The Thomas Transmission System as applied to Road and Rail Traction," K. J. Thomson, M.I.A.E., M.I.E.E.: (12th July) "Coal Resources of New Zealand, with Some Consideration of its Economic Use," P. G. Morgan, M.A., F.G.S.: (9th August) "Design and Construction of Ferro-concrete Structures, with Special Reference to Marine Works," J. E. L. Cull, A.M.I.M.E.: (11th October) "Alloys from the Point of View of Modern Chemistry," Professor Easterfield, M.A., Ph.D. Mr. Cull also gave the results of the tests of some steel rolled at the Otago Ironworks, and Mr. Parry exhibited an Edison storage battery, some aluminium wire corroded while in electrical use, and some samples of aluminium soldered by a new process invented by two New-Zealanders.

On the 13th September Mr. W. S. La Trobe, M.A., conducted the section through the Wellington Technical College.

The office-bearers for 1917 were elected as follows: *Chairman*: F. W. Furkert, A.M.Inst.C.E. *Vice-Chairmen*: J. Marchbanks, M.Inst.C.E.: E. Parry, A.M.Inst.C.E. *Committee*: W. Ferguson, B.E., M.Inst.C.E; A. Atkins, F.R.I.B.A., A.M.Inst.C.E.: R. W. Holmes, M.Inst.C.E.; H. Sladden, Member Surveyors' Board: J. S. Maclaurin, D.Sc., F.C.S. *Secretary*: S. H. Jenkinson.

## AUCKLAND INSTITUTE.

First Meeting: *5th June, 1916.*

Hon. E. Mitchelson, President, in the chair.

*New Members.*—J. Alexander, E. W. Alison, jun., W. H. Bartlett, L. Benjamin, H. Buckleton, H. B. Burnett, J. Butler, W. Casey, R. G. Clark, C. Z. Clayton, D. L. Clayton, M. Copeland, A. W. Donald, H. J. Edmiston, W. Elliott, J. C. Entrican, W. Frater, J. W. Hardley, A. Kidd, J. A. Lamb, W. H. Long, G. J. Mackay, H. O. Nolan, H. H. Ostler, T. G. Price, Miss Pulling, H. P. Richmond, F. C. Rollett, J. Rowe, H. M. Skeet, D. F. Stewart, W. F. Massey, W. H. Herries.

*Lecture.*—"Canada, the Land of Mystery, Romance, and Gold," by W. A. Beddoe, Canadian Trade Commissioner.

Second Meeting: *3rd July, 1916.*

Mr. J. H. Upton in the chair.

*New Members.*—F. J. Bankart, G. R. Bloomfield, H. P. Bloomfield, D. R. Caldwell, J. Carlaw, E. J. Carr, E. A. Craig, R. W. Duder, W. Fallon, R. Fenwick, A. M. Ferguson, H. Goldie, Louis Harris, R. E. Isaacs, J. D. Jones, H. P. Kissling, B. A. Laurie, R. Logan, J. D. Macfarlane, L. Marriner, J. Marshall, B. Myers, M. O'Connor, H. E. Pacey, E. V. Ralph, W. C. Somers, J. C. Spedding, G. Thompson, R. Tudehope, F. A. Winstone.

*Lecture.*—"The Economic Aspects of the War," by Professor H. W. Segar.

Third Meeting: *31st July, 1916.*

Professor H. W. Segar, Vice-President, in the chair.

*New Members.*—L. Adams, J. M. Carpenter, Victor B. Casey, S. G. Chambers, W. J. Crompton, J. Field, Mrs. F. Mason, J. R. Reed, J. Robertson.

*Lecture.*—"Shakespeare: the Man and his Work," by Professor Maxwell Walker.

Fourth Meeting: *28th August, 1916.*

Professor H. W. Segar, Vice-President, in the chair.

*New Members.*—A. Brett, W. Blomfield, W. Carter, H. Hayr, F. Kneebone, P. M. Mackay, F. Mander, A. Mulgan, Dr. McIlraith, G. A. Rawson, F. Wiseman.

*Lecture.*—"Mountains, their Origin and Growth," by J. A. Bartrum, Lecturer on Geology, Auckland University College.

FIFTH MEETING: *25th September, 1916.*

Professor H. W. Segar, Vice-President, in the chair.

*Lecture.*—"Light and the Plant," by Professor J. C. Johnson.

SIXTH MEETING: *2nd October, 1916.*

Professor H. W. Segar, Vice-President, in the chair.

*Papers.*—1. "The European Sugar Bounties," by E. V. Miller.

2. "Price Movements in New Zealand, their Industrial and Social Effects," by Dr. McIlraith.

SEVENTH MEETING: *16th October, 1916.*

Professor H. W. Segar, Vice-President, in the chair.

*Lecture.*—"The Water-supply of Cities," by W. E. Bush, City Engineer.

EIGHTH MEETING: *6th November, 1916.*

Hon. E. Mitchelson, President, in the chair.

*Lecture.*—"Victory, and After," by Archdeacon G. McMurray.

NINTH MEETING: *13th December, 1916.*

Hon. E. Mitchelson, President, in the chair.

*Papers.*—1. "The Vegetation of Lord Howe Island," by W. R. B. Oliver.

2. "On a New South Polynesian Palm, with Notes on the Genus *Rhopalostylis*," by Dr. Odoardo Beccari (communicated by T. F. Cheeseman).

3. "Descriptions of New Genera and Species af Coleoptera," by Major T. Broun, F.E.S.

4. "Descriptions of New Native Flowering-plants," by D. Petrie.

5. "Additional Facts concerning the Distribution of Igneous Rocks in New Zealand," by J. A. Bartrum, M.Sc.

6. "Concretions in the Recent Sediments of Auckland Harbour," by J. A. Bartrum, M.Sc.

ANNUAL MEETING: *26th February, 1917.*

Hon. E. Mitchelson, President, in the chair.

*Annual Report.*—The annual report and audited financial statement was read to the meeting, and ordered to be printed and distributed to the members.

ABSTRACT.

*Members.*—The number of new members elected has been unusually large, amounting to no less than eighty-four. Against this, twenty-nine names have been withdrawn—nine by death, thirteen by resignation or removal from the district, and seven owing to non-payment of subscription for more than two consecutive years. The net gain has thus been fifty-five, the total number on the roll at the present time being 391. It may be remarked that this is the highest figure yet attained during the history of the society.

The number of members removed by death is above the average, and includes several active workers. In Bishop W. L. Williams the Institute loses not only the leading authority on the philology of the Maori race, but also a botanist of no mean rank. Mr. A. T. Urquhart was for many years the chief worker on the spiders of the Dominion, and twenty-one papers are credited to his name in the *Transactions*. Mr. E. G. B. Moss interested himself chiefly in the Mollusca. Other members of old standing are Mr. J. J. Craig, Mr. R. Cranwell, Mr. P. Gleeson, Mr. J. W. James, and Mr. R. S. Lamb.

In common with almost all societies and associations within the British Empire, the Institute includes among its members no small number who are serving their King and country in the cruel and terrible war which the greed and rapacity of Germany has plunged the greater part of the civilized world. It has been suggested that the Institute might well be proud to retain such on its roll, as dormant members without payment of fees, so long as they are absent from the Dominion.

*Finance.*—An inspection of the balance-sheets accompanying this report will prove that the finances of the society are in a thoroughly satisfactory position. The total revenue of the working account, deducting the balance in hand at the beginning of the year, has been £1,741 12s. 6d., showing an increase of no less than £257 15s. 1d. on the amount credited last year. This is partly due to several additions made to the invested funds during the last eighteen months, consequent on the sale of certain important endowments, and partly to the increase in the membership of the society. Examining the various items, it will be seen that the members' subscriptions have yielded £373 16s., against £308 14s. realized last year. The receipts from the Museum Endowment, in rents and interest, have been £754 12s. 2d., last year's sum being £550 16s. The invested funds of the Costley Bequest have provided £429 8s. 11d., the amount for the previous year being £441 15s. The total expenditure has been unusually large, amounting to £1,960 11s. 11d. Exceptional items have been £245 16s. 2d., being part of the cost of refitting and rearranging both the new ethnographical hall and the mineral-room, particulars of which will be given farther on; £200 in part liquidation of the loan of £600 borrowed last year from the Investment Fund to provide for the cost of the above work; and a totally unexpected item of £114 5s. for necessary repairs to the caretaker's house. The above payments have naturally caused the balance in hand (£101 15s. 3d.) to be smaller than usual, but the amount will suffice to carry on the operations of the society until it is replenished by the regular income.

With respect to the invested funds of the society, the additions alluded to in the previous paragraph have raised the total amount to the sum of £22,793 7s. 5d. With the exception of about £200, the whole of this is invested in specially selected mortgages or in municipal debentures.

*Meetings.*—Nine meetings have been held during the year, at which fifteen papers and lectures were read, and an opportunity afforded for discussion.

Those papers which were prepared for publication in the *Transactions of the New Zealand Institute* have been forwarded to the Editor, and will probably appear in Volume 49, now being sent to press. Volume 48, containing the papers read before the various branches of the Institute during the year 1915, was not received for distribution among the members until the end of November. Delays or irregularities in the appearance of the annual volume are decidedly objectionable, and authors will ultimately hesitate before submitting important memoirs to a society which may retain them for nearly two years before publication.

The Council regrets that the Government has seen fit to withdraw the special grant of £250 which for several years has been voted in aid of the publication of the *Transactions*. This action has compelled the Board of Governors of the Institute to levy a call of 2s. 6d. per volume on the copies supplied to the incorporated societies, thus seriously hampering the activities of the societies themselves.

In connection with this subject, it may be remarked that the statutory grant to the New Zealand Institute still remains at the sum of £500, the amount fixed at the foundation of the Institute forty-nine years ago. At that time the total membership of the Institute in all its branches amounted to only 178. At present the membership is about 1,100, nearly 400 of which are enrolled with the Auckland Institute. Surely it is time that the Government increased its annual subsidy to an amount more proportionate to that raised by the incorporated societies.

*Co-ordination of Science and Industry.*—Throughout the British Empire the present war has led to much discussion on the need of a more active co-operation between science and industry, and of a fuller recognition by the State of the value of scientific method and training in the furtherance of national progress. During the year a committee of the Council has discussed the matter so far as it applies to New Zealand, and its report, together with others prepared in various parts of the Dominion, have been placed before a recently constituted Efficiency Board, now sitting at Wellington. In most parts of the Empire the war has revealed many educational and scientific deficiencies; and it is abundantly evident that drastic changes are necesasry in educational and national policy. What is done in New Zealand may not affect those major decisions to be arrived at elsewhere, but it is hoped that they may assist in some small degree in the solution of a grave and important question.

*Museum.*—In last year's report particulars were given of the arrangement made with the City Council under which the Russell collection of plaster casts from the antique was deposited in the Art Gallery, and the Grey collection of Maori antiquities lodged in the Museum. This change made the former statue-hall available for other purposes; and it was decided to utilize it in the first place for the reception of the Grey collection, and, secondly, for the fine series of foreign ethnographical articles in the possession of the Museum, a large portion of which had never been exhibited. Since then the work of constructing the show-cases and placing them in position has been completed Much time and labour was then devoted to what may be called the installation of the specimens; and it can be claimed that they have been displayed in an orderly sequence, and mounted in an attractive and appropriate manner. Further, in the hope of affording as much information as possible to visitors, each exhibit has been provided with a printed descriptive label. The hall was opened to the public on the 17th April.

The arrangement of all foreign ethnographical specimens in this hall has liberated the smaller hall in which a portion of them had been previously exhibited. This has been converted into a mineral-room, and several months have been occupied in examining and sorting the whole of the geological specimens, fossils, &c., in the Museum. From these a series has been selected for exhibition, and suitably arranged and labelled. This work being completed, the room was opened to the public on the 4th December. This change will make it possible to reserve the gallery of the main hall entirely for representatives of the New Zealand fauna — birds, fishes, reptiles, shells, and other invertebrata—and, in addition, will gain a little space for exhibits to be prepared by the taxidermist.

Many important additions have been made to the ethnographical collections during the year. From Mr. C. Douglas Tod the Museum has acquired by purchase a series of eighty-eight Maori articles, the chief of which are an ancient stone-carved *pare* of the rare Taranaki type; a carved stone fire-carrier (?) with lid complete; an ancient and finely carved *koauau*, or bone flute; a stone flute, or *ngungura*; two old wooden fish-hooks; a series of wooden tops; and many greenstone and ordinary stone adzes, &c. Mr. H. E. Partridge has presented a beautifully prepared plaster cast of the head of Wiremu Te Manawa, taken from a mould obtained during life by Mr. Lindauer and Sir Walter Buller. Te Manawa, who was the leading chief of the Ngatiraukawa Tribe, was for many years considered to be the most perfectly tattooed Maori living, and an accurate representation of his tattoo has consequently great value. Mr. L. S. Bidwell has donated a number of remarkable carved bone spools or beads, found at Mercury Bay, and probably part of a necklace. Such articles are of great rarity, and do not appear to have been used by the Maoris in European times. Mr. R. E. Isaacs has given an unusually large *kumete*, or wooden bowl, dug up in a swamp near Helensville. Such bowls are now very seldom seen. Other noteworthy additions are a remarkable stone carving intended to represent a shark, presented by Mr. J. A. Court; an elaborately carved stone anchor contributed by Mr. Davis, and another of a different type presented by Mr. C. Ford; a series of Maori grindstones from Captain Bollons; an interesting series of stone articles excavated on Mangare Hill, near Onehunga, donated by Mr. F. E. Powell; and various specimens presented by Mr. G. Graham, for many years a regular contributor to the Museum. Lastly, during the preparation of this report, a large and valuable collection, comprising fifty Maori specimens and about seventy Polynesian and Melanesian, has been received as a bequest from the late Miss Ruth G. Northcroft. Among the Maori articles are several obtained by Captain Northcroft during the Maori War or shortly after it. Among these may be specially mentioned an unusually fine decorated *taiaha*, three carved boxes of considerable merit, two *meres*, a fine ancient *patiti*, and an elaborately carved bone *manaia*.

During the year an American scientist, Mr. Elmore, has made a painstaking examination of some limestone caves and rock shelters in the South Island, on the walls of which elaborate Maori pictographs have long been known to exist. These pictographs appear to be of greater interest than has hitherto been supposed; and at the suggestion of Dr. Benham the Auckland Museum has agreed to join with the Otago

Museum and Dominion Museum in removing a number of slabs from the caves for permanent exhibition in the three Museums. The share for Auckland, consisting of ten slabs, is now being packed for transit, and will soon be received

Lieutenant J. C. Drewet, once a resident of Auckland, but in recent years employed in survey work in the Federated Malay States, has presented to the Museum, through the kind offices of the High Commissioner for New Zealand, a well-selected collection of twenty-seven articles, including spears, swords, krises, and domestic utensils. All have been obtained in the Malay State of Pahang, and form an acceptable addition to the Museum.

The Council are indebted to Dr. C. E. Wood, Bishop of Melanesia, for two remarkably fine full-sized canoes from the Solomon Islands—one a fishing-canoe inlaid with pearl-shell, the other the kind usually employed in voyages from island to island. The Council have had pleasure in showing their appreciation of the services rendered by Dr. Wood to the Museum by electing him an honorary member of the Institute.

Negotiations were opened with the Gizeh Museum, at Cairo, and a collection of over seventy articles has been obtained, covering a wide range of subjects. These have been carefully packed in Cairo, and by this time are probably on their way.

The following are the chief additions to the natural-history department during the year: An albino penguin (*Eudyptula minor*), obtained on the Great Barrier Island, and presented by Mr. Victor Blackwell; a specimen of the rare tooth-billed pigeon (*Didunculus strigirostris*) from the Samoan Islands, contributed by Mr. Mason Mitchell, United States Consul at Apia; a sea-snake (*Hydrus platurus*), stranded on the Seventy-mile Beach, north of Ahipara, and donated by Mr. Leslie Henderson; a fine specimen of the bonito (*Thynnus pelamys*), taken during a voyage between Gisborne and Napier, and forwarded by Mr. P. C. Annan; some interesting fishes, presented by Mr. H. C. Wright, including specimens of the New Zealand anchovy (*Engraulis ecrasicholus*), the sowfish (*Maccullochia labiosa*), and a rare gurnard (*Pterygotrigla picta*).

*Library.*—The expenditure over the library has been rather smaller than usual, amounting to £111 0s. 4d. An order for over seventy volumes was received soon after the last annual meeting, and another was despatched early in June, but did not arrive until the middle of November. The Council have to acknowledge several donations. Among these, Mr. E. A. W. Budge's elaborate folio volume, *The Book of the Dead*, may be mentioned as a contribution from the Free Public Library; and also copies of *Science Abstracts* for 1914 and 1915, presented by Professor Brown.

*Election of Officers for 1917.*—*President*—Mr. J. H. Gunson, Mayor of Auckland; *Vice-Presidents*—Hon. E. Mitchelson, Mr. C. J. Parr, C.M.G.; *Council*—Professor C. W. Egerton, Mr. J. Kenderdine, Mr. T. W. Leys, Mr. E. V. Miller, Mr. T. Peacock, Mr. D. Petrie, Professor H. W. Segar, Professor A. P. W. Thomas, Mr. J. H. Upton, Mr. H. E. Vaile, Professor F. P. Worley; *Trustees*—Messrs. T. Peacock, J. H. Upton, J. Reid; *Auditor*—Mr. A. Gray.

# PHILOSOPHICAL INSTITUTE OF CANTERBURY.

SPECIAL MEETING: *10th April, 1916.*

Present: Mr. L. Birks, President, in the chair, and two hundred others.

Welcome to Captain Ault and staff of survey ship "Carnegie."

FIRST MEETING: *3rd May, 1916.*

Present: Mr. L. Birks, President, in the chair, and thirty others.

*New Member.*—Mr. John Waddell.

*Ex-Presidential Address.*—"Surveys: (1) Pioneer, (2) Land Settlement, (3) Engineering," by Mr. A. D. Dobson.

SECOND MEETING: *7th June, 1916.*

Present: Mr. L. Birks, President, in the chair, and thirty-five others.

*New Member.*—Mr. G. A. Tapper.

*Papers.*—1. "The Occurrence in New Zealand of *Craterostigmus tasmanicus* Pocock," by Mr. G. E. Archey.

2. "Science in Relation to the Development of Agriculture," by Mr. L. J. Wild.

THIRD MEETING: *5th July, 1916.*

Present: Mr. L. Birks, President, in the chair, and fifty others.

*New Member.*—Mr. A. D. Paterson.

*Address.*—"Education and our National Requirements," by Mr. G. M. Thomson.

FOURTH MEETING: *19th July, 1916.*

Present: Mr. A. D. Dobson, Vice-President, in the chair, and fifty others.

*Address.*—"The Rock Paintings of the South African Bushman, and the Rock Carvings of the Australian Natives," by Mr. J. L. Elmore.

Fifth Meeting: *2nd August, 1916.*

Present: Mr. A. D. Dobson, Vice-President, in the chair, and twenty-five others.

*New Members.*—Messrs. R. T. Tosswill and J. B. Laurenson.

*Papers.*—1. "On the Water-supply, Irrigation, and Drainage of the Canterbury Plains," by Mr. A. D. Paterson.

2. "On the Fluctuations in the Water-level of some Artesian Wells." by Mr. A. D. Dobson, Dr. F. W. Hilgendorf, and Mr. L. P. Symes.

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Sixth Meeting: *6th September, 1916.*

Present: Mr. L. Birks, President, in the chair, and fifty others.

*Papers.*—1. "An Arrangement for quieting the Flow of a Stream of Disturbed Water," by Professor R. J. Scott.

2. "Apparatus for the Determination of the Magnitude of Small Forces, especially useful in connection with Hydraulic Experiments," by Professor R. J. Scott.

*Lecture.*—"The Electric Smelting of Iron and Steel," by Mr. E. Parry.

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Seventh Meeting: *4th October, 1916.*

Present: Mr. L. Birks, President, in the chair, and seventy others.

*New Member.*—Mr. J. R. Templin.

*Lecture.*—"The Importance of Scientific Research to Industry and Commerce," by Professor T. H. Easterfield.

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Eighth Meeting: *18th October, 1916.*

Present: Mr. L. Birks, President, in the chair, and twenty-seven others.

*Papers.*—1. "Notes suggested by Mr. Parry's September Paper on 'Electric Smelting,'" by Professor W. P. Evans.

2. "The Extraction of Potassium Salts from Silicate Rocks," by Professor W. P. Evans.

3. "The Lithobiomorpha of New Zealand," by Mr. G. E. Archey.

4. "Notes from the Canterbury College Mountain Biological Station, Cass: No 5—The Mat and Cushion Plants of the Cass River Bed," by Mr. C. E. Foweraker.

5. "The New Zealand Sand-hoppers of the Genus *Talorchestia*," by Dr. Charles Chilton.

*Exhibit.*—Australian grass-tree gum, by Professor W. P. Evans.

Ninth Meeting: *1st November, 1916.*

Present: Mr. L. Birks, President, in the chair, and thirty-three others.

*New Member.*—Mr. G. Henry.

*Papers.*—1. "On the Origin of a New Species by Isolation," by Mr. Henry Suter.

2. "An Explanation of the Hardness or otherwise of the World's Timber-trees," by Mr. R. Nairn.

3. "On certain Tripolar Relations, Part 3," by Mr. E. G. Hogg.

*Exhibits.*—1. Dr. F. W. Hilgendorf exhibited a peculiarly malformed beak of a starling.

2. Mr. E. F. Stead exhibited a wineberry sucker which had enveloped and killed a *Parsonsia* growing on it.

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Annual Meeting: *6th December, 1916.*

Present: Mr. L. Birks, President, in the chair, and twenty-seven others.

*New Members.*—Messrs. W. S. Newburgh, James Keir, and George Holford.

*Annual Report.*—The annual report and balance-sheet were adopted.

Abstract.

The Council has held ten meetings during the year. Two members of the Council, Messrs. A. M. Wright and G. E. Archey, have gone on active service.

A special meeting of the Institute was held on the 10th April to welcome Captain Ault and the staff of the Magnetic Survey yacht "Carnegie" on their return from circumnavigating the South Polar regions.

Ten ordinary meetings (including two additional) were held, at which five addresses were given. Also twenty-four papers were read, which may be classified as follows: Zoology, 6; botany, 2; geology, 5; engineering, 2; chemistry, 6; mathematics, 1; and general, 2.

During the year ten new members were elected and one transferred; nine having lapsed membership, through resignation or other causes, there are now 181 members on the roll.

The Council desires to record that the following members are now on active service: Drs. H. Acland and F. G. Gibson, Messrs. G. E. Archey, F. M. Corkill, A. Fairbairn, C. E. Foweraker, G. MacIndoe, P. S. Nelson, F. S. Oliver, A. Taylor, G. T. Weston, F. S. Wilding, and A. M. Wright.

The Council records with regret that during the year four members have died—Mrs. Hutton, Mr. T. H. Jackson, and, in action, Captain L. S. Jennings and Lieutenant H. Lang.

At the request of the Council, the Hon. the High Commissioner has kindly undertaken the distribution of the London stock of the volumes of the *Subantarctic Islands of New Zealand* and *Index Faunae Novae Zealandiae*. Letters of appreciation and a number of publications have been received in exchange.

The Council has recognized the importance of furthering the national movement to advance scientific research and extend the application of scientific knowledge. The addresses by Mr. G. M. Thomson and Professor Easterfield were arranged in this direction. The action of the Council, following on Mr. Wild's proposals in connection with agricultural research, promises to bear fruit. In order that matters connected with research and the technical application of science should be constantly watched, the Council set up a special committee, with Dr. C. C. Farr as honorary secretary. The New Zealand Board of Industries having invited the Institute to send delegates to confer with the Board on matters affecting post-war reconstructions, the Council has appointed the President, with Dr. Farr and Dr. Hilgendorf, to act.

The Council has pleasure in reporting that the application by this Institute for part of the £250 granted by the Government for research has been approved by the

New Zealand Institute. Investigations are now being arranged on the phosphate rocks of Canterbury, the deterioration of apples in cold storage, and the electrical prevention of frosting in orchards.

The Institute's representative on the Board of Trustees of the Riccarton Bush reports that during the year the bush has been carefully attended to, introduced plants removed, and the paths further improved. A cottage for the ranger has been erected at the entrance to the bush by means of funds contributed by the City Council, the Waimairi County Council, and a vote from the Government, and the ranger is now living in the cottage. It is hoped that the ceremony of opening the bush will take place in December, and that His Excellency the Governor will be present.

The library has been maintained in an efficient condition during the past year. The scientific pamphlets which have accumulated during many years have been arranged in cases according to subject, and a card catalogue has been made for the use of members. It is desirable that this branch of the library should be developed, and members are invited to present to the library papers and pamphlets of scientific interest in their possession.

The balance-sheet shows that the receipts, including a balance of £114 9s. 8d. from the previous year, have been £274 12s. 10d. The expenditure has been £101 5s. 2d., leaving a credit balance of £169 7s. 8d., of which £147 7s. 3d. belongs to the Tunnel Investigation Account. In accordance with the new regulation, £22 7s. 6d. is due to the New Zealand Institute, being the 2s. 6d. levy for vol. 48 of the *Transactions*. Of the expenditure, £61 0s. 8d. has been spent on periodicals, books, binding, and other work connected with the library. The Life Members' Subscription Account shows a balance of £131 4s. 10d. deposited with the Permanent Investment and Loan Association.

*Election of Officers for 1917.*—*President*—Mr. L. Birks; *Vice-Presidents*—Mr. P. H. Powell and Dr. F. J. Botrie; *Secretary*—Mr. L. P. Symes; *Treasurer*—Dr. Charles Chilton: *Librarian*—Mr. E. G. Hogg; *Council*—Dr. C. Coleridge Farr, Mr. A. D. Dobson, Dr. F. W. Hilgendorf, Mr. H. T. Ferrar, and Mr. W. G. Aldridge; *Auditor*—Mr. G. E. Way.

*Papers.*—1. "Some Structural Features of North-east Canterbury, together with Lists of Fossils from the Greta Beds," by Rev. A. Purchas.

2. "An Ancient Buried Forest near Riccarton: its Bearing on the Mode of Formation of the Canterbury Plains," by Mr. R. Speight.

3. "An Unrecorded Tertiary Outlier in the Basin of the Rakaia," by Mr. R. Speight.

4. "The Stratigraphical Relationship of the Tertiary Beds of the Trelissick or Castle Hill Basin," by Mr. R. Speight.

5. "The Blepharoceridae (Diptera) of New Zealand," by Mr. David Miller (communicated by Dr. Charles Chilton).

6. "Notes on the Occurrence and Habits of the Fresh-water Crustacean *Lepidurus viridis*," by Miss E. M. Herriott, M.A. (communicated by Dr. Charles Chilton).

7. "A Study of the Electrical Deposition of Nickel in the Presence of Nitrate," by Mr. J. G. Anderson (communicated by Mr. L. J. Wild).

8. "On the Proposed Soil Survey of New Zealand," by Mr. L. J. Wild.

9. "On the Lime Requirements of Soils," by Messrs. L. J. Wild and J. G. Anderson.

10. "Contributions to the Soil Survey of New Zealand: No. 2—Southland," by Mr. L. J. Wild.

11 "Further Observations on the Resistances of Earth Connections," by Mr. L. Birks.

12. "Notes on the Effects of the 1916 Snowstorm on the Vegetation of Stewart Island," by Mr. Walter Traill (communicated by Dr. Charles Chilton).

13. "Studies in the New Zealand Species of the Genus *Lycopodium*: Part II—Methods of Vegetative Propagation," by the Rev. J. E. Holloway.

# OTAGO INSTITUTE.

First Meeting : *2nd May, 1916.*

Present : Dr. P. Marshall, President, in the chair, and about thirty others.

*Presidential Address.*—" Prehistoric Otago," by Dr. P. Marshall.

Second Meeting : *4th July, 1916.*

Present : Dr. P. Marshall, President, in the chair, and about thirty others.

*New Members.*—Messrs. F. J. Jones and H. Whitcombe.

*Addresses.*—1. " Flightless Birds," by Dr. W. B. Benham, F.R.S.

2. " The Urewera Country," by Dr. H. P. Pickerill.

Third Meeting : *1st August, 1916.*

Present : Mr. R. Gilkison, Vice-President, in the chair, and twenty-five others.

*Addresses.*—1. " Mana Island," by Mr. W. G. Howes.

2. " Entomological Illustrations " (lantern-slides), by Mr. M. N. Watt.

*Papers.*—1. " Some Corals from the Kermadec Islands," by Mr. T. W. Vaughan, U.S. Geological Survey (communicated by Dr. W. B. Benham, F.R.S.).

2. " New Lepidoptera," by Mr. W. G. Howes, F.E.S.

3. " Notes on a Botanical Excursion to Long Island, near Stewart Island," by Mr. D. L. Poppelwell.

4. " Notes on a Botanical Excursion to the Upper Makarora Valley and Haast Pass," by Mr. D. L. Poppelwell.

Fourth Meeting : *5th September, 1916.*

Present : Dr. P. Marshall, President, in the chair, and twenty-five others.

*Papers.*—1. " Descriptions of New Species of Lepidoptera," by Mr. A. Philpott (communicated by Dr. W. B. Benham, F.R.S.).

2. " French Wit and Humour," by Mr. G. L. Thompson, M.A.

FIFTH MEETING: *3rd October, 1916.*

Present: Dr. P. Marshall, President, in the chair, and twenty-five others.

*New Member.*—Mr. E. G. Taylor.

*Papers.*—1. "Rennet," by Dr. J. Malcolm.

2. "Motor-fuels," by Dr. J. K. H. Inglis, F.I.C.

SPECIAL MEETING: *10th October, 1916.*

Present: Dr. P. Marshall, President, in the chair, and twenty-five others.

*Address.*—"Maori Rock Paintings," by Mr. J. L. Elmore.

SIXTH MEETING: *7th November, 1916.*

Present: Dr. P. Marshall, President, in the chair, and twenty others.

*Addresses.*—1. "The Kaipara District," by Dr. P. Marshall.

2. "Dunedin Weather Records," by Mr. D. Tannock.

*Paper.*—"Cainozoic Fossils from the Okapua Creek, near Chatton, Gore," by Mr. R. A. W. Sutherland, M.Sc. (communicated by Dr. P. Marshall).

SEVENTH MEETING: *5th December, 1916.*

Present: Dr. P. Marshall, President, in the chair, and fifteen others.

*Papers.*—1. "The Geology of the Central Kaipara," by Professor P. Marshall, D.Sc., F.G.S.

2. "The Wangaloa Beds," by Professor P. Marshall, D.Sc., F.G.S.

3. "Additional Fossils from Target Gully, near Oamaru," by Professor P. Marshall, D.Sc., F.G.S.

4. "Fossils of the Hampden (Onekakara) Beds," by Professor P. Marshall, D.Sc., F.G.S.

5. "Contributions to the Diptera Fauna of New Zealand," by Mr. D. Miller (communicated by Dr. W. B. Benham, F.R.S.).

6. "Observations for Latitude with 5 in. Transit Theodolite at Tanna Hill, Dunedin," by Professor Park, F.G.S.

7. "On a New Species of Coral from the Lower Oamaruian Tuffs," by Professor J. Park, F.G.S.

8. "The Rate of Erosion of Hooker and Mueller Glaciers," by Professor J. Park, F.G.S.

9. "The Relationship of the Upper Cretaceous and Lower Cainozoic Formations of New Zealand," by Professor J. Park, F.G.S.

*Annual Report.*—The annual report and balance-sheet for 1916 were read and adopted.

## Abstract.

During the year the Council has met seven times for the transaction of the business of the Institute.

Steps were taken early in the year to urge upon the Government the importance of the completion of the publication of the scientific results of the Australasian Antarctic Expedition, and a request was made to the Prime Minister by the Council that the Government should make a grant to Sir Douglas Mawson of £500, extending over two years, to enable him to complete this work. It is gratifying to record that the representations of this Institute, and of other kindred societies in New Zealand, have been of assistance in obtaining a substantial grant for the purpose referred to.

In August your Council, sitting in conjunction with the committees of the Technological and Astronomical Branches, carefully considered the question of the relationship of science and industry, and of the need of stimulating and directing industrial research in the Dominion. Information as to what had already been done in Australia in the way of establishing a Scientific Institute was laid before the meeting, and it was decided to urge our own Government to take similar steps in New Zealand at as early a date as possible. A public meeting was also arranged for, at which representatives of science and industry would place before the public the necessity of devising some plan for organizing scientific methods of industrial research.

As a result of the efforts of your Council a very successful public meeting was held in the Town Hall on the 4th September, His Worship the Mayor presiding. Excellent speeches calling attention to the present neglect of scientific method in our industries were made by the President of the Chamber of Commerce, the President of the New Zealand Institute, and others, and it was resolved to request the Government to consider the better organization of science in relation to industry and education. Further, a committee consisting of both scientific men and leaders of industry was set up to advise as to how this organization might best be attained, and to what extent science could be made to assist the industries of the Dominion. The committee has since become a separate body—"The Institute of Industrial Science of Otago"—and its subsequent activities consequently do not come within the scope of this report. It may be noted, however, that of the thirty-two gentlemen at present on the committee no fewer than twenty-six are also members of this Institute. It may be added also that the active sympathy of the Minister of Internal Affairs has been secured, and his Department has already taken some preliminary steps in the desired direction.

*Meetings.*—During the year seven ordinary meetings of the Institute have been held, at which there have been read or received fifteen papers, embodying the results of original research. A number of addresses have also been delivered during the past session.

In October advantage was taken of the presence in Dunedin of Mr. J. L. Elmore, a visitor who had spent many years in the careful study of aboriginal pictographs in several countries, to ask him to address a special meeting of the Institute on "Maori Rock Paintings." A special feature of this meeting was the display of large and accurate tracings of practically all the known rock paintings in the South Island. Impressed with the desirability of permanently preserving a number of these designs before weathering destroys them, your Council subsequently made a grant of £12 10s., the Auckland Institute contributing a similar amount, to enable Mr. Elmore to remove a number of the paintings from the rock shelters near Duntroon. This undertaking has since been successfully accomplished, and over thirty pieces are now lodged in the Museum. Some of these will later be forwarded to Auckland in accordance with the terms of the agreement.

*Membership.*—During the year six new members have been elected. On the other hand, twenty-four members have resigned their membership, in most cases owing to their removal from Dunedin, and two members (Sir Joshua S. Williams, K.C.M.G., and Major F. H. Statham) have been removed by death. The membership roll, therefore, has suffered a net decrease of twenty members, and now stands at 164.

It is with deep regret that we have to record the approaching departure of our President, Professor Marshall, in order to take up his duties as head master of the Wanganui Collegiate School. During his sixteen years' residence in Dunedin Dr. Marshall has been of invaluable assistance to the Institute. He has served on the Council for fifteen years; for two of these he acted as Hon. Secretary, and he has twice filled the President's chair (in 1906 and 1916). Last year, it will be remembered, the New Zealand Institute awarded him the Hector Memorial Medal. In addition to his contributing a large number of papers on research work to this society, Dr. Marshall has time and again willingly assisted with most interesting matter in making up an evening's programme, often at very short notice. His ever-ready and valuable help will be very much missed by the Council and members of the Institute.

*Balance-sheet.*—The balance-sheet presented by the Treasurer (Mr. R. N. Vanes) showed a credit of £50. The gross receipts totalled £674, including subscriptions amounting to £143, deposits at call amounting to £455.

*Election of Officers.*—The election of officers for the year 1917 resulted as follows: *President*—Professor J. K. H. Inglis; *Vice-Presidents*—Professors R. Jack and J. Park; *Hon. Secretary*—Mr. E. J. Parr; *Hon. Treasurer*—Mr. R. N. Vanes; *Hon. Auditor*—Mr. W. S. Wilson; *Hon. Librarian*—Professor W. B. Benham; *Council*—Professor W. B. Benham, Dr. R. V. Fulton, Messrs. H. Brasch, R. Gilkison, W. G. Howes, J. B. Mason, and G. M. Thomson.

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## TECHNOLOGICAL BRANCH.

Six meetings were held during 1916, and the following papers and addresses were read: (16th May) "Evolution in Bridge-building," by Mr. J. B. Mason; (20th June) "The Cromwell Development Scheme," by Mr. F. J. Williams; (18th July) "The Architecture of the Renaissance," by Mr. L. D. Coombs; (15th August) "The Preservation of Structural Timber," by Mr. C. S. Hicks, M.Sc.; (19th September) "The Evolution of Modern Dyestuffs," by Mr. O. J. W. Napier, M.A.; (17th October) "New Zealand Timbers," by Mr. F. J. Jones, M.Inst.C.E., and "Some Increases in the Cost of Building," by Mr. H. Mandeno.

At the meeting on the 17th October the annual report was read and adopted, and the following officers for 1917 were elected: *Chairman*—Mr. J. B. Mason; *Vice-Chairmen*—Professor J. Park, Professor D. B. Waters, and Mr. B. B. Hooper; *Committee*—Messrs. G. W. Davies, F. J. Jones, H. Mandeno, G. Simpson, and R. N. Vanes; *Hon. Secretary*—Mr. H. Brasch.

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## ASTRONOMICAL BRANCH.

Six meetings were held during 1916, at which the following papers were read: (23rd May) "The Sun," by Mr. R. Gilkison; (27th June) "Speculations about the Moon," by Rev. P. W. Fairclough, F.R.A.S.; (25th July) "The Magnetism of the Earth and the Sun," by Professor R. Jack, D.Sc.; (22nd August) "The Movement of the Heavenly Bodies as a Measure of Time," by Mr. J. C. Begg, and "Tinkering with the Clock," a paper sent anonymously by a Wellington resident; (26th September) "Atmospheric Refraction, Part II," by Mr. W. T. Neill, and "Meteors," by Mr. J. W. Milnes; (24th October) "A Visit to Greenwich Observatory," by Professor D. R. White, M.A.

At the meeting on the 26th October the annual report was read and adopted, and the following officers for 1917 were elected: *Chairman*—Mr. R. Gilkison; *Vice-Chairmen*—Professors R. Jack, J. Park, and D. R. White; *Hon. Secretary*—Mr. J. W. Milnes; *Committee*—Dr. P. D. Cameron, Messrs. H. Brasch, C. Frye, W. T. Neill, and W. S. Wilson.

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# HAWKE'S BAY PHILOSOPHICAL INSTITUTE.

Nine meetings were held during 1916, and the following papers were read: "Shakespeare's Tercentenary," by several members; "Educational Science," by D. A. Strachan, M.A.; "Colenso's Diaries," by W. Dinwiddie; "Some High Temperatures in Modern Industry" (illustrated), by J. H. Edmundson; "A Trip Across the Kaikouras" (including discovery there of the black land-snail), by F. Hutchinson, jun.; "Mind in Animals," by Sir Robert Stout; "The Artesian Wells of Hawke's Bay," by H. Hill, B.A., F.G.S.; "The Battle of Omarunui" (two versions, illustrated), by W. Heslop, J. B. Fielder, and Colonel Porter; "Distinctive Features of Modern Civilization," by W. Kerr, M.A.

At the annual meeting, 2nd December, 1916, the annual report was read and adopted.

ABSTRACT.

At the end of the session the membership of the Institute was seventy-nine, two members having left the district and four new members having joined. The Council met five times. The Treasurer's statement shows a credit balance of £63 0s. 3d.

*Officers for 1917.—President*—W. Dinwiddie. *Vice-President*—T. Hyde. *Council*—W. A. Armour, M.A., M.Sc.; J. W. Craig; H. Hill, B.A., F.G.S.; F. Hutchinson, jun.; W. Kerr, M.A.; T. C. Moore, M.D. *Hon. Secretary*—E. F. Northcroft (Roslyn Road, Napier). *Hon. Treasurer*—D. A. Strachan, M.A. (Education Office, Napier). *Hon. Auditor*—J. S. Large. *Hon. Lanternest*—E. G. Loten. *Representative*—H. Hill, B.A., F.G.S.

# NELSON INSTITUTE.

At the annual general meeting, held on the 22nd December, 1916, the annual report of the Scientific and Literary Branch was read and adopted.

ABSTRACT.

During 1916 no general meetings of the Scientific Branch were held, but a committee meeting was held on the 17th April, when those present decided that an attempt should be made to hold one or two meetings during the session, and the Secretary was instructed to interview members of the branch about the end of June to ascertain their opinions in this respect. On the Secretary's doing so, however, the opinion expressed was unfavourable, owing to pressure of work created by the European war, and no meetings were held. It is hoped, however, that during the coming year pressure will not be so great and that a number of meetings may be held.

With respect to the Museum there is nothing to report except a few small donations.

During the year the Atkinson Observatory has, weather permitting, been opened to the general public on Tuesday evenings, but the number of days that have given good seeing has been small, and the attendance of the public has fallen off slightly in consequence.

In conclusion, reference must be made to the proposed Cawthron Institute, the establishment of which, by attracting to this city scientists of high qualifications, will make Nelson, if not the greatest, at least one of the great centres of scientific research in the Southern Hemisphere, and thus in every way increase the activity of our Institute.

*Election of Officers for 1917.—President*—Mr. G. J. Lancaster; *Committee*—Messrs. F. G. Gibbs, F. V. Knapp, T. A. H. Field, M.P., J. R. Strachan, F. Whitwell, and W. F. Worley; *Hon. Secretary and Treasurer*—Mr. E. L. Morley; *Hon. Auditor*—Mr. F. Whitwell.

# MANAWATU PHILOSOPHICAL SOCIETY.

During 1916 seven general and two special meetings were held, in addition to the annual meeting. The following papers were read: "Recent Progress in Chemical and Physical Research," by A. J. Colquhoun, M.Sc.; "The Use and Influence of Novel Machines in Warfare," by T. C. Salmon, Assoc. in Eng.; "The Dundonald Terror," by J. Robertson; "Science and Story," by J. A. Stevens; "Weather Notes," by J. E. Vernon, M.A.; "The Timber Industry in New Zealand, its Present and Future," by C. N. Clausen: "River Conservation, with special reference to the Manawatu," by R. Edwards: "The Use of a Knowledge of Botany to a Farming Community," by L. Cockayne, Ph.D., F.R.S.: "Taranaki Ironsand, its Treatment and Value," by F. Smallbone; "The Great Wairarapa — a Lost River," by H. Hill, B.A., F.G.S.: "Afforestation, or Tree-planting on the Farm," by Rev. J. H. Simmonds, M.A.; "The Drama in the Reign of Elizabeth," by H. R. Hatherly, M.R.C.S.: "Leguminous Plants: their Importance in Nature and their Value to Man," by J. W. Poynton, S.M.; "Experiences during Recent Travels in America," by W. Welch, F.R.G.S.

At the annual meeting, 7th December, 1916, the annual report and balance-sheet were taken as read, and adopted.

ABSTRACT.

During the year the Council has continued its efforts for the preservation of the New Zealand bush, and, taking advantage of Dr. Cockayne's visit, invited representatives of the Borough Council, the Chamber of Commerce, the Agricultural and Pastoral Association, and the Farmers' Union to meet him, when he gave a most interesting address on the unique nature of the native bush and its economic value; and a deputation was appointed to urge the importance of the question upon the Government. The Council has good reason to believe that its action has been successful, and that the Government will take the necessary measures for the extension of the Tongariro Park, and the preservation of the bush adjoining the Manawatu Gorge.

During the year the Council has had to lament the loss of three members of the society by death—Dr. Martin, a former President; Mr. E. J. Armstrong, formerly on the Council; and Mr. John Stevens. Six members have resigned through leaving the district or from other causes; four are absent on foreign service; three have been written off for not paying their subscriptions; and seven new members have been elected.

About thirty exhibits have been added to the Museum, among them being various products from the working of the Taranaki ironsand, and relics from the seat of war. The attendance shows some increase during the year, the average daily number being twenty-four, and for Sundays thirty-six. As the majority of these are children of school age, it is a matter of regret that their visits are not made more systematically under the care of their teachers, thereby resulting in definite instruction as well as amusement.

The Government Astronomer (Dr. C. E. Adams) has requested co-operation in the work of systematic observation of variables and binaries, and the Director has promised to do whatever the facilities of the Observatory permit. This work, although tedious, and apparently without prospect of any immediate results, is nevertheless of great and increasing importance, and it is strongly urged that an astronomical section be formed from members as soon as the programme of work is submitted, and a real effort be made to assist the investigation.

*Election of Officers for 1917.* *President*—C. T. Salmon, Assoc. in Eng. *Vice-Presidents*—J. W. Poynton, S.M.; A. J. Colquhoun, M.Sc. *Officer in charge of Observatory*—C. T. Salmon, Assoc. in Eng. *Council*—Miss Ironside, M.A.; J. L. Barnicoat; M. A. Elliott; W. Park, F.R.H.S.; D. Sinclair, C.E.; J. E. Vernon, M.A., B.Sc. *Secretary and Treasurer*—K. Wilson, M.A. *Auditor*—W. E. Bendall, F.P.A.N.Z.

# WANGANUI PHILOSOPHICAL SOCIETY.

Seven meetings were held during the year 1916, at which the following lectures were delivered and papers read: (24th July) "Daylight-saving," by Mr. J. T. Ward: (16th August) "Post-war Problems," papers by Mr. C. Palmer Brown, M.A., LL.B., Mr. H. M. Payne, Mr. C. Park, M.A., Mr. C. Reginald Ford, F.R.G.S.: (2nd October) "Problems engendered by the Contact of Races," by Mr. C. Reginald Ford, F.R.G.S.: (16th October) "Contemporary English Painting," by Mr. C. Hay Campbell, R.D.S.: (30th October) "Dust," by Mr. C. M. Bevan-Brown, M.A.: (27th November) "American Observatories," by Mr. C. E. Adams, D.Sc.: (4th December) "Insect Assassins," by Mr. W. J. Rainbow, F.E.S.

At the annual meeting, 26th March, 1917, the annual report and balance-sheet were adopted.

ABSTRACT.

Attendance at meetings showed a falling-off, doubtless due to the public mind being concentrated on national affairs in this grave crisis. The small meetings, however, were marked by vigorous and interesting discussions.

The roll at the end of the session shows forty-seven active and thirty associate members.

The financial position is satisfactory, there being a credit balance on hand of £50 12s. 6d. after payment of Museum subsidy of £13 7s. 6d.

Dr. J. Allan Thomson's proposals for the reform of the New Zealand Institute, and a report thereon by Dr. Hatherly, Mr. C. Palmer Brown, and Mr T. W. Downes, were discussed. It was agreed to circulate Dr. Thomson's proposals and the sub-committee's report, and to discuss the matter at a later meeting.

Dr. Hatherly's intimation that he had decided to relinquish the position of President was received with regret, and it was agreed to record the society's appreciation of his services in that office, which he had held since the inception of the society.

*Election of Officers for 1917.*—*President*—Dr. P. Marshall, F.R.G.S. *Vice-Presidents*—Mr. J. A. Neame, B.A., and Mr. J. T. Ward. *Council* (including Mr. H. Drew, *ex officio* as Hon. Curator of the Museum)—Messrs. T. Allison; C. Palmer Brown, M.A., LL.B.; R. Murdoch; T. W. Downes; H. E. Sturge, M.A.; H. R. Hatherly, M.R.C.S. *Hon. Treasurer*—Mr. F. P. Talboys. *Hon. Secretary*—Mr. J. P. Williamson.

# APPENDIX.

## NEW ZEALAND INSTITUTE ACT, 1908.

1908, No. 130.

An Act to consolidate certain Enactments of the General Assembly relating to the New Zealand Institute.

Be it enacted by the General Assembly of New Zealand in Parliament assembled, and by the authority of the same, as follows:—

1. (1.) The Short Title of this Act is the New Zealand Institute Act, 1908.

(2.) This Act is a consolidation of the enactments mentioned in the Schedule hereto, and with respect to those enactments the following provisions shall apply:—

(*a.*) The Institute and Board respectively constituted under those enactments, and subsisting on the coming into operation of this Act, shall be deemed to be the same Institute and Board respectively constituted under this Act without any change of constitution or corporate entity or otherwise; and the members thereof in office on the coming into operation of this Act shall continue in office until their successors under this Act come into office.

(*b.*) All Orders in Council, regulations, appointments, societies incorporated with the Institute, and generally all acts of authority which originated under the said enactments or any enactment thereby repealed, and are subsisting or in force on the coming into operation of this Act, shall enure for the purposes of this Act as fully and effectually as if they had originated under the corresponding provisions of this Act, and accordingly shall, where necessary, be deemed to have so originated.

(*c.*) All property vested in the Board constituted as aforesaid shall be deemed to be vested in the Board established and recognized by this Act.

(*d.*) All matters and proceedings commenced under the said enactments, and pending or in progress on the coming into operation of this Act, may be continued, completed, and enforced under this Act.

2. (1.) The body now known as the New Zealand Institute (hereinafter referred to as "the Institute") shall consist of the Auckland Institute, the Wellington Philosophical Society, the Philosophical Institute of Canterbury, the Otago Institute, the Hawke's Bay Philosophical Institute, the Nelson Institute, the Westland Institute, the Southland Institute, and such others as heretofore have been or may hereafter be incorporated therewith in accordance with regulations heretofore made or hereafter to be made by the Board of Governors.

(2.) Members of the above-named incorporated societies shall be *ipso facto* members of the Institute.

3. The control and management of the Institute shall be vested in a Board of Governors (hereinafter referred to as "the Board"), constituted as follows:—

The Governor:

The Minister of Internal Affairs:

Four members to be appointed by the Governor in Council, of whom two shall be appointed during the month of December in every year:

Two members to be appointed by each of the incorporated societies at Auckland, Wellington, Christchurch, and Dunedin during the month of December in each alternate year; and the next year in which such an appointment shall be made is the year one thousand nine hundred and nine:

One member to be appointed by each of the other incorporated societies during the month of December in each alternate year; and the next year in which such an appointment shall be made is the year one thousand nine hundred and nine.

4. (1.) Of the members appointed by the Governor in Council, the two members longest in office without reappointment shall retire annually on the appointment of their successors.

(2.) Subject to the last preceding subsection, the appointed members of the Board shall hold office until the appointment of their successors.

5. The Board shall be a body corporate by the name of the "New Zealand Institute," and by that name shall have perpetual succession and a common seal, and may sue and be sued, and shall have power and authority to take, purchase, and hold lands for the purposes hereinafter mentioned.

6. (1.) The Board shall have power to appoint a fit person, to be known as the "President," to superintend and carry out all necessary work in connection with the affairs of the Institute, and to provide him with such further assistance as may be required.

(2.) The Board shall also appoint the President or some other fit person to be editor of the Transactions of the Institute, and may appoint a committee to assist him in the work of editing the same.

(3.) The Board shall have power from time to time to make regulations under which societies may become incorporated with the Institute, and to declare that any incorporated society shall cease to be incorporated if such regulations are not complied with; and such regulations on being published in the *Gazette* shall have the force of law.

(4.) The Board may receive any grants, bequests, or gifts of books or specimens of any kind whatsoever for the use of the Institute, and dispose of them as it thinks fit.

(5.) The Board shall have control of the property from time to time vested in it or acquired by it; and shall make regulations for the management of the same, and for the encouragement of research by the members of the Institute; and in all matters, specified or unspecified, shall have power to act for and on behalf of the Institute.

7. (1.) Any casual vacancy in the Board, howsoever caused, shall be filled within three months by the society or authority that appointed the member whose place has become vacant, and if not filled within that time the vacancy shall be filled by the Board.

(2.) Any person appointed to fill a casual vacancy shall only hold office for such period as his predecessor would have held office under this Act.

8. (1.) Annual meetings of the Board shall be held in the month of January in each year, the date and place of such annual meeting to be fixed at the previous annual meeting.

(2.) The Board may meet during the year at such other times and places as it deems necessary.

(3.) At each annual meeting the President shall present to the meeting a report of the work of the Institute for the year preceding, and a balance-sheet, duly audited, of all sums received and paid on behalf of the Institute.

9. The Board may from time to time, as it sees fit, make arrangements for the holding of general meetings of members of the Institute, at times and places to be arranged, for the reading of scientific papers, the delivery of lectures, and for the general promotion of science in New Zealand by any means that may appear desirable.

10. The Minister of Finance shall from time to time, without further appropriation than this Act, pay to the Board the sum of five hundred pounds in each financial year, to be applied in or towards payment of the general current expenses of the Institute.

11. Forthwith upon the making of any regulations or the publication of any Transactions, the Board shall transmit a copy thereof to the Minister of Internal Affairs, who shall lay the same before Parliament if sitting, or if not, then within twenty days after the commencement of the next ensuing session thereof.

### Schedule.

*Enactments consolidated.*

1903, No. 48.—The New Zealand Institute Act, 1903.

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## REGULATIONS.

The following are the regulations of the New Zealand Institute under he Act of 1903 :—*

The word "Institute" used in the following regulations means the New Zealand Institute as constituted by the New Zealand Institute Act, 1903.

### Incorporation of Societies.

1. No society shall be incorporated with the Institute under the provisions of the New Zealand Institute Act, 1903, unless such society shall consist of not less than twenty-five members, subscribing in the aggregate a sum of not less than £25 sterling annually for the promotion of art, science, or such other branch of knowledge for which it is associated, to be from time to time certified to the satisfaction of the Board of Governors of the Institute by the President for the time being of the society.

2. Any society incorporated as aforesaid shall cease to be incorporated with the Institute in case the number of the members of the said society shall at any time become less than twenty-five, or the amount of money annually subscribed by such members shall at any time be less than £25.

* *New Zealand Gazette*, 14th July, 1904.

3. The by-laws of every society to be incorporated as aforesaid shall provide for the expenditure of not less than one-third of the annual revenue in or towards the formation or support of some local public museum or library, or otherwise shall provide for the contribution of not less than one-sixth of its said revenue towards the extension and maintenance of the New Zealand Institute.

4. Any society incorporated as aforesaid which shall in any one year fail to expend the proportion of revenue specified in Regulation No. 3 aforesaid in manner provided shall from henceforth cease to be incorporated with the Institute.

## Publications.

5. All papers read before any society for the time being incorporated with the Institute shall be deemed to be communications to the Institute, and then may be published as Proceedings or Transactions of the Institute, subject to the following regulations of the Board of the Institute regarding publications :—

(*a.*) The publications of the Institute shall consist of—

(1.) A current abstract of the proceedings of the societies for the time being incorporated with the Institute, to be intituled "Proceedings of the New Zealand Institute":

(2.) And of transactions comprising papers read before the incorporated societies (subject, however, to selection as hereinafter mentioned), and of such other matter as the Board of Governors shall from time to time determine to publish, to be intituled "Transactions of the New Zealand Institute."

(*b.*) The Board of Governors shall determine what papers are to be published.

(*c.*) Papers not recommended for publication may be returned to their authors if so desired.

(*d.*) All papers sent in for publication must be legibly written, typewritten, or printed.

(*e.*) A proportional contribution may be required from each society towards the cost of publishing Proceedings and Transactions of the Institute.

(*f.*) Each incorporated society will be entitled to receive a proportional number of copies of the Transactions and Proceedings of the New Zealand Institute, to be from time to time fixed by the Board of Governors.

## Management of the Property of the Institute.

6. All property accumulated by or with funds derived from incorporated societies, and placed in charge of the Institute, shall be vested in the Institute, and be used and applied at the discretion of the Board of Governors for public advantage, in like manner with any other of the property of the Institute.

7. All donations by societies, public Departments, or private individuals to the Institute shall be acknowledged by a printed form of receipt and shall be entered in the books of the Institute provided for that purpose, and shall then be dealt with as the Board of Governors may direct.

### Honorary Members.

8. The Board of Governors shall have power to elect honorary members (being persons not residing in the Colony of New Zealand), provided that the total number of honorary members shall not exceed thirty.

9. In case of a vacancy in the list of honorary members, each incorporated society, after intimation from the Secretary of the Institute, may nominate for election as honorary member one person.

10. The names, descriptions, and addresses of persons so nominated, together with the grounds on which their election as honorary members is recommended, shall be forthwith forwarded to the President of the New Zealand Institute, and shall by him be submitted to the Governors at the next succeeding meeting.

### General Regulations.

11. Subject to the New Zealand Institute Act, 1908, and to the foregoing rules, all societies incorporated with the Institute shall be entitled to retain or alter their own form of constitution and the by-laws for their own management, and shall conduct their own affairs.

12. Upon application signed by the President and countersigned by the Secretary of any society, accompanied by the certificate required under Regulation No. 1, a certificate of incorporation will be granted under the seal of the Institute, and will remain in force as long as the foregoing regulations of the Institute are complied with by the society.

13. In voting on any subject the President is to have a deliberate as well as a casting vote.

14. The President may at any time call a meeting of the Board, and shall do so on the requisition in writing of four Governors.

15. Twenty-one days' notice of every meeting of the Board shall be given by posting the same to each Governor at an address furnished by him to the Secretary.

16. In case of a vacancy in the office of President, a meeting of the Board shall be called by the Secretary within twenty-one days to elect a new President.

17. The Governors for the time being resident or present in Wellington shall be a Standing Committee for the purpose of transacting urgent business and assisting the officers.

18. The Standing Committee may appoint persons to perform the duties of any other office which may become vacant. Any such appointment shall hold good until the next meeting of the Board, when the vacancy shall be filled.

19. The foregoing regulations may be altered or amended at any annual meeting, provided that notice be given in writing to the Secretary of the Institute not later than the 30th November.

## THE HUTTON MEMORIAL MEDAL AND RESEARCH FUND.

### Declaration of Trust.

This deed, made the fifteenth day of February, one thousand nine hundred and nine (1909), between the New Zealand Institute of the one part, and the Public Trustee of the other part: Whereas the New Zealand Institute is possessed of a fund consisting now of the sum of five hundred and fifty-five pounds one shilling (£555 1s.), held for the purposes of the Hutton Memorial Medal and Research Fund on the terms of the rules and regulations made by the Governors of the said Institute, a copy whereof is hereto annexed: And whereas the said money has been transferred to the Public Trustee for the purposes of investment, and the Public Trustee now holds the same for such purposes, and it is expedient to declare the trusts upon which the same is held by the Public Trustee:

Now this deed witnesseth that the Public Trustee shall hold the said moneys and all other moneys which shall be handed to him by the said Governors for the same purposes upon trust from time to time to invest the same upon such securities as are lawful for the Public Trustee to invest on, and to hold the principal and income thereof for the purposes set out in the said rules hereto attached.

And it is hereby declared that it shall be lawful for the Public Trustee to pay all or any of the said moneys, both principal and interest, to the Treasurer of the said New Zealand Institute upon being directed so to do by a resolution of the Governors of the said Institute, and a letter signed by the Secretary of the said Institute enclosing a copy of such resolution certified by him and by the President as correct shall be sufficient evidence to the Public Trustee of the due passing of such resolution: And upon receipt of such letter and copy the receipt of the Treasurer for the time being of the said Institute shall be a sufficient discharge to the Public Trustee: And in no case shall the Public Trustee be concerned to inquire into the administration of the said moneys by the Governors of the said Institute.

As witness the seals of the said parties hereto, the day and year hereinbefore written.

### Resolutions of Board of Governors.

Resolved by the Board of Governors of the New Zealand Institute that—

1. The funds placed in the hands of the Board by the committee of subscribers to the Hutton Memorial Fund be called "The Hutton Memorial Research Fund," in memory of the late Captain Frederick Wollaston Hutton, F.R.S. Such fund shall consist of the moneys subscribed and granted for the purpose of the Hutton Memorial, and all other funds which may be given or granted for the same purpose.

2. The funds shall be vested in the Institute. The Board of Governors of the Institute shall have the control of the said moneys, and may invest the same upon any securities proper for trust-moneys.

3. A sum not exceeding £100 shall be expended in procuring a bronze medal to be known as "The Hutton Memorial Medal."

4. The fund, or such part thereof as shall not be used as aforesaid, shall be invested in such securities as aforesaid as may be approved of by the Board of Governors, and the interest arising from such investment shall be used for the furtherance of the objects of the fund.

5. The Hutton Memorial Medal shall be awarded from time to time by the Board of Governors, in accordance with these regulations, to persons who have made some noticeable contribution in connection with the zoology, botany, or geology of New Zealand.

6. The Board shall make regulations setting out the manner in which the funds shall be administered. Such regulations shall conform to the terms of the trust.

7. The Board of Governors may, in the manner prescribed in the regulations, make grants from time to time from the accrued interest to persons or committees who require assistance in prosecuting researches in the zoology, botany, or geology of New Zealand.

8. There shall be published annually in the "Transactions of the New Zealand Institute" the regulations adopted by the Board as aforesaid, a list of the recipients of the Hutton Memorial Medal, a list of the persons to whom grants have been made during the previous year, and also, whe  possible, an abstract of researches made by them.

## Regulations under which the Hutton Memorial Medal shall be awarded and the Research Fund administered.

1. Unless in exceptional circumstances, the Hutton Memorial Medal shall be awarded not oftener than once in every three years; and in no case shall any medal be awarded unless, in the opinion of the Board, some contribution really deserving of the honour has been made.

2. The medal shall not be awarded for any research published previous to the 31st December, 1906.

3. The research for which the medal is awarded must have a distinct bearing on New Zealand zoology, botany, or geology.

4. The medal shall be awarded only to those who have received the greater part of their education in New Zealand or who have resided in New Zealand for not less than ten years.

5. Whenever possible, the medal shall be presented in some public manner.

6. The Board of Governors may, at an annual meeting, make grants from the accrued interest of the fund to any person, society, or committee for the encouragement of research in New Zealand zoology, botany, or geology.

7. Applications for such grants shall be made to the Board before the 30th September.

8. In making such grants the Board of Governors shall give preference to such persons as are defined in regulation 4.

9. The recipients of such grants shall report to the Board before the 31st December in the year following, showing in a general way how the grant has been expended and what progress has been made with the research.

10. The results of researches aided by grants from the fund shall, where possible, be published in New Zealand.

11. The Board of Governors may from time to time amend or alter the regulations, such amendments or alterations being in all cases in conformity with resolutions 1 to 4.

### Award of the Hutton Memorial Medal.

1911. Professor W. B. Benham, D.Sc., F.R.S., University of Otago—For researches in New Zealand zoology.

1914. Dr. L. Cockayne, F.L.S., F.R.S.—For researches on the ecology of New Zealand plants.

1917. Professor P. Marshall, M.A., D.Sc.—For researches in New Zealand geology.

### Grants from the Hutton Memorial Research Fund.

1916. (1.) To the Portobello Marine Fish-hatchery—£25 for the purpose of prosecuting research on the distribution of native marine food fishes.

(2.) To Major Broun—£50 towards the publication of researches on New Zealand Coleoptera as a bulletin.

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## HECTOR MEMORIAL RESEARCH FUND.

### Declaration of Trust.

This deed, made the thirty-first day of July, one thousand nine hundred and fourteen, between the New Zealand Institute, a body corporate duly incorporated by the New Zealand Institute Act, 1908, of the one part, and the Public Trustee of the other part: Whereas by a declaration of trust dated the twenty-seventh day of January, one thousand nine hundred and twelve, after reciting that the New Zealand Institute was possessed of a fund consisting of the sum of £1,045 10s. 2d., held for the purposes of the Hector Memorial Research Fund on the terms of the rules and regulations therein mentioned, which said moneys had been handed to the Public Trustee for investment, it was declared (*inter alia*) that the Public Trustee should hold the said moneys and all other moneys which should be handed to him by the said Governors of the Institute for the same purpose upon trust from time to time, to invest the same in the common fund of the Public Trust Office, and to hold the principal and income thereof for the purposes set out in the said rules and regulations in the said deed set forth: And whereas the said rules and regulations have been amended by the Governors of the New Zealand Institute, and as amended are hereinafter set forth: And whereas it is expedient to declare that the said moneys are held by the Public Trustee upon the trusts declared by the said deed of trust and for the purposes set forth in the said rules and regulations as amended as aforesaid:

Now this deed witnesseth and it is hereby declared that the Public Trustee shall hold the said moneys and all other moneys which shall be handed to him by the said Governors for the same purpose upon trust from time to time to invest the same in the common fund of the Public Trust Office, and to hold the principal and income thereof for the purposes set out in the said rules and regulations hereinafter set forth:

And it is hereby declared that it shall be lawful for the Public Trustee to pay, and he shall pay, all or any of the said moneys, both principal and interest, to the Treasurer of the said New Zealand Institute upon being directed to do so by a resolution of the Governors of the said Institute, and a letter signed by the Secretary of the said Institute enclosing a copy of such resolution certified by him and by the

President as correct shall be sufficient evidence to the Public Trustee of the due passing of such resolution: And upon receipt of such letter and copy the receipt of the Treasurer for the time being of the said Institute shall be a sufficient discharge to the Public Trustee: And in no case shall the Public Trustee be concerned to inquire into the administration of the said moneys by the Governors of the said Institute.

As witness the seals of the said parties hereto, the day and year first hereinbefore written.

*Rules and Regulations made by the Governors of the New Zealand Institute in relation to the Hector Memorial Research Fund.*

1. The funds placed in the hands of the Board by the Wellington Hector Memorial Committee be called "The Hector Memorial Research Fund," in memory of the late Sir James Hector, K.C.M.G., F.R.S. The object of such fund shall be the encouragement of scientific research in New Zealand, and such fund shall consist of the moneys subscribed and granted for the purpose of the memorial and all other funds which may be given or granted for the same purpose.

2. The funds shall be vested in the Institute. The Board of Governors of the Institute shall have the control of the said moneys, and may invest the same upon any securities proper for trust-moneys.

3. A sum not exceeding one hundred pounds (£100) shall be expended in procuring a bronze medal, to be known as the Hector Memorial Medal.

4. The fund, or such part thereof as shall not be used as aforesaid, shall be invested in such securities as may be approved by the Board of Governors, and the interest arising from such investment shall be used for the furtherance of the objects of the fund by providing thereout a prize for the encouragement of such scientific research in New Zealand of such amount as the Board of Governors shall from time to time determine.

5. The Hector Memorial Medal and Prize shall be awarded annually by the Board of Governors.

6. The prize and medal shall be awarded by rotation for the following subjects, namely—(1) Botany, (2) chemistry, (3) ethnology, (4) geology, (5) physics (including mathematics and astronomy), (6) zoology (including animal physiology).

In each year the medal and prize shall be awarded to that investigator who, working within the Dominion of New Zealand, shall in the opinion of the Board of Governors have done most towards the advancement of that branch of science to which the medal and prize are in such year allotted.

7. Whenever possible the medal shall be presented in some public manner.

AWARD OF THE HECTOR MEMORIAL RESEARCH FUND.

1912. L. Cockayne, Ph.D., F.L.S., F.R.S.—For researches in New Zealand botany.
1913. T. H. Easterfield, M.A., Ph.D.—For researches in chemistry.
1914. Elsdon Best—For researches in New Zealand ethnology.
1915. P. Marshall, M.A., D.Sc., F.G.S.—For researches in New Zealand geology.
1916. Sir Ernest Rutherford, F.R.S.—For researches in physics.
1917. Charles Chilton, M.A., D.Sc., F.L.S., C.M.Z.S.—For researches in zoology.

## REGULATIONS FOR ADMINISTERING THE GOVERNMENT RESEARCH GRANT.

All grants shall be subject to the following conditions, and each grantee shall be duly informed of these conditions :—

1. All instruments, specimens, objects, or materials of permanent value, whether purchased or obtained out of or by means of the grant, or supplied from among those at the disposal of the Institute, are to be regarded, unless the Research Grants Committee decide otherwise, as the property of the Institute, and are to be returned by the grantee, for disposal according to the orders of the committee, at the conclusion of his research, or at such other time as the committee may determine.

2. Every one receiving a grant shall furnish to the Research Grants Committee, on or before the 1st January following upon the allotment of the grant, a report (or, if the object of the grant be not attained, an interim report, to be renewed at the same date in each subsequent year until a final report can be furnished or the committee dispense with further reports) containing (*a*) a brief statement showing the results arrived at or the stage which the inquiry has reached ; (*b*) a general statement of the expenditure incurred, accompanied, as far as is possible, with vouchers; (*c*) a list of the instruments, specimens, objects, or materials purchased or obtained out of the grant, or supplied by the committee, which are at present in his possession ; and (*d*) references to any transactions, journals, or other publications in which results of the research have been printed. In the event of the grantee failing to send in within three months of the said 1st January a report satisfactory to the committee he may be required, on resolution of the Board of Governors, to return the whole of the sum allotted to him.

3. Where a grant is made to two or more persons acting as a committee for the purpose of carrying out some research, one member of the said committee shall assume the responsibility of furnishing the report and receiving and disbursing the money.

4. Papers in which results are published that have been obtained through and furnished by the Government grant should contain an acknowledgment of that fact.

5. Every grantee shall, before any of the grant is paid to him, be required to sign an engagement that he is prepared to carry out the general conditions applicable to all grants, as well as any conditions which may be attached to his particular grant.

6. In cases where specimens or preparations of permanent value are obtained through a grant the committee shall, as far as possible, direct that such specimens shall be deposited in a museum or University college within the province where the specimens or material were obtained, or in which the grantee has worked. The acknowledgement of the receipt of the specimens by such institution shall fully satisfy the claims of the Institute.

7. In cases where, after completion of a research, the committee directs that any instrument or apparatus obtained by means of the grant shall be deposited in an institution of higher learning, such deposit shall be subject to an annual report from the institution in question as to the condition of the instrument or apparatus, and as to the use that has been made of it.

## List of Grantees, 1916.

Mr. L. P. Symes, Christchurch (through the Philosophical Institute of Canterbury), £50 for investigating the causes of the deterioration and decay of apples and other fruits in cold storage. (Granted 9th November, 1916.)

Mr. L. Birks, Christchurch (through the Philosophical Institute of Canterbury), £10 for experiments in the electrical prevention of frosts in orchards. (Granted 9th November, 1916.)

Messrs. Speight and Wild, Christchurch (through the Philosophical Institute of Canterbury), £50 towards the expenses incurred in an investigation of the phosphate-yielding rocks of Canterbury. (Granted 9th November, 1916.)

Mr. H. Hill, Napier (through the Hawke's Bay Philosophical Society), £20 for aid in making an inquiry into the artesian-water supply of the Taupo Plain. (Granted 13th January, 1917.)

Professor Kirk, Wellington (through the Wellington Philosophical Society), £25 towards the out-of-pocket expenses for investigation of methods of killing mosquitoes and larvae. (Granted 13th January, 1917.)

Messrs. La Trobe and Adams, Wellington (through the Wellington Philosophical Society), £50 towards the out-of-pocket expenses in connection with the construction of a tide-predicting machine. (Granted 13th January, 1917.)

Professor Jack, Dunedin (through the Otago Institute), £25 for expenses in connection with the investigation of the electric charge on rain and its connection with the meteorological conditions. (Granted 13th January, 1917.)

Mr. D. Petrie, Auckland (through the Auckland Institute), £20 for aid in carrying out an exploration of the grass flora of southern Nelson and south-western Marlborough. (Granted 30th January, 1917.)

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## THE CARTER BEQUEST.

For extracts from the will of Charles Rooking Carter see vol. 48, 1916, pp. 565–66.

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# NEW ZEALAND INSTITUTE.

ESTABLISHED UNDER AN ACT OF THE GENERAL ASSEMBLY OF NEW ZEALAND INTITULED THE NEW ZEALAND INSTITUTE ACT, 1867; RECONSTITUTED BY AN ACT OF THE GENERAL ASSEMBLY OF NEW ZEALAND UNDER THE NEW ZEALAND INSTITUTE ACT, 1903, AND CONTINUED BY THE NEW ZEALAND INSTITUTE ACT, 1908.

## Board of Governors.

EX OFFICIO.

His Excellency the Governor.
The Hon. the Minister of Internal Affairs.

NOMINATED BY THE GOVERNMENT.

Mr. Charles A. Ewen (reappointed December, 1916); Dr. J. Allan Thomson, F.G.S. (appointed December, 1915); Mr. B. C. Aston, F.I.C. (appointed December, 1915); Dr. Charles Chilton, F.L.S., C.M.Z.S., (reappointed December, 1916).

ELECTED BY AFFILIATED SOCIETIES (DECEMBER, 1915).

| | |
|---|---|
| Wellington Philosophical Society ... | Professor T. H. Easterfield, M.A., Ph.D.<br>Professor H. B. Kirk, M.A. |
| Auckland Institute ... ... ... | Mr. D. Petrie, M.A., Ph.D.<br>Professor H. W. Segar, M.A. |
| Philosophical Institute of Canterbury ... | Dr. Hilgendorf, M.A.<br>Mr. A. M. Wright, F.C.S. |
| Otago Institute ... ... ... | Professor Marshall, M.A., D.Sc., F.G.S.<br>Mr. G. M. Thomson, F.C.S., F.L.S. |
| Hawke's Bay Philosophical Institute ... | Mr. H. Hill, B.A., F.G.S. |
| Nelson Institute ... ... ... | Dr. L. Cockayne, F.L.S., F.R.S. |
| Manawatu Philosophical Society ... | Mr. J. W. Poynton, S.M. |
| Wanganui Philosophical Society .. | Dr. H. R. Hatherly, M.R.C.S. |

OFFICERS FOR THE YEAR 1917.

President: Professor Benham, M.A., D.Sc., F.Z.S., F.R.S.
Hon. Treasurer: Mr. C. A. Ewen.
Hon. Editors: Dr. L. Cockayne, F.R.S.; Dr. C. A. Cotton, F.G.S.
Hon. Librarian: Dr. J. Allan Thomson, F.G.S.
Hon. Secretary: Mr. B. C. Aston, F.I.C., F.C.S.
(Box 40, Post-office, Wellington).

AFFILIATED SOCIETIES.

| Name of Society. | Secretary's Name and Address. | Date of Affiliation. |
|---|---|---|
| Wellington Philosophical Society | C. E. Adams, Hector Observatory, Wellington | 10th June, 1868. |
| Auckland Institute .. | T. F. Cheeseman, Museum .. | 10th June, 1868. |
| Philosophical Institute of Canterbury | L. P. Symes, 22 Mays Road, Christchurch | 22nd October, 1868. |
| Otago Institute .. .. | E. J. Parr, Boys' High School, Dunedin | 18th October, 1869. |
| Hawke's Bay Philosophical Institute | James Niven, Technical College, Napier | 31st March, 1875. |
| Nelson Institute .. .. | E. L. Morley, Waimea Street .. | 20th December, 1883. |
| Manawatu Philosophical Society | K. Wilson, Palmerston North .. | 6th January, 1905. |
| Wanganui Philosophical Society | J. P. Williamson, Box 171, Wanganui | 2nd December, 1911. |

## FORMER HONORARY MEMBERS.

### 1870.

Agassiz, Professor Louis.
Drury, Captain Byron, R.N.
Flower, Professor W. H., F.R.S.
Hocbstetter, Dr. Ferdinand von.
Hooker, Sir J. D., G.C.S.I., C.B., M.D., F.R.S., O.M.
Mueller, Ferdinand von, M.D., F.R.S., C.M.G.
Owen, Professor Riohard, F.R.S.
Richards, Rear-Admiral G. H.

### 1871.

Darwin, Charles. M.A., F.R.S.
Gray, J. E., Ph.D., F.R.S.
Lindsay, W. Lauder, M.D., F.R.S.E.

### 1872.

Grey, Sir George, K.C.B.
Huxley, Thomas H., LL.D., F.R.S.
Stokes, Vice-Admiral J. L.

### 1873.

Bowen, Sir George Ferguson, G.C.M.G.
Günther, A., M.D., M.A., Ph.D., F.R.S.
Lyell, Sir Charles, Bart., D.C.L., F.R.S.

### 1874.

McLachlan, Robert, F.L.S.
Newton, Alfred, F.R.S.
Thomson, Professor Wyville, F.R.S.

### 1875.

Filhol, Dr. H.
Rolleston, Professor G., M.D., F.R.S.
Sclater, P. L., M.A., Ph.D., F.R.S.

### 1876.

Clarke, Rev. W. B., M.A., F.R.S.
Etheridge, Professor R., F.R.S.

### 1877.

Baird, Professor Spencer F.
Weld, Frederick A., C.M.G.

### 1878.

Garrod, Professor A. H., F.R.S.
Müller, Professor Max, F.R.S.
Tenison-Woods, Rev. J. E., F.L.S.

### 1880.

The Most Noble the Marquis of Normanby, G.C.M.G.

### 1883.

Carpenter, Dr. W. B., C.B., F.R.S.
Ellery, Robert L. J., F.R.S.
Thomson, Sir William, F.R.S.

### 1885.

Gray, Professor Asa.
Sharp, Richard Bowdler, M.A., F.R.S.
Wallace, A. R., F.R.S., O.M.

### 1888.

Beneden, Professor J. P. van.
Ettingshausen, Baron von.
McCoy, Professor F., D.Sc., C.M.G., F.R.S.

### 1890.

Riley, Professor C. V.

### 1891.

Davis, J. W., F.G.S., F.L.S.

1895.

Mitten, William, F.R.S.

1896.

Langley, S. P.

1900.

Agardh, Dr. J. G. | Avebury, Lord, P.C., F.R.S.

1901.

Eve, H. W., M.A. | Howes, G. B., LL.D., F.R.S.

1906.

Milne, J., F.R.S.

1909.

Darwin, Sir George, F.R.S.

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## FORMER MANAGER AND EDITOR.

[Under the New Zealand Institute Act, 1867.]

1867–1903.

Hector, Sir James, M.D., K.C.M.G., F.R.S.

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## PAST PRESIDENTS.

1903–4.

Hutton, Captain Frederick Wollaston, F.R.S.

1905–6.

Hector, Sir James, M.D., K.C.M.G., F.R.S.

1907–8.

Thomson, George Malcolm, F.L.S., F.C.S.

1909–10.

Hamilton, A.

1911–12.

Cheeseman, T. F., F.L.S., F.Z.S.

1913–14.

Chilton, C., M.A., D.Sc., LL.D., F.L.S., C.M.Z.S.

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## HONORARY MEMBERS.

1870.

Finsch, Professor Otto, Ph.D., Braunschweig, Germany.

1873.

Pickard-Cambridge, The Rev. O., M.A., C.M.Z.S.

1876

Berggren, Dr. S., Lund, Sweden.

1877.

Sharp, Dr. D., University Museum, Cambridge.

1890.

Liversidge, Professor A., M.A., F.R.S., Fieldhead, Coombe Warren, Kingston Hill, England.

Nordstedt, Professor Otto, Ph.D., University of Lund, Sweden.

1891.

Goodale, Professor G. L., M.D., LL.D., Harvard University, Massachusetts, U.S.A.

1894.

Codrington, Rev. R. H., D.D., Wadhurst Rectory, Sussex, England.

Thiselton-Dyer, Sir W. T., K.C.M.G., C.I.E., LL.D., M.A., F.R.S., Witcombe, Gloucester, England.

1896.

Lydekker, Richard, B.A., F.R.S., British Museum, South Kensington.

1900.

Massee, George, F.R.M.S., Royal Botanic Gardens, Kew.

1901.

Goebel, Professor Dr. Carl von, University of Munich.

1902.

Sars, Professor G. O., University of Christiania, Norway.

1903.

Klotz, Professor Otto J., 437 Albert Street, Ottawa, Canada.

1904.

Rutherford, Professor Sir E., D.Sc., F.R.S., Nobel Laureate, University of Manchester.

David, Professor T. Edgeworth, F.R.S., C.M.G., Sydney University, N.S.W.

1906.

Beddard, F. E., D.Sc., F.R.S., Zoological Society, London.

Brady, G. S., D.Sc., F.R.S., University of Durham, England.

1907.

Dendy, Dr. A., F.R.S., King's College, University of London, England.

Diels, Professor L., Ph.D., University of Marburg.

Meyrick, E., B.A., F.R.S., Marlborough College, England.

Stebbing, Rev. T. R. R., F.R.S., Tunbridge Wells, England.

1910.

Bruce, Dr. W. S., Edinburgh.

1913.

Davis, Professor W. Morris, Harvard University.

Hemsley, Dr. W. Botting, F.R.S., Strawberry Hill, London, England.

1914.

Arber, Dr. E. Newell, Cambridge, England.

Balfour, Professor I. Bayley, F.R.S., Royal Botanic Gardens, Edinburgh.

Haswell, Professor W. A., F.R.S, University, Sydney.

1915.

Bateson, Professor W., F.R.S., Merton, Surrey, England.

1916.

Massart, Professor Jean, University of Brussels, Belgium.

# ORDINARY MEMBERS.

## WELLINGTON PHILOSOPHICAL SOCIETY.

[* Life members. † On active service.]

Acland, E. W., P.O. Box 928, Wellington
Adams, C. E., D.Sc., A.I.A. (London), F.R.A.S., Hector Observatory, Wellington
Adams, C. W., Bellevue Road, Lower Hutt*
Adamson, Professor J., M.A., LL.B., Victoria University College, Wellington
Adkin, G. L., Queen Street, Levin
Alabaster, A. H., Head Office, Railway Department, Wellington
Andersen, Johannes C., Gener 1 Assembly Library, Wellington
Anderson, W. J., M.A., LL.D., Education Department, Wellington
Andrew, R. L., Dominion Laboratory, Wellington
Aston, B. C., F.I.C., F.C.S., P.O. Box 40, Wellington
Atkins, A., F.R.I.B.A., A.M. Inst.C.E., 9 Grey Street, Wellington
Atkinson, E. H., Agricultural Department, Wellington†
Bagley, G., care of Young's Chemical Company, 14 Egmont Street, Wellington
Bakewell, F. H., M.A., Education Board, Mercer Street, Wellington
Baldwin, E. S., 215 Lambton Quay, Wellington
Beetham, W. H., Masterton
Begg, Dr. C. M., 164 Willis Street, Wellington†
Bell, E. D., Panama Street, Wellington
Bell, Hon. Sir Francis H. D., K.C., M.L.C., Panama Street, Wellington
Berry, C. G. G., 35 Bolton Street, Wellington
Blair, David K., M.I.Mech.E., 9 Grey Street, Wellington
Brandon, A. de B., B.A., Featherston Street, Wellington
Bretherton, A. C., Public Trust Office, Wellington
Bridges, G. G., 2 Wesley Road, Wellington
Broadgate, F. L. K., M.Sc., Dominion Museum, Wellington†
Brodrick, T. N., Under-Secretary, Lands and Survey Department, Wellington
Brown, J., Experimental Farm, Weraroa
Browne, M. H., Education Department, Wellington
Burbidge, P. W., M.Sc., Victoria University College, Wellington
Burnett, J., M.Inst.C.E., care of M. Burnett, of Richardson, McCabe, and Co., 11 Grey Street, Wellington
Burton, Richard F., Longner Hall, Salop, Shrewsbury, England*
Campbell, J., F.R.I.B.A., Government Architect, Public Works Department, Wellington
Carter, W. H., care of Dr. Henry, The Terrace, Wellington†
Chamberlin, T. Chamberlin, Crescent Road, Khandallah
Chambers, J. M., 18 Bower Street, Manly, N.S.W.

Chapman, Martin, K.C., Brandon Street, Wellington
Chudleigh, E. R., Orongomairoa, Waihou
Clark, Professor H., Victoria University College, Wellington
Cockayne, L., Ph.D., F.L.S., F.R.S., Ngaio, Wellington
Cook, H. D., M.Sc., B.E. (Elect.), Bank Chambers, Lambton Quay, Wellington
Cotton, C. A., D.Sc., F.G.S., Victoria University College, Wellington
Crawford, A. D., Box 126, G.P.O., Wellington
Cull, J. E. L., B.Sc. in Eng. (Mech.), Public Works Department, Wellington
Curtis, H. F., 19 May Street, Wellington
Darling, J., Kelburn
Davies, V. C., Devon Street, New Plymouth†
Donovan, W., M.Sc., Dominion Laboratory, Wellington
Dougall, Archibald, 9 Claremont Grove, Wellington
Dymock, E. R., F.I.A.N.Z., A.I.A.V., Woodward Street, Wellington
Earnshaw, W., 4 Watson Street, Wellington†
Easterfield, Professor T. H., M.A., Ph.D., Victoria University College, Wellington
Ewen, Charles A., Heretaunga, Upper Hutt
Ferguson, William, M.A., M.Inst. C.E., M.Inst.Mech.E., 131 Coromandel Street, Wellington
Findlay, Sir John G., K.C., LL.D., 197 Lambton Quay, Wellington
FitzGerald, Gerald, A.M.Inst.C.E., P.O. Box 461, Wellington
Fletcher, Rev. H. J., The Manse, Taupo
Fortune, Alfred, Huia Road, Hataitai
Fox, Thomas O., Borough Engineer, Miramar, Wellington
Fraser, G. V. R., Head Office, Railways, Wellington
Freeman, C. J., 95 Webb Street, Wellington*
Freyberg, C., Macdonald Crescent, Wellington†
Fulton, J., 14 North Terrace, Kelburn†
Furkert, F. W., A.M.Inst.C.E., Public Works Department, Wellington
Garrow, Professor J. M. E., B.A., LL.B., Victoria College, Wellington*
Gavin, W. H., Public Works Department, Wellington
Gibbs, Dr. H. E., 240 Willis Street, Wellington
Gifford, A. C., M.A., F.R.A.S., 6 Shannon Street, Wellington*
Girdlestone, H. E., F.R.G.S., Lands and Survey Department, Wellington
Goudie, H. A., Whakarewarewa
Hamilton, H., A.O.S.M., 58 Bowen Street, Wellington†
Hanify, H. P., 18 Panama Street, Wellington
Hansford, George D., Parliamentary Buildings, Wellington
Harding, V. Coupland, 63 Matai Road, Hataitai
Hastie, Miss J. A., care of Street and Co., 30 Cornhill, London E.C.*
Hector, C. Monro, M.D., B.Sc., F.R.A.S., Lower Hutt
Helyer, Miss E., 13 Tonks Grove, Wellington
Henderson, J., M.A., D.Sc., B.Sc. in Engineering (Metall.), Geological Survey Department, Wellington
Hislop, J., Internal Affairs Department, Wellington
Hodson, W. H., 40 Pirie Street, Wellington
Hogben, G., C.M.G., M.A., F.G.S., 32 Crescent Road, Khandallah
Holmes, R. L., F.R.Met.Soc., "Kia Ora," Fern Street, Randwick, Sydney*
Holmes, R. W., M.Inst.C.E., Engineer-in-Chief, Public Works Department, Wellington
Hooper, Captain G. S., Grant Road, North Wellington
Hudson, G. V., F.E.S., Inspector's Office, G.P.O., Wellington

Humphries, Thomas, F.R.G.S., Laery Street, Lower Hutt
Jack, J. W., 170 Featherston Street, Wellington
James, L. G., P.O. Box 94 (Hunter Street), Wellington
Jenkinson, S. H., Railway Department, Wellington
Johnston, C. G., Head Office, Railway Department, Wellington†
Johnston, Hon. G. Randall, care of Martin Chapman, K.C., Wellington*
Jones, E. G., B.A., 33 Ellice Avenue, Wellington†
Joseph, Joseph, P.O. Box 443, Wellington
Kempthorne, Mrs. H. E., Bellevue Road, Lower Hutt
Kennedy, Rev. Dr. D., F.R.A.S., St. Patrick's College, Wellington
King, G. W., B.E., care of A. H. King, P.O. Box 116, Christchurch†
Kirk, Professor H. B., M.A., Victoria University College, Wellington
La Trobe, W. S., M.A., Technical College, Wellington
Levi, P., M.A., care of Wilford and Levi, 15 Stout Street, Wellington
Lomas, E. K., M.A., M.Sc., Training College, Wellington
Lomax, Major H. A., Araruhe, Aramoho, Wanganui
Luke, John P., C.M.G., Hiropi Street, Wellington
McCabe, Ultan F., care of Richardson and McCabe, 11 Grey Street, Wellington
McDonald, J., Dominion Museum, Wellington
McKenzie, Donald, care of Mrs. Elizabeth McKenzie, Marton†
Maclaurin, J. S., D.Sc., F.C.S., Dominion Laboratory, Wellington
MacLean, F. W., M.Inst.C.E., Chief Engineer, Head Office, Railway Department, Wellington
Marchbanks, J., M.Inst.C.E., Harbour Board, Wellington
Marsden, Professor E., D.Sc., Victoria University College, Wellington†
Mason, J. Malcolm, M.D., F.C.S., D.P.H., Lower Hutt
Maxwell, J. P., M.Inst.C.E., 145 Dixon Street, Wellington
Mestayer, R. L., M.Inst.C.E., 139 Sydney Street, Wellington
Miller, H. M., Public Works Department, Wellington†
Mills, Leonard, New Parliamentary Buildings, Wellington
Moore, G., Eparaima, *via* Masterton
Moore, W. Lancelot, care of H. D. Cook, Bank Chambers, Lambton Quay, Wellington†
Moorhouse, W. H. Sefton, 134 Dixon Street, Wellington
Morgan, P. G., M.A., F.G.S., Director Geological Survey, Routh's Buildings, Wellington
Morice, J. M., B.Sc., Town Hall, Wellington
Morison, C. B., Stout Street, Wellington
Morrison, J. C., P.O. Box 8, Eltham
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