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TRANSACTIONS

AND

PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE

VOL. LI

(NEW ISSUE)

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

ISSUED 1ST SEPTEMBER, 1919

Wellington, N.Z.
MARCUS F. MARKS, GOVERNMENT PRINTING OFFICE
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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.

When references are not in alphabetical order the initials of the author should precede the surname, and the year of publication should be placed at the end.

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ALEXANDER HORSBURGH TURNBULL.

[Face p. iii.

OBITUARY.

ALEXANDER HORSBURGH TURNBULL, 1868-1918.

Alexander Horsburgh Turnbull was born in Wellington on the 11th September, 1868, and was educated at Dulwich College England.

His father was Mr. Walter Turnbull, one of the founders of the firm W. and G. Turnbull and Co (now Wright, Stephenson, and Co.); and on his entering on a mercantile career Mr. Turnbull joined his father's London office, returning to Wellington in 1890. For many years he was associated with the late Mr. Nicholas Reid in the management of the business of W. and G. Turnbull and Co., but owing to failing health he was compelled some eighteen months before his death to relinquish most of his business activities retiring altogether in October, 1917. The whole of his activities and the considerable means resulting from his business were then devoted to the augmenting of his collection of books of history, travel, and literature. He became one of the best-known book-collectors of New Zealand, and his library was known far beyond the limits of New Zealand. He devoted himself largely to the gathering of a representative collection of accounts of voyages to the islands of the Pacific, and the histories of those islands, including Australia and New Zealand; and the collection gathered by him is reputed to be one of the best in the world. It includes not only works in English, but many in Dutch, French, Spanish, German, and other languages, the Dutch being especially valuable. This portion forms, however, only about one-fourth of the library, the rest being devoted to histories of early colonization in various countries, and to poetry and general literature. Besides having copies of every obtainable edition of the better-known poets, the library is rich in works of the minor poets. His collection of autographs, letters, poems, logs, and journals is most representative; and he secured many rare editions both of well-known and out-of-the-way writers, so that the library contains wealth for the historian and for the lover of pure literature as well as for the bibliophile. He also specialized in New Zealand and Australian pamphlets, original drawings, and sketches of early New Zealand and Australia, maps, charts, photographs, &c.

The library contains over 32,000 bound volumes, thousands being almost jewel-like in their artistic binding, the work of such well-known firms as Zaehnsdorf and Riviere, of London; thousands of unbound pamphlets, leaflets, maps, etchings, drawings and prints, all of inestimable value from an historical point of view.

Whilst Mr. Turnbull was a member of the Wellington Philosophical Society from 1897 to the day of his death, he was not an active member so far as the reading of papers was concerned. He was, however, indefatigable in the gathering together of this splendid collection, which he commenced whilst still in London, and the number and extent of manuscript notes in the various volumes show that he was a wide and unremitting reader who loved his books and knew them thoroughly. Apparently his sole object in making the collection, apart from present pleasure, was the eventual presentation of it to the Dominion. Not only did he at all times place the library at the disposal of students and researchers, but by his knowledge of the contents of the books he was able to render them valuable assistance, and never refused to do so. Whilst, therefore, he did no original creative work, he did what was even more important—gathered a wealth of material that will give inspiration for original work for many years to come. This wealth he bequeathed to His Majesty the King in trust as a reference library to be housed in Wellington. The bequest is the most valuable by which the city of Wellington has ever benefited, and one of the most valuable ever made in the Dominion.

Mr. Turnbull possessed an extensive collection of Maori carvings, weapons, implements, articles of clothing, and other objects of ethnological value, and this collection he presented to the Dominion Museum in January, 1913. His desire for anonymity was respected, but it is due to his memory that this should now be known.

He was also a prominent member of the New Zealand Academy of Fine Arts, and had gathered a valuable collection of pictures by New Zealand and other artists. Many of these pictures, which deal with matters of historic interest to New Zealand and Australia, passed with his bequest and are now housed in the library which is known after the donor as the Turnbull Library

Mr. Turnbull died in Wellington on the 28th June, 1918. He was a Fellow of the Linnean Society and a Fellow of the Royal Geographical Society; and, whilst his name does not appear among the illustrious in the world of science, the original work that will result from his labours and pleasures of collecting will certainly enrich the world of science no less than its sister world of literature.

JOHANNES C. ANDERSEN.

HENRY SUTER, 1841–1918.

WITH the issue of the twenty-second volume of the *Transactions* a new star rose on the conchological world. For here, under a name hitherto unknown, appeared a series of excellent descriptions of small land-shells, illustrated with unusually clear and detailed drawings by the same hand. In continuation an account followed of the jaws and radula of various minute snails. This very difficult work was beautifully done.

These contributions, signed "H. Suter," were warmly welcomed by a little band of zoological research workers in Australasia. In answer to inquiries as to who our new comrade was, Captain Hutton replied that he was a Swiss, lately arrived in New Zealand with introductions from well-known European zoologists.

Henry Suter was born on the 9th March, 1841, and was the son of a prosperous silk-manufacturer of Zurich. He was educated at the local school and university, being trained as an analytical chemist. He joined the business of his father, and for some years engaged in various commercial pursuits.

From his boyhood he was deeply interested in natural history. He enjoyed the friendship and help of such men as Dr. August Forel, Professor Paul Godet, the brothers de Saussure, Escher von der Linth, and especially the well-known conchologist Dr. Albert Mousson.

Partly to improve his financial prospects and partly lured by the attraction of the fauna of a new country, Suter resolved to emigrate to New Zealand. It was the last day of the year 1886 when with his wife and a family of young children he landed in New Zealand.

He began his colonial career by taking up a remote selection in the Forty-mile Bush, in the Wairarapa district. It is only in a story that a middle-aged townsman can ever turn backwoodsman with success, and so after about a year Suter relinquished the hard and hopeless struggle.

At this critical time Captain Hutton, always a firm friend to zoologists, succeeded in obtaining for his protégé a post as assistant manager at the Mount Cook Hermitage. Subsequently work was available at the Canterbury Museum. After that, at one or another of the scientific institutions of New Zealand Suter spent the remainder of his life at congenial employment.

Henry Suter was an expert collector. He excelled in taking the minutest land-shells, to find which requires knowledge, patience, and the sharpest eyes. Specialists in other groups were often supplied by Suter with valuable material. In Switzerland he had formed a fine collection of European land and fresh-water shells. This was afterwards acquired by the Australian Museum.

For several years Suter restricted his studies to the terrestrial and fluviatile Mollusca of his adopted country. When his work on these approached completion he proposed to extend his investigations to land Mollusca abroad. Hence his scattered papers on land Mollusca from Brazil, South Africa, and Tasmania. His friends, however, persuaded him that science would be better served if he relinquished the foreign shells and transferred his attention to the marine Mollusca of New Zealand. Not only did he take this course, but he finally embraced the Tertiary Mollusca also in his sphere of operations.

Glancing over his papers, it is apparent that his writings were largely modelled on those of his distinguished predecessor, Captain Hutton. It was indeed fortunate that the work of the one should have succeeded that of the other without the intervention of what the geologists describe as an unconformity. Perhaps at no time did Suter quite realize the undiscovered residue of the fauna on which he worked. In his various reviews and revisions and supplements he wrote as if he had in hand if not all at least almost all the species of the area under examination.

Patience, perseverance, and concentration, rather than any great breadth of view, were his characteristics. His *magnum opus*, the *Manual of the New Zealand Mollusca*,* was approached by a whole quarter-century of study and labour.

It was the late Mr. Augustus Hamilton who planned the *Manual*, and obtained from the Government the means for its production.

A competent critic wrote† of this magnificent volume that it made an extraordinary advance in Antipodean conchology. The nomenclature of the subject was raised to a modern standard, so that by its guidance any one can now correctly name the shells of New Zealand. Suter needs no other eulogy than his *Manual*.

After the *Manual* was completed he was engaged by the Geological Survey to describe collections of Tertiary Mollusca gathered by the Department. On this he was busy for the remainder of his life, and the results are embodied in three *Palaeontological Bulletins* of the Geological Survey.

After a brief illness Henry Suter passed away at his home in Christchurch on the 30th July, 1918.

CHARLES HEDLEY.

* Published in 1913-15.
† *Journ. of Conch.*, vol. 14, p. 287. 1915.

HENRY SUTER.

Face p. x.

THOMAS WILLIAM ADAMS.

THOMAS WILLIAM ADAMS, 1841-1919.

THOMAS WILLIAM ADAMS was born in 1841 at Gravely, Cambridgeshire, England. He was educated first at a private school in Cambridge, and later at the British and Foreign Normal School, London. In 1862 he arrived at Lyttelton, and soon after took up land at Greendale, on the Canterbury Plain, where he successfully followed farming for many years.

The necessity for providing shelter for his stock against the frequent high winds showed Mr. Adams, as it did many of the pioneers, that the planting of shelter-belts was essential. A little later tree-planting was encouraged by the Government of the day by means of land grants in proportion to the area planted. As time went on he was not content to plant only the usual trees, but, stimulated by the true spirit of research, he sought to find out what other trees were suited to the conditions supplied by his neighbourhood—an area typical of much of the Canterbury Plain. So it came about that before many years had passed by he had growing upon his property pretty well all the exotic trees which at that time had been introduced into New Zealand. This made it necessary for him to go farther afield for his material, and he got into touch with some of the most celebrated arboriculturists of the day, and also botanical collectors in little-known regions, so that seeds of many species of trees and shrubs came yearly into his hands.

As the years passed by, thanks to his love for the self-imposed task and to his superabundant energy, his Greendale estate not only possessed fine mixed plantations, but easily the largest collection of living specimens of exotic trees and shrubs in New Zealand, representing not unworthily the hardy tree and shrub flora of the world. In conjunction with this practical work Mr. Adams became a close student of the literature relating to that class of plants which interested him so greatly, so that no one in the Dominion possessed such a wide knowledge of the subject. Nor did he neglect the broader aspects of his pursuit. Here his researches with regard to the Monterey pine (*Pinus radiata*) as a timber-tree can without hesitation be declared the most important advance which forestry has made in New Zealand up to the present time, and one which will eventually add great wealth to the country. That a tree universally despised as economically worthless (unless for inferior firewood) should, through Mr. Adams's experiments and unceasing advocacy of its value, come to be recognized by all New Zealand foresters as a most important timber-tree speaks volumes as to his acumen and careful investigations. Indeed, Mr. Adams through his teaching regarding the value of the Monterey pine materially modified the forestry policy of the Dominion. Here was a tree, hardly used in the early forestry operations, whose rapidity of growth combined with the many uses of its timber made its planting on the largest scale a highly payable proposition easy of demonstration.

In 1897 Mr. Adams joined the Canterbury branch of the New Zealand Institute. Though living too far from Christchurch to take an active part in the management of the Philosophical Institute of Canterbury, he attended the meetings whenever possible, read papers at times, delivered addresses, and showed interesting exhibits from his arboretum. Several of his papers appear in our *Transactions*, one in the *Report of the Australasian Association* for 1904, and a number in the *Journal of the Canterbury Agricultural and Pastoral Association*. These papers form a record of most important work, and give valuable details regarding the growth and behaviour of many species of economic trees. Apart from their economic value they have also a considerable phytogeographical bearing.

On account of his valuable work in arboriculture Mr. Adams some years ago was elected an honorary member of the Royal British Arboricultural Society, and last year he was made a life member of the New Zealand Forestry League.

As a public man Mr. Adams took great interest in education. He was for twenty-six years a member of the North Canterbury Education Board, and for twenty years a member of the Board of Governors of Canterbury College. To this institution he left by will 100 acres of land at Greendale on which are many of his plantations, and his entire general collection of trees and shrubs. To this bequest was added the sum of £2,000, the money and the land with its collections to form the nucleus of a forestry school in connection with Canterbury College. In 1913 he was one of the members of the Royal Commission on Forestry, and was of the greatest service to the Commission both from his knowledge and clear judgment.

Mr. Adams, who had been far from well for some time, passed away on the 1st June, 1919. His end was not altogether unexpected by his friends, notwithstanding he had attended the Science Congress in February, and gone to Dyer's Pass on one of the excursions. His lamented death has left a gap in New Zealand science which will not readily be filled. No man was more respected: few of our members have rendered more disinterested service to their country.

L. Cockayne.

CONTENTS.

ANTHROPOLOGY.

BOTANY.

GEOLOGY.

ZOOLOGY.

MISCELLANEOUS.

PROCEEDINGS.

APPENDIX.

LIST OF PLATES.

TRANSACTIONS.

Art. I.—*On the Toxicity of Tutu Fruit and Seed.**

By Professor John Malcolm, M.D., Physiology Department, University of Otago.

[*Read before the Otago Institute, 10th September, 1918; received by Editors, 13th September, 1918; issued separately, 14th May, 1919.*]

Attention has frequently been drawn to the remarkable fact, discovered by the Maoris, that the juice of the ripe tutu-berry is harmless, while the seed is intensely toxic.

It says much for the intelligence and powers of observation of that race that such a discovery should have been made. Perhaps the possession of subjects of experiment in the form of prisoners of war played a part in establishing the fact. As the writer had already reported some experiments on the toxicity of shoots and leaves of *Coriaria ruscifolia* and *C. angustissima*, the opportunity was taken last summer of collecting some of the fruit in order to test the degree of toxicity of the seed of *C. ruscifolia*, and at the same time to examine the juice. The material was obtained by stripping the so-called "berries" off the stalks of the racemes (sample I), and in another case (sample II) by simply shaking twigs laden with fruit inside the calico collecting-bag. In the latter case only the fully ripe berries dropped off.

The juice was expressed by simple pressure on the bag, and the seed was obtained from the remainder by washing and kneading the bag till the strainings were almost colourless. By suspension in water it was then comparatively easy to separate the seed from other debris, for the latter remained suspended for a longer time than the seed. A considerable proportion of the seeds rose at once to the top and floated there, but the bulk of them sank rapidly to the bottom. The seed was dried in the air, and thus preserved for future use.

The Juice.

A known quantity of the juice as first expressed from the bag was evaporated down on a slow fire. The reaction remained acid during the

* The expenses incurred in this research were defrayed out of a Government grant made through the New Zealand Institute.

evaporation. It did not seem to form a jelly at any stage in the evaporation, and merely thickened to a stiff syrup. In this state it did not grow moulds, although weaker concentrations readily did so and also readily underwent fermentation with brewers' yeast.

After standing some weeks the syrup became crystalline, but the crystals were mingled with so much precipitated material and pigment, and recrystallization was so slow, that it was difficult to obtain a quantity of the purified crystalline substance. The small quantity that was obtained evidently consisted of glucose, as shown by its physical appearance and its osazone crystals. That laevulose was also present in the crude syrup was, however, clearly shown by the following observation: The syrup was extracted with hot alcohol, clarified with charcoal, and examined in the polarimeter in watery solution; the result was laevo-rotation; and the solution gave very distinctly Seliwanoff's test for laevulose. That this solution contained a mixture of dextro- and laevo-rotatory sugars was proved by the fact that in a clear solution containing 15·5 per cent. reducing-sugar as estimated by Allihn's method the rotation corresponded to only 2·3 per cent. laevulose.

The syrup was also tested for galactose by the mucic-acid test, but with negative results, so that no evidence was found of the presence of raffinose.

The ash of the juice was found to contain a considerable amount of iron salts.

Two experiments were made in order to test whether the concentrated juice contained any of the poisonous properties of the other parts of the plant. In one a known amount of the crude syrup was diluted and administered by stomach-tube to a rabbit. No symptoms followed. The dose corresponded to about 54 grammes of the juice as expressed from the ripe fruit. It would correspond to about 2 lb. to a human adult.

In the other an attempt was made to extract any tutin that might be present. The quantity used would correspond to about 1 kilogram (2·2 lb.) of the original juice. It was covered with acetone in a stoppered bottle, and left for three weeks, with frequent stirring and shaking. The extract so obtained was heated to drive off the acetone, dissolved in water, and administered to a rabbit. No symptoms resulted which could be ascribed to tutin. The animal became practically anaesthetized and unconscious, but recovered fully in a few hours. The symptoms were probably due to some acetone or acetone compounds which had not been completely removed by the heating.

From these experiments it seems extremely unlikely that the juice contains any tutin.

Toxicity of the Seed.

After trying the hypodermic injection of solutions obtained by various methods of extracting the tutin, the conclusion was arrived at that oral administration of the seed would be the best in this case, as it resembled more closely the natural way in which poisoning might occur. Accordingly, since rabbits could not be induced to swallow the amount of seed required, a watery extract containing suspended matter was made by grinding the dose of seed in a coffee-mill, adding successive small quantities of water, and straining the extracts through cheesecloth. In this way the pulverizable part of the seed was separated from the husk, and a muddy-looking suspension was obtained which could be administered to the rabbit by stomach-tube. The residue left on the straining-cloth was considerable; in several cases where it was collected and dried it amounted to 50 to 60 per cent. of the whole dose of crushed seed. In order to test whether such residues contained any appreciable amount of tutin, a fairly large amount was dried, extracted with ether, and the ether-soluble material administered to a rabbit in watery suspension by stomach-tube. It produced no symptoms whatever in a dose equal to 7·5 grm. of "husk" per kilogram body weight, so that the bulk of the tutin may be supposed to have been present in the watery suspension. When the seed was administered in this way the results shown in the table were obtained.

TOXICITY OF SEED.

No.	Material used.	Dose per Kilogram, in Grammes.	Result.	Estimated Percentage of Tutin in Seed.
256c	Sample I	3·7	Death in three hours	0·16
267	Sample II	3·7	Slight, if any, symptoms ..	..
270	"	4·0	Distinct minor symptoms ..	0·14
*295	"	4·3	Death in about three hours ..	0·16
272	"	4·5	Symptoms more marked than in exp. 270	0·12
274	"	5·0	Severe symptoms, but recovered	0·11
282	"	6·5	Death in three hours	0·10
296	Green seed	6·0	Death in one hour and a half ..	0·125

* This animal had been used for exp. 274, and had then had its thyroid gland removed, about four weeks before being used for exp. 295

The percentages of tutin in these experiments have been calculated from the results of previous work by Fitchett and other experiments by the writer. The standards adopted for rabbits were that a dose of 5 milligrams per kilogram produces no marked symptoms; 6 milligrams produces symptoms in one hour and a half, and is ultimately fatal; 7·5 milligrams produces symptoms in about half an hour, and death between one and two hours.

Sample I of the seed was used in only one experiment, and in that case was more toxic than sample II. It occurred to me that this might be due to a difference in the toxicity of green seed as compared to ripe, for, owing to the method of collecting it, sample II contained more ripe seed than sample I. Fortunately, although it was late in the year (May), I was able to procure locally sufficient green berries to put the matter to a test.

At first it seemed impossible without serious loss of time to mechanically separate the small unripe seeds from the green fleshy petals, and after separating enough to find the percentage of seed present (18·2) the whole unripe fruit was administered in the form of a watery suspension. This gave the following results: 27 grm. fruit per kilogram caused death in forty-five minutes; 14·4 grm. in ninety-five minutes; 10 grm. in two hours and a half. As 10 grm. fruit contained only 1·8 grm. seed, it followed that either the unripe seed contained a very large amount of tutin, or that, at this stage, it was also present in the fleshy petals. To decide this point it was necessary to obtain a clean sample of unripe seed, and after several attempts the following method was found to be successful: Berries were dried in air at a moderate temperature and rubbed between the fingers; by this means the seeds were isolated from the remainder. The material was then put, in small quantities at a time, into a mixture of naphtha and chloroform of such a specific gravity that the seeds floated while all the debris sank, and by skimming off and drying the seed a fine clean sample was obtained. When administered to a rabbit this gave the result shown in the table, exp. 296—viz., the percentage of tutin was no greater than the average. It follows, therefore, that at an early stage in the formation of the berry the fleshy petals contain as much tutin as other green parts of the plant—in fact, the percentage works out to the same (0·06) as was found in the green shoots of *Coriaria ruscifolia.*

It would be interesting to be able to follow the fate of the tutin in the petals. Is it transformed *in situ* into a constituent of the innocuous juice, or is it transported to other parts of the plant? If the former takes place, one is tempted to believe a ferment might be found capable of affecting the transformation, and such a ferment would be of value in destroying tutin while still in the paunch of stock poisoned by tutu. So far I have not been able to get any evidence of the presence of such a ferment.

Effects of Administration of the Oils.

Practically all parts of the tutu-plant, but especially the seeds, contain a considerable amount of a green-coloured oil—"oil of tutu"—which was believed by the earlier workers (Skey, Christie) to be or to contain the poisonous principle. That the latter supposition was the correct one was proved by Easterfield and Aston, who showed that tutin, quite apart from the oil, was sufficiently active and abundant to account for most, if not all, of the symptoms of tutu poisoning. The question still remained, however, whether the oil or oils had any action which if not toxic itself might influence the toxicity of the tutin. To throw some light on this I used the oil as obtained by extraction with mineral naphtha, which had proved itself a good solvent for oil, while it was unlikely to dissolve tutin, as this substance had been shown by Easterfield and Aston to be insoluble in benzene. Chloroform extracts were also investigated, because it was noticed that, after naphtha extraction had been carried on till the extracts were colourless, chloroform was still able to extract some green-coloured oil, probably another fraction of the mixture of oils present. The following experiments were done:—

(*a.*) 50 grm. seed (sample II) was extracted first with mineral naphtha till the extracts were colourless, then with chloroform. The chloroform-soluble part was mixed with a little alcohol and added to water, the result being a fine precipitate or suspension of the oil. This was administered to a rabbit by stomach-tube. The animal became unconscious, and remained so for about three hours. Next day it appeared to be quite well. The symptoms were probably due to the dose of alcohol, which unfortunately was not measured. No distinct tutin effects were observed.

(*b.*) A quantity of the oil extracted with naphtha was freed from all but traces of the solvent by heating it on a water bath; some olive-oil was added, and a small amount of egg-white and 1 per cent. sodium carbonate. The mixture was then emulsified by shaking, and administered by stomach-tube. No symptoms developed beyond some somnolescence. The amount of green oil given would amount to about 10 grm. = 8 grm. per kilogram for the rabbit used.

(*c.*) 50 grm. seed (sample II) was extracted with alcohol, and the residue extracted with chloroform. A considerable amount of green oil resulted. This was boiled with about a litre of water, filtered, and evaporated down on a water bath. More "oil" continued to separate as evaporation proceeded, and was removed by filtration. The final result was 10 c.c. of watery extract of the "oils." Of this 5 c.c. was administered by hypodermic injection to a medium-sized rabbit. No symptoms followed.

(*d.*) 20 grm. seed (sample I), previously extracted with naphtha, was extracted with chloroform, which removed a further quantity of green oil. After driving off the chloroform the oily residue was extracted with 100 c.c. water, filtered, and concentrated to 10 c.c. Of this 5 c.c. given hypodermically produced no symptoms.

The conclusion to be drawn from these experiments is that the oil, or oils, has no toxic action. It is probable that the chloroform extracts contained some tutin, for tutin is soluble therein to a small extent, but the amount was either originally too small to produce symptoms or it underwent destruction in making the hot-water extracts.

METHODS OF EXTRACTING TUTIN.

Although at present there seems little likelihood that the pure substance, tutin, will ever be of any therapeutic or other commercial value, it may be of use to workers on the subject to add a note on the methods of extracting it. The best source of tutin is the seed—ripe or unripe. Drying in the air probably does not lead to any loss, but crushing and grinding, especially when combined with watery extraction and evaporation, lead to considerable loss. So far as my present experience goes, the best method is to extract the oils from the dried and recently crushed seed with mineral naphtha, and then extract the residue with ether. The ether-soluble material can then be again extracted with naphtha to remove more of the oils, and the result is an extremely toxic material, which can be further purified as described by Easterfield and Aston.

SUMMARY AND CONCLUSIONS.

1. No evidence was obtained of any toxic substance in the juice of the ripe tutu-fruit.

2. The green petals of the unripe fruit contain as much tutin as other green parts of the plant.

3. Both ripe and unripe seeds contain between 0·1 per cent. and 0·6 per cent. of tutin, being about double what is found in young shoots in the natural state. (When the water percentage is taken into account there is not much difference.)

4. The constituents of the seeds soluble in naphtha and chloroform (oils and resins) were not found to possess any toxic action.

5. The sugars present in the juice of the berry appear to be a mixture of dextrose and laevulose.

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Art. II. *The Significant Features of Reef-bordered Coasts.*

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In recognition of the honour conferred by the New Zealand Institute in adding me to its list of honorary members, and in return for the kind reception given me at its meetings during my Pacific journey in 1914, I desire to offer the following notes for publication in its *Transactions*, in the hope that they may aid students of coral reefs in observing certain features of significance in connection with the origin of those extraordinary structures. References are appended to a number of my articles, the product of observation, reading, and reflection during five years past, where certain aspects of the coral-reef problem are treated more fully than they can be here.

Sea-level Coral Reefs are silent as to their Origin.—The corals and other organisms of a sea-level reef are truly of marvellous interest, and from a zoological point of view merit all the attention they have received; but when a reef is examined from a geological point of view its organisms are found to be reluctant, not to say incompetent, witnesses as to the manner of its formation. An observer may sail along the front of a reef, wander over its surface, or row about in its lagoon, and discover many facts regarding the varied forms of life there visible, and regarding the processes, organic and inorganic, now in operation; but, apart from such factors as the temperature and the depth of sea-water at which reef-building corals grow, he can learn little, if anything, about the past conditions under which the reef has been developed, so long as his study is directed to the reef alone.

On atoll reefs there are, indeed, no facts visible at the surface by which the various theories of the origin of coral reefs can be tested: it is only from borings in sea-level atolls or from natural sections of elevated atolls that competent testimony as to their origin can be gained. In this connection it may be noted that the interpretation of the Funafuti boring recently published by Professor E. W. Skeats, of Melbourne (1918),* gives a much better statement of its evidence as to the origin of that atoll than is to be found in the original report published by the Royal Society, which was almost silent as to the meaning of the facts that it set forth so minutely.

Fringing and barrier reefs are, on the other hand, associated with the coasts of land-masses, which may yield much information as to the past conditions and processes of reef-formation, if the geological structure and the physiographic development of the coastal slope are examined. For these reasons it is to the coasts of the land-masses which fringing or barrier reefs adjoin that attention is here chiefly directed.

Coasts of Emergence and of Submergence.

The general features of coasts on which coral reefs occur—either fringing reefs alone, or fringing reefs in the lagoons enclosed by barrier reefs—give helpful indications of the relative changes of level that the coasts have

* For references see p. 30.

suffered. Some coasts have a smooth seaward slope, and consist of imperfectly consolidated marine strata, dipping gently seaward, which have been little eroded since their emergence from the sea in which they were deposited: these are typical coasts of emergence. Other coasts, whatever their structure may be, exhibit forms of subaerial erosion, such as hills and valleys, the slopes of which appear to continue below sea-level, as if they had been partly submerged since they were eroded: these are coasts of submergence.

Coasts of Emergence.—Along coasts of emergence of the kind above specified the shore-line will generally be almost rectilinear or of simple curvature. The amount of emergence may be inferred from the altitude to which the marine strata rise along their inland border. It may be at once stated that coasts of this kind are seldom fronted by coral reefs, apparently because the loose sediments of their beaches and submarine slopes do not afford a suitable foundation for coral-growth: witness the Madras coast of India, the south coast of Java, and the west and south coasts of Borneo, all of which bear marks of sub-recent emergence. Another class of coasts of emergence, on which coral reefs abound, will be given special description below.

Young Volcanic Islands.—The coasts of young volcanic islands may be associated with coasts of emergence, especially if composed largely of ash and not of solid lava. They are frequently cliffed and beached, without reefs. Barren Island, east of the Andamans, in the Bay of Bengal, is somewhat cliffed, and but little fringed with corals. Réunion, in the western Indian Ocean, has reached a rather mature stage of erosion and abrasion, with a very imperfect development of fringing reefs, as will be further explained below. It therefore resembles certain strongly cliffed volcanic islands in temperate latitudes. Let it be noted that the cliffs of such islands are usually cut back by the waves at a faster rate than the valleys are cut down by their streams, so that the valleys are left hanging above sea-level, and their streams cascade down the cliffs to the beach.

Coasts of Submergence.—On coasts of submergence the shore-line will necessarily be irregular, advancing seaward around the outstanding points of partly submerged spurs and entering landward around the branching embayments of partly submerged valleys. Conversely, shore-lines of this kind indicate that the coasts which they border have been submerged, as Dana pointed out in 1849. Singularly enough, Darwin never perceived the value of this evidence in support of his theory (Davis, 1913).

The spur-ends of coasts of submergence in the coral seas usually offer excellent opportunity for the growth of fringing reefs, for their firm rocks are soon swept bare by the waves, and they are free from the detritus that accumulates in the bay-heads. If the submergence be slowly continued, a fringing reef, A (fig. 1), may be transformed into a barrier reef, B, by upward growth as the sea-level changes from S to T; but if the submergence be renewed at a more rapid rate, changing the sea-level from T to U, the barrier reef will be drowned, and, if a pause then occurs, a fringing reef of a new generation, G, will be formed, as will be more fully stated below.

Unconformable Reef Contacts.—In all cases of reefs bordering coasts of submergence the original fringing reef which forms the base of an upgrowing barrier reef, as well as the lagoon deposits within the barrier reef and the secondary fringing reefs that grow on the spur-ends of the lagoon shore, and also all fringing reefs of new generations, must rest unconformably on an uneven foundation of subaerial erosion. This point has been too generally overlooked, although it is of the highest theoretical importance. Its converse is of practical value: reefs that rest unconformably on surfaces of subaerial erosion must have been initiated by submergence. Hence the nature of the contact of a reef and its foundation should be carefully observed, whether the reef be at sea-level or elevated above it.

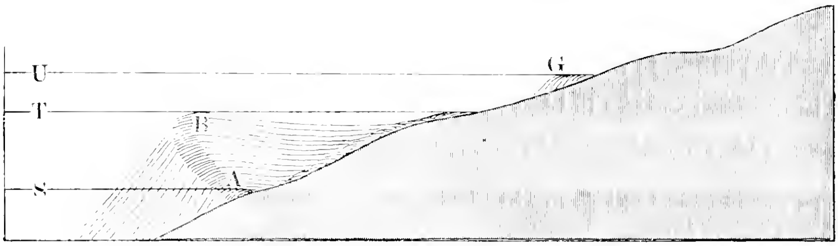

Fig. 1.

Amount of Submergence.—The amount of submergence that an embayed coast has suffered is not well indicated by the depth of its embayments, for they may be much filled with sediments: the amount is better inferred by drawing a true-scale cross profile, as at P, fig. 2, of the spurs that enclose a bay-mouth, and continuing their slopes with decreasing declivity below sea-level until they meet. The visible cross-section of the valley above the

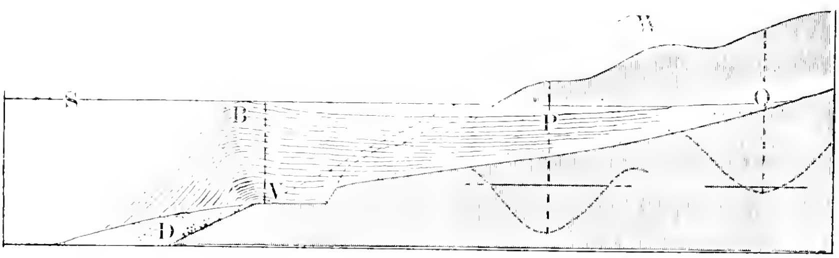

Fig. 2.

bay-head at Q should be taken as indicating the pattern of the submerged cross-section at the bay-mouth, P. The measure of submergence thus gained is only a minimum value, for, as shown in fig. 2, the depth of the submerged valley near the bay-mouth may be only about half the depth of the original valley-mouth, V.

Pre-submergence Period.—The duration of the pre-submergence period of subaerial erosion should be estimated as short, long, or very long, by comparing the actual form of the visible land-surface with its inferred initial form, due allowance being made for rock-resistance. In the case of dissected and embayed volcanic islands this comparison may often be made without much difficulty. On the coasts of continents and of continental islands the comparison may not be so easily instituted, but an attentive examination of the form of the coastal slopes will usually suffice to determine whether the cycle of erosion was in an early, middle, or late stage of its progress when it was interrupted by submergence.

Thus the submergence of the Queensland coast, in association with which the Great Barrier Reef of Australia and the discontinuous fringing reef in the broad lagoon were formed, did not occur until the rather resistant rocks which there prevail had been reduced to subdued forms of late maturity or even to the low relief of old age. The same may be said of much of the south-western coast of New Caledonia, except that the rocks there present near the shore are for the most part weaker than those of Queensland. In both these examples the pre-submergence period of subaerial erosion must have been of long duration.

In view of these various considerations it is evident that careful observation should be made of reef-bordered coasts from a physiographic as well as from a geological point of view, in order to determine whether the reefs have been formed in association with the submergence or the emergence of their foundation. It is also important that reef-free coasts in the coral seas should be similarly observed, in order to discover the conditions that do not favour reef-formation.

Rate of Submergence.—The ordinary statement of Darwin's theory of coral reefs implies that the rate at which reef-foundations have been submerged as a result of their own subsidence must not be greater, but may be less, than the rate of reef-upgrowth: and this has been held to be an improbable condition. Darwin's own statement of the problem made no such limitation as to the rate of subsidence, except where barrier reefs and atolls are actually found. For those reefs he stated that relatively rapid subsidences of small amount alternating with long stationary pauses probably represent the ordinary succession of events, and he believed that the average rate of submergence thus determined was not in such cases faster than the rate of reef-upgrowth.

This seems to hold true for the greater part of the open Pacific, where atolls and barrier reefs prevail, even though the submergence due to insular subsidence there has been accelerated by a sub-recent rise of ocean-level during the melting of the Pleistocene ice-sheets—a matter which has come into importance in recent years, as will be shown in more detail below. But exception to this statement is needed for an area to the north of the Fiji Group, where fifteen or more submarine banks, apparently submerged reefs or "drowned atolls," have been discovered since Darwin's time; and also for the region of the Tonga Islands, where extensive submarine banks occur. In both these regions of the mid-Pacific, and in a few others, submergence appears to have taken place at a faster rate than reef-upgrowth. They thus correspond to a large part of the Indian Ocean, where submarine banks, apparently "drowned atolls," prevail, as Darwin clearly understood.

Darwin on Fringing Reefs.—Furthermore, although Darwin regarded most fringing reefs as having been formed on stationary or on rising coasts, he clearly understood that rapid subsidence might drown earlier-formed reefs, whereupon the reefs that would grow on the new shore-line would be of the fringing class, as noted above. The statement of this point on page 124 of his *Coral Reefs* (1842) deserves attentive reading. True, inasmuch as Darwin did not understand that embayed shore-lines and unconformable reef contacts around spur-ends are sure signs of submergence, he discovered no examples of fringing reefs of this kind in the records that he studied, and all the fringing reefs on his chart are classed as occurring on stationary or rising coasts.

But his deductive expectation may now be confirmed, for the Australasian and other archipelagoes contain numerous examples of fringing reefs unconformably contouring around the spur-ends of embayed coasts—witness Palawan, the south-westernmost member of the Philippines, and many other embayed islands in that group—well represented in recent charts of the United States Coast and Geodetic Survey: also the Andaman Islands, in the Bay of Bengal: for in all these examples the coast is elaborately embayed; and hence their fringing reefs must be unconformable, and their submergence must have taken place at a faster rate than reef-upgrowth. Many other examples of the same kind might be cited.

Fringing Reefs and Submarine Platforms.—Fringing reefs thus assume a much greater interest than is generally allowed to them: their relations to the features of the coasts they border deserve close attention. The breadth of the reefs should be noted as a means of estimating the time that has elapsed since the last movement of submergence took place. The off-shore soundings of reef-fringed coasts of submergence are also of importance, for they frequently reveal a submarine platform that in all probability represents a drowned barrier reef and its lagoon.

Such submarine platforms, several miles in width, are found in association with Palawan and the Andamans, although the sea-level fringing reefs of these islands are narrow. A well-developed submarine platform surrounds the greatly denuded "volcanic wreck" of Fauro, a small island with narrow fringing reefs in the Solomon Group. A similar platform is shown by the latest surveys of the United States Hydrographic Office to surround the Samoan island of Tutuila; but the fact that the spur-ends of this island are rather strongly cliffed behind their fringing reefs distinguishes it from the other examples named. Submarine platforms occur around the Marquesas Islands also; but here, although the spur-ends are cliffed, as in Tutuila, they are not fronted by fringing reefs.

The depth of the submarine platforms off reef-fringed shores is not constant: along the west coast of Palawan the platform varies in depth from 25 or 30 fathoms near its southern end to 60 fathoms near its mid-length; the Fauro platform has depths of 70 or more fathoms; the Andaman platform is 30 or 40 fathoms in depth. On the other hand, part of the coast of Samar, in the Philippines, facing the open Pacific, has fringing reefs around its headlands, but its submarine slope descends rapidly to great depths. Now, let it be noted, first, that the three chief elements of the fringing-reef problem as here considered—duration of the pre-submergence period of subaerial erosion, rate and amount of submergence, and duration of post-submergence period of fringing-reef growth—have unlike values on different islands; secondly, that many other islands have well-developed barrier reefs which suggest slow submergence, and that some barrier reefs are broad and others are narrow, thus suggesting that the rate and date of their submergence are unlike: and, thirdly, that many elevated reefs occur at different altitudes and in different stages of erosion.

It thus becomes evident that the history of various reef-encircled islands must consist of unlike sequences of movements and pauses. Hence local movements of the reef-formations themselves, which may vary greatly, explain the varied facts much better than changes of ocean-level, which must everywhere be of the same rate, date, and amount. In order to learn how greatly the values of the various elements differ from place to place, their value for every coast should be determined independently. One of the most important of these elements is the duration of the post-emergence or post-submergence stationary period, the estimation of which may now be considered in some detail.

Time since Emergence.—The shore-line of an emerged and thenceforward stationary coastal plain may be locally built forward, or "prograded," by deltas if its rivers are of large volume and well charged with detritus from an elevated backland; and sand reefs enclosing shallow or marshy lagoons may be cast up by the waves between the deltas, and may advance seaward as the delta-fronts advance. Conditions of this sort appear to prevail along the Madras border of India, and around the south-west side of Borneo, thus proving that these coasts have been somewhat changed from their simpler initial form; but the littoral conditions are still manifestly unfavourable to coral-reef formation.

It is conceivable, however, that after a temporary supply of gravel and cobbles has been washed out by a flooded river to a certain part of the front of a delta that is for the most part composed of finer sediments the river may change its course, as rivers on deltas are prone to do. Then corals, attaching themselves to the larger cobbles, may spread sufficiently to form a small fringing reef, until a return of the river buries the corals. A buried reef of this kind will slant forward with the delta-front, and will lie conformably between the earlier and later foreset delta-beds. Such seems to have been the origin of a small elevated reef near Suva, Fiji: it lies on a local deposit of gravel, and both the gravel and the reef lie conformably in the slanting beds of volcanic mud, there known as "soapstone."

The extent of the littoral lowland that is prograded along the border of a coastal plain will give some idea of the time that has elapsed since the plain emerged. But such lowlands are not always developed; for, if large rivers are wanting, the shore-line of a coastal plain may be cut back or retrograded farther and farther by the sea, as long as no change of level takes place. The farther it is cut back, the higher will be the resulting bluffs along the coastal-plain margin. The height of the bluffs along the shore of a retrograded coastal plain will therefore give an indication of the time during which it has been attacked by the sea. A more important point is that, however far such a stationary coast may be retrograded, a beach of loose detritus, continued off shore by a sheet of finer sediments, will, according to accepted physiographic theory, always cloak the abraded platform along the base of the retreating bluffs. No reefs are therefore to be expected on such a coast.

The Reef-free Coast of Madras.—It is important that the coasts of the coral seas should be examined with these principles in mind in order to test their correctness. As far as I have read, there is no published account of a strongly retrograded coast in the torrid seas that is still suffering abrasion in its original stand with respect to sea-level. It is interesting to note, however, that the high, hard-rock cliffs which, as described by Cushing, rise a short distance inland on the coast of Madras appear to have been cut back by the sea before the emergence of the present Madras coastal plain; hence the cliffs must, before the sub-recent movement of emergence by which a negative shift of the shore-line was caused, have exemplified a maturely retrograded, reef-free coast; and at the beginning of their abrasion the hard-rock land-mass must in all probability have been covered, near its shore-line at least, with the sediments of an ancient coastal plain of emergence, just as the emerged platform of marine abrasion which fronts the high cliffs is covered by a modern coastal plain to-day; for otherwise it is difficult to understand why coral reefs should not have been formed there and have prevented the cutting of the high cliffs.

Cliffed Volcanic Islands.—It has been suggested above that the shore-lines of volcanic islands may be regarded as shore-lines of emergence, particularly if the island is largely composed of loosely compacted volcanic ash: for such a shore-line will be of comparatively simple outline, without pronounced salients or embayments, and the detritus washed down its slopes by its streams, added to that cut by the waves along the shore, will soon form a continuous beach, extending seaward in a sheet of loose sediments, on which reef-building corals cannot attach themselves (Davis, 1916B). Under such conditions the island will be continuously attacked by the waves, cliffs will be cut around its shore while valleys are eroded in its slopes, and if the island stand still long enough it will be completely truncated. Even then it may be difficult for corals to find a firm foundation for their growth until nearly all the loose detritus is swept off the surface of truncation.

According to Admiral Wharton, atolls were supposed to have been built up around the margin of truncated volcanic islands, no change of sea-level and no subsidence of the island being postulated. Darwin had previously considered this possibility and rejected it, because the resulting lagoons would be too shallow. According to Daly, atolls are supposed to have been built up on volcanic platforms that were abraded while the ocean was lowered and reef-building corals were killed, during the Glacial period. The best test of these suppositions involves a series of borings along the diameter of an atoll to a depth of 50 or more fathoms below present sea-level: the elevated atolls of the Loyalty Islands are to be recommended for such examination.

If it be true, as above suggested, that still-standing volcanic islands may, in the absence of protecting reefs, be cut away by the sea, a number of examples in different stages of abrasion should be found in the coral seas of to-day. Réunion is the best example of the kind, still in process of abrasion, that has come to my attention. Tahiti is an equally good example, but it has been somewhat submerged, and its shores are now defended by coral reefs, as will be more fully described below. Tutuila, in Samoa, and the Marquesas Islands probably, as noted above, belong to this series, but their place cannot be safely determined at present. Most volcanic islands in the coral seas are surrounded by barrier reefs, and their shore-lines are not cliffed. It is very desirable that all islands of the coral seas should be examined with the points here set forth in mind. The brief accounts now available of many such islands do not suffice to determine what stage of erosional and abrasional evolution they have reached.

Time since Submergence.—The headlands of coasts of submergence in temperate latitudes, not being defended by coral reefs, are vigorously attacked by storm waves: thus a cliff is formed rising high above sea-level, and a platform lying a little below sea-level. Coasts of submergence in the coral seas are as a rule fronted by barrier reefs or bordered by fringing reefs; hence they do not generally show the strongly cliffed spur-ends that characterize similar coasts in temperate latitudes. True, the spur-ends of such coasts are often cut off in low bluffs, B (fig. 4), 10 ft. to 50 ft. in height, forward from which one may see low-tide rock platforms 30 ft. to 100 ft. in breadth before one reaches the fringing reef, F, that is ordinarily found in such situations.

The absence of talus at the base of such bluffs shows that they are still washed by storm waves, but the strength of attack is not great. Indeed, it is probable enough that the greater part of the abrasion that these low spur-end cliffs attest was accomplished by waves that rolled in, little impeded, from the open ocean, shortly after the last period of submergence and before the present barrier reef was built up to sea-level. This implies that the submergence was rapidly accomplished and was followed by a pause. The form of the abraded rock platform on many spur-ends supports that view: for its outer border is about in line with the sloping ridge-crest above the cut-off bluff, as it should be if all the abrasion had been accomplished since submergence took place. If some abrasion had been accomplished during the progress of slow submergence the outer border of the platform could not be so nearly in line with the ridge-crest. Detailed observation of spur-end bluffs and platforms is therefore desirable.

If the above suggestion as to the origin of the spur-end bluffs be correct, their height will not be so good an indication of the time since submergence as may be found in the breadth of the fringing and barrier reefs, or in the area of the bay-head deltas. If the reefs are narrow and the deltas are small (due consideration being given the drainage-area and slope of their streams) the latest submergence must be recent; if the reefs are broad and the deltas are large enough to fill the embayments the submergence must be less recent, though by no means of ancient date. Careful record of all these features should be made.

BARRIER REEFS.

The transformation of original discontinuous fringing reefs on the spur-ends of a slightly submerged coast into a nearly continuous barrier reef a mile or more outside of a more deeply submerged coast involves the tangential extension of the fringing reefs as they grow upward, so that they shall close most of the broad breaches that would otherwise mark the sites of the original embayments. The barrier reef on the eastern side of Tahiti is a good example of discontinuous growth still interrupted by wide passages; on the western side the reef is more continuous. It may be noted in this connection that barrier reefs in Fiji are, unlike those of Tahiti, more generally interrupted on their leeward than on their windward side: this may be due to the injury to coral-growth caused by the drift of fine sediment in the lagoon-waters.

The depth of a barrier-reef foundation, or the amount of submergence that has taken place since the barrier reef began its growth as a fringing reef, cannot be determined readily, because it is impossible to say whether the upgrowth of the reef has taken place vertically or on an inward or an outward slant. The rate of submergence appears to be the chief factor in determining the angle of upgrowth (Davis, 1916c). The vertical depth from a barrier reef to the underlying rock can be more safely estimated, because the submarine slope of the foundation mass can often be fairly well inferred.

It is not necessary here to proceed merely on the empirical principle, introduced by Dampier and followed by Darwin, to the effect that "a considerable degree of relation subsists between the inclination of that part of the land which is beneath the water and that above it," for it is now possible to infer the declivity of a submarine slope more reasonably by observation of the structure and form of the land-mass above sea-level. In the case of many volcanic islands it is not unreasonable to conclude that a barrier reef a mile from the island-shore has a vertical thickness of 1,000 ft. This conclusion evidently rejects the idea that a barrier reef is built upon a shallow platform of non-reef origin, which appears to me as improbable as that a volcanic island rests upon a shallow foundation of non-volcanic origin.

Mature Reef Plains.—Although coasts of recent submergence usually present favourable conditions for the growth of fringing or of barrier reefs, these conditions may not persist indefinitely on coasts that long remain stationary after a less recent submergence; for, if the land drained by the coastal rivers is of large-enough area, deltas, E (fig. 3), will in time not

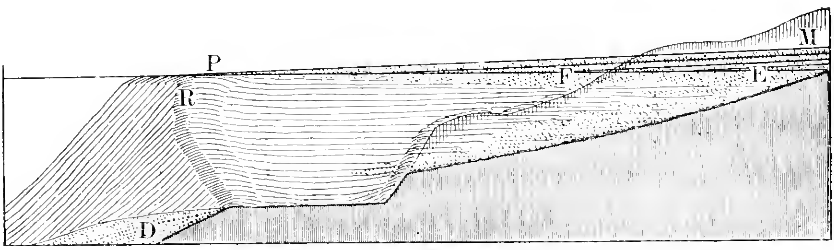

Fig. 3.

only fill the drowned-valley embayments of a still-standing island, but will unite around the spur-ends and form a confluent alluvial lagoon plain, F, with a shore-line of comparatively simple pattern. As the advance or the progradation of such a plain continues, the fringing reefs on the spur-ends will be smothered with detritus. Such appears to have been the fate of many fringing reefs on the island of Tahiti, where an alluvial plain extends along much of the island-border. As the plain is still farther prograded, and as overwash of debris from the outer face to the inner slope of the outgrowing reef continues, the lagoon will be filled and converted into a mature reef plain, MP.

If the outwash of alluvium still goes on, the barrier reef, R, in spite of the width it may have then attained by outward growth, will be smothered, and its corals will be killed. Thereupon the sea will attack the reef and cut it away; and if this process be once begun there appears to be no reason for it to stop. The alluvial reef plain must in time be consumed, and then the central island will be attacked and cliffed; for as long as the island stands still, and as long as outwashed alluvium supplies material for a beach, coral growth cannot be re-established (Davis, 1917a). This sequence of events is evidently hypothetical in a high degree; nevertheless, the successive stages of such a sequence, and of all other reasonable sequences, should be carefully conceived by an observer of coral reefs while he is still on his voyage of investigation, in order that he may be able to confront the successive stages of the various sequences with the reefs that he sees, and thus discover which sequence gives the best history of their origin.

The danger of being buried and smothered in alluvium appears to threaten the barrier reef along the south coast of Viti Levu, Fiji, where the delta of the Rewa River has almost filled the lagoon; and a long stretch of the barrier reef on the south side of New Guinea appears to be already smothered where the great delta of the Fly River has advanced far into the sea.

Most barrier reefs are, however, in no immediate danger of such a fate; their lagoons are far from being filled with alluvium; deltas, indeed, as a rule do not fill the embayments in which they head. Both the Rewa and the Fly are exceptional in being much larger than the rivers of most islands within barrier reefs. The prevalence of open lagoons shows that no such constant relation of land and sea level has been maintained as was provisionally postulated above, but that submergence has prevented lagoon-filling not only by providing new depths to be filled up, but also in the case of islands by diminishing the area and the altitude of the land from which part of the filling-material should come.

On the other hand, in view of the many possible changes of land and sea level, and of their many possible combinations with periods of rest, it is surprising that, among the many examples of reef-encircled islands, none are found with mature reef plains approaching or realizing the stage of smothering the corals on the reef-face. For if the development of barrier reefs depended only on the subsidence of their foundations, and if their foundations were of different ages and had subsided by different measures and at different dates, we should expect to see all stages of reef-development to-day—some close-set, discontinuous barriers; others broader and farther from their central island, the embayments of which should contain good-sized deltas; and so on through all the stages to a mature reef plain, the alluvium of which is just overlapping the reef; and then an old reef plain, much reduced from its original breadth by abrasion. But, with such exceptions as the Rewa and Fly deltas, no mature reef plains are known.

Combination of Island-subsidence with Changes of Ocean-level.—The absence of completed reef plains cannot be due to lack of detritus for their formation, for the amounts of detritus that have been discharged from many deeply denuded volcanic islands are vastly greater than the volumes of the lagoons enclosed by their barrier reefs. Hence the prevalence to-day of young barrier reefs with open lagoons must be taken as suggesting that some recent and widespread cause has produced a more general submergence than should be expected from island-subsidence alone; and this cause is perhaps to be found in the post-Glacial rise of ocean-level, for a rise of ocean-level combined with a prevalent but intermittent subsidence of reef-foundations would tend to maintain the barrier reefs of to-day in an early stage of their development and prevent the attainment of the more mature stage which they would reach during a long period of fixed levels of islands and ocean.

On the other hand, a fall of ocean-level, such as must have accompanied the oncoming of the last glacial epoch, would have tended to lessen or even to neutralize the submergence due to prevalent subsidence; hence during a glacial epoch lagoons may have been more generally filled than during an interglacial epoch or during the present post-Glacial epoch (Davis, 1915, p. 267; 1916A, p. 565). These somewhat transcendental aspects of the coral-reef problem are mentioned here in hopes that they may incite special observations, by means of which the possibilities here sketched may be assigned their proper values.

That the post-Glacial rise of ocean-level is not the entire or even the chief cause of the submergence under which barrier reefs as well as unconformable fringing reefs have been developed is proved by the great diversity in the succession and the value of the movements and pauses recorded by the physiographic features of the islands within the reefs, as has already been briefly noted in an earlier paragraph, and as will be set forth more fully in a later one.

Origin of Lagoons.

According to Darwin's theory of intermittent subsidence, the lagoon occupying the depression or "moat" between an island slope and an upgrowing barrier reef is more or less completely filled by the outwash of detritus from the central island, by the inwash of debris from the reef-face, and by the accumulation of locally formed organic material. Recent observations warrant the assignment of a large value to the last-named process, which is further important because it is just as effective in aggrading a large lagoon as a small lagoon. If subsidence cease for a long period, the lagoon may be converted into a reef plain, as suggested in a preceding section.

This view of the relation between barrier reefs and their lagoon is the very opposite of that implied in Murray's theory of outgrowing reefs on non-subsiding foundations, for it is there postulated that lagoons are formed by the solution of the outgrowing reef along its inner border. There can be no question that sea-water flows into lagoons in sufficient quantity to dissolve away a large volume of limestone; but, as far as observational evidence goes, the loss thus occasioned is far overbalanced by the supply of new detritus from the various sources above mentioned.

According to Murray's solution theory, the inner slope of a barrier reef should consist of ragged and decaying limestone, and the lagoon-floor should be covered with insoluble silts (Davis, 1914, p. 641); but as a matter of fact the inner slope of barrier reefs usually consists of white coral sand, washed in from the outer reef-face; and the lagoon-floor is covered with accumulating calcareous deposits, except that near the deltas of large streams inorganic deposits preponderate. Detailed observations should be made by dredging in lagoons in order to test the generality of the above statements. Atoll lagoons deserve as much attention as barrier-reef lagoons in this phase of the problem.

Attention may here be called to Vaughan's view that many barrier reefs are built upon platforms which were produced by other than coral-reef agencies. Inasmuch as the supposed platforms beneath sea-level reefs are not open to direct observation, their existence as structures independent of reef-forming agencies is for the present only an inference. Any observable facts that bear on this aspect of the problem should be carefully noted. Among such facts pointed out by Vaughan, three may be noted: the first is that the exterior profile of most reefs shows a change from a moderate slope to a steep pitch at a depth of about 40 fathoms; the second is that reefs ocasionally stand a short distance back from the outer margin of a 40-fathom bench; the third is that where reefs are breached, as frequently happens on their leeward side, the lagoon-floor or "platform" continues.

It may, however, be reasonably urged that none of these facts necessarily leads to the conclusion that the production of a platform by some agency independent of reef-formation preceded the formation of the present reefs. As to the change from a gentle slope to a steep pitch in the exterior profile, many observers, including Darwin, Murray, and Gardiner, are agreed that this is the result of wave-action on reef detritus at present sea-level: the exterior slope of a reef is, in effect, a small "reef shelf," corresponding to the great continental shelves in origin, though not in size. The continuity of the "platform" where a surface barrier reef is wanting, especially on the leeward side of its circuit, may be readily explained as resulting from the continued action of reef-building and lagoon-flooring processes, during subsidences of varying rates and pauses of varying duration, under the influence of prevailing winds. The location of a reef a short distance back of a platform-margin is perfectly consistent with the production of the platform as a mature reef plain, afterwards submerged, and by no means demands that the platform shall have been made by processes in which reef-growth had no part. The discussion of this point by observers on reef-encircled islands is much to be desired.

Partly Emerged Coasts of Submergence.

A peculiar class of coasts of emergence, mentioned above as needing special consideration, includes mountainous land-borders that have partly emerged shortly after a greater submergence at too rapid a rate for the upgrowth of barrier reefs. They are characterized by irregular shore-lines with many salients and re-entrants, on which a comparatively thin cover of marine deposits accumulated during their brief submergence hardly conceals the hill-and-valley topography that was produced during a previous and much longer pre-submergence erosional period. On such a shore-line the unconsolidated marine deposits are soon worn away from the headlands during pauses in the emergence, so that unconformable fringing reefs may be formed there. If emergence continue intermittently, the fringing reefs will appear as terraces on the emerged slopes.

Coasts of this kind appear to be of importance in the coral-reef problem, because they are found to be of frequent occurrence on the deep-water shores of the Australasian region, where unconformable fringing-reef terraces are reported on many inlands that have embayed shore-lines. It is nevertheless a mistake to conclude, without further question, that all such terracing reefs have been formed during pauses in emergence, although this conclusion has nearly always been adopted by their observers. Such a conclusion tacitly postulates that the previous submergence took place at so rapid a rate that no reefs were formed during its progress. Yet it is evidently equally conceivable that the reefs may have been formed during pauses in a slow submergence and revealed by a rapid emergence (Davis, 1916a, p. 499). Discrimination between the two conditions of origin may be made if the structure of the emerged reef is laid bare by erosion, as will be shown in a later section. In any case, coasts of this kind merit special attention as indicating a pronounced instability.

Partly Submerged Coasts of Emergence.

Just as the rule that coasts of emergence are unfavourable to reef-growth is departed from in the case of steep coasts that are partly emerged after a brief submergence, so the rule that coasts of submergence are favourable to reef-growth is departed from in the case of gently sloping coasts that are moderately submerged after a long emergence, during which the adjoining sea-bottom was shoaled by the accumulation of sediments; for on such coasts the waves will sweep in so much sediment from the shallow bottom that any corals which may for a time attempt to grow on the headlands will soon be smothered and killed. The scarcity of reefs on those islands of the Australasian archipelagoes that have embayed shore-lines fronted by shallow seas may perhaps be thus explained; but, as this aspect of the problem has been little considered by observers on the ground, the chief object of this paragraph is to stimulate local and critical observation rather than to announce an assured conclusion.

Cliffed Coasts, partly submerged.

Since the proposal of the glacial-control theory of coral reefs (Daly, 1910; 1915) it has become important to note whether the spur-ends of embayed coasts inside of fringing or barrier reefs are cut off in cliffs that descend steeply below sea-level. That theory assumes that mid-Pacific volcanic islands have long stood still, and that their embayments occupy valleys which were eroded while the ocean was lowered during the Glacial period. It assumes furthermore that the lowered ocean was chilled sufficiently to kill the corals and other organisms of coral reefs, so that the reefs would be cut away, probably at some such level as 40 fathoms below the present ocean-surface.

Now, if these assumptions are correct, it follows that an embayed island, like Murea in the Society Group, which is now surrounded by a barrier reef about half a mile from the shore, must, after its corals were killed and its reef was cut away by the waves of the lowered sea, have been strongly cut back in cliffs: for, if the sea were actively abrading the island during a period long enough for the excavation of the open valleys now occupied by arms of the sea, the spurs between the valleys must have been cliffed. Be it remembered here that, according to the testimony of volcanic islands in the temperate oceans, the retreat of cliffs under the attack of sea-waves is more rapid than the deepening of valleys by streams, and hence all the more rapid than the slow widening of valleys by the weathering of their side slopes. Rock-resistance need not be considered, for it will affect cliff-cutting and valley-widening in similar fashion.

It is evident, therefore, that close attention should be given to the forms of spur-ends where they disappear in the lagoons of barrier reefs, particularly where the barrier reefs are not far off shore. If the spurs are cut off

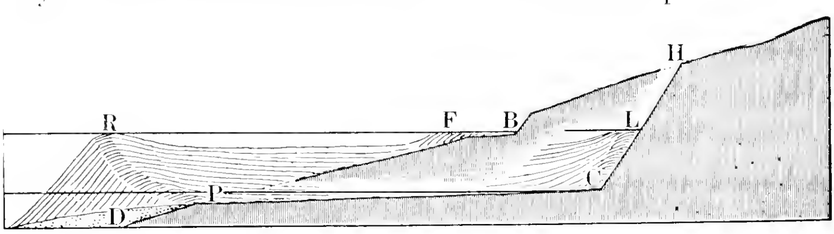

Fig. 4.

in bluffs, B (fig. 4), from 10 ft. to 50 ft. in height, in front of which rock platforms extend from 30 ft. to 100 ft. forward, such bluffs and platforms must be attributed to wave-action at present sea-level, as has been explained above.

If, on the other hand, high spur-end bluffs or cliffs, LH, are found but no rock platforms are visible in front of them, and if (except for a narrow fringing reef) the lagoon has depths of 10 or 20 fathoms near the cliffed spur-ends, then the cliffs should be attributed to wave-action producing a profile HCP when the sea was lower or the land was higher than now. As far as I can learn, low spur-end bluffs fronted by narrow rock platforms are of much more common occurrence than strong spur-end cliffs that plunge, except for their fringing reefs, into comparatively deep water. But fortunately certain islands possess strong spur-end cliffs fronting on deep lagoons: such islands deserve particular attention.

The Half-submerged Cliffs of Tahiti.—Tahiti, the largest island of the Society Group, is a volcanic doublet—that is, a larger and a smaller cone connected by an isthmus—now submaturely dissected by radial consequent valleys. In the central areas, where the valleys are close together and of great depth, the initial surface of the cones is lost; but it is well preserved in the peripheral areas, where the valleys are more widely separated and of moderate depth, as Dana long ago explained. The inter-valley spurs are, except at the north-western (or leeward) corner of the large cone, cut back in cliffs, which on the windward coasts rise 500 ft. to 1,000 ft. above present sea-level. Agassiz is, as far as I have read, the only observer of this beautiful island who has recognized the prevalence of cliffs around its shores.

Many of the smaller valleys are not cut down to present sea-level; their wet-weather streams fall in cascades from cliff-top notches. The larger valleys have been cut to a greater depth, for they descend below sea-level, and their mouths are occupied either by small arms of the sea or by delta-plains. The island is to-day bordered either by a fringing reef or by an alluvial plain, which is formed by the confluence of many delta-plains that have outgrown their valley-mouth embayments. Moreover, a somewhat discontinuous barrier reef now holds off the waves from most of the island circuit. Evidently, then, the cliffs have not been cut while the island has stood at its present level: they must have been cut when it stood relatively higher—that is, when the valleys were in process of deep erosion beneath present sea-level. Evidently, also, no reefs could have been present when the cliffs were cut.

The question then arises whether Tahiti stood still and had its cliffs cut while the ocean was lowered and chilled during the Glacial period, or whether Tahiti, besides experiencing changes of ocean-level in the Glacial period, itself subsided after cliffs had been cut around it, the cliffs having been formerly cut around Tahiti for the same reason that cliffs are now cut around Réunion—namely, because reef-forming corals cannot establish their colonies on the cobbles and gravels of the beaches that are ordinarily developed around the shore of a young volcanic island.

The latter alternative appears the more probable one of the two, for two reasons. First, the amount of the submergence by which the Tahitian valleys have been submerged appears to be 500 ft. or 600 ft. at least, and this is much more than the amount of lowering that the ocean is believed to have suffered during the Glacial period. Secondly, if the cliffs of Tahiti were cut around a still-standing island by the waves of the lowered and chilled ocean during the Glacial period, then the neighbouring island of Murea, as well as the other more distant members of the Society Group, should also be cut back in cliffs; but, apart from a few very exceptional cliffed spur-ends, that is not the case. The reefs of Tahiti should therefore be regarded not as having found their opportunity for upgrowth when the warming waters of the post-Glacial ocean were rising to their present level, but as having found their opportunity when submergence, caused in part at least by subsidence, embayed the island valleys so that the stream-washed detritus was pocketed in the embayments. In the absence of detritus the waves washed the cliffs and the rock platform in front of them bare, and this gave the corals a firm foundation on which to attach themselves.

If this interpretation be correct, the cliffs and reefs of Tahiti are not only beyond explanation by the glacial-control theory, but the island is a strong witness against the theory. It testifies that a reef-free island may be strongly cliffed in a time that suffices only for the erosion of steep-sided valleys: hence other islands, like Murea, Raiatea, and Huaheine, in the Society Group, in which the submerged valleys are much less steep-sided than those of Tahiti, ought to have been more strongly cliffed than Tahiti if they were reef-free while their now-submerged valleys were in process of erosion. The fact that they are not cliffed shows that they must have been protected by living reefs, and thus discredits the assumption that reef-corals were killed during the Glacial period. The possible less resistance of the lavas on Murea and the other islands than on Tahiti does not affect the argument, for if the Murean valleys are wider than the Tahitian valleys because the rocks of Murea are weaker than those of Tahiti, then for the same reason the spurs of Murea ought to be cut back in cliffs of greater height than those of Tahiti.

The reason for giving a special account of Tahiti is that, among the many reef-encircled volcanic islands of the Pacific, it is unique in being cut nearly all around its circuit by strong cliffs the bases of which are now below sea-level. Similarly, as noted above, Réunion is unique among islands in the coral seas in being cut all around by cliffs the bases of which are at the sea-level of to-day and are now undergoing attack by the sea in the absence of protecting reefs. Two intermediate stages are represented by the Marquesas and Tutuila (Samoa), which have submerged cliffs but are not surrounded by barrier reefs. Of these two stages, Tutuila is the later, because it has well-developed fringing reefs, while the Marquesas are reef-free. Search for other islands of the Réunion, Tahiti, and intermediate types is evidently desirable, for it is manifestly unsafe to generalize on a few examples. Yet, inasmuch as these few examples confirm each other, one is tempted to ask whether they do not show the typical stages of early development through which many deeply-dissected, reef-encircled volcanic islands have long ago passed—that is, whether many deeply-dissected, reef-encircled volcanic islands would not show reef-buried cliffs and platforms on their submarine slopes if they could be examined.

In a group of phenomena which offer few examples of early stages and many examples of later stages of development it certainly seems reasonable to regard the examples of later stages as having passed through the stages represented by the early examples, particularly when the early examples present the very features which a deliberate analysis of the problem leads one to regard as essential preliminaries to the features of the more advanced examples. This interpretation appeals strongly to me, because, instead of empirically entering the problem of reef-encircled islands at a middle stage of progress, the attempt is made to trace out all the stages of the problem from beginning to end.

On the other hand, many students of coral reefs may regard it as fanciful, not to say fantastic, to say that the cliffs which are still in process of abrasion on Réunion, and which are partly submerged and fairly well protected from wave-attack on Tahiti, are probably the counterparts of similar cliffs now completely submerged on the reef-buried lower slopes of many other volcanic islands. But another aspect of the problem deserves consideration before a decision on this question should be declared.

THE VANISHED DETRITUS OF DEEPLY DENUDED ISLANDS.

Many volcanic islands, now deeply denuded in irregular forms, give clear indication of their initial conical form in the outward slant of their marginal lava-beds. It is in such cases a comparatively simple matter to reconstruct their original cone, VW (fig. 5), and to estimate the volume of detritus that has been removed in reducing the island to its present maturely denuded form, RM. Even if no submergence be assumed, the volume of detritus that has been carried away from so much of the initial volcanic mass as is now above sea-level is, as noted above, vastly greater than the volume of the lagoon waters, G, on all the reef-encircled islands that I have seen. How has this great volume of detritus been disposed of?

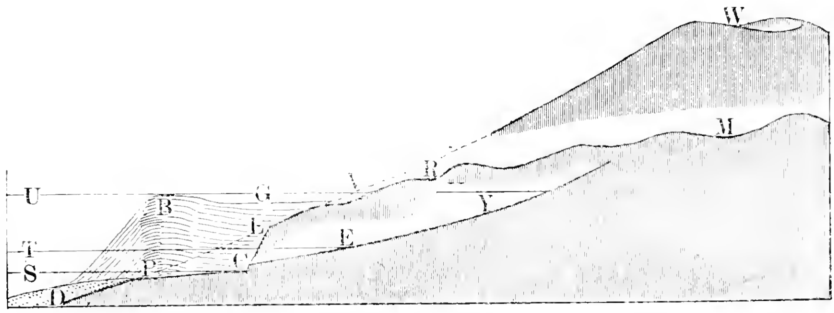

FIG. 5.

Let the island be supposed to have been formerly more emerged than now, and let it stand still with respect to sea-level, SC, during a period of deep dissection. Under these conditions the detritus washed out from its valleys would soon completely overwhelm any fringing reef that might by chance be established on its shores, and the waves would then cut cliffs, CL, all around its circuit, as is now the case on Réunion. This consideration alone is sufficient to discredit Murray's theory of outgrowing reefs on still-standing islands. Moreover, if the island stand still, cliff-cutting will continue and no opportunity for barrier-reef formation will be allowed. Under what conditions, then, is the formation of barrier reefs permitted?

An apparent escape from the difficulty of accounting for the vanished detritus around a still-standing island is found in changes of ocean-level during the Glacial period; for the detritus discharged while the ocean stood at a lower level than now would be deposited on the lower slopes of the island, and when the ocean rose again a barrier reef might grow up with it. But during the discharge of the detritus reefs could not flourish, and waves would then cut the island-shores back in cliffs; and if cliff-cutting endured through the time required to excavate the valleys now drowned in embayments the cliffs would surely be high enough to be still visible after the ocean has resumed its normal level. Hence the amount of submergence thus provided is insufficient for the needs of the problem. Moreover, all volcanic islands the eruptional growth of which was completed earlier than the beginning of the Glacial period should have had cliffs cut around their margin in pre-Glacial time, and some trace of these cliffs should now be found. Another supposition must therefore be made, as follows:—

If an island, VW (fig. 6), with sea-level originally at NV, does not stand still, it must subside to a great depth, NS, if no cliffs are to be cut around its margin and if the larger part of its discharged detritus is to be deposited in the lagoon, G, of an upgrowing barrier reef, B; but in this case the early stages of subsidence must be so rapid, in order to provide sufficient lagoon-space for the deposition of detritus, that the upgrowth of a reef could hardly keep pace with it. It is not likely that the numerous barrier reefs of to-day have all survived so threatening a danger: hence a slower rate of early subsidence must be postulated.

Let the island, therefore, stand almost or quite still during a considerable period after its eruptive growth ceases. In this case the detritus supplied by the erosion of deep valleys, CY (fig. 5), and by the abrasion of high cliffs, CL, will be swept off shore in large amount, D, by vigorous waves, unimpeded by a barrier reef; then, if intermittent subsidence begin, placing sea-level at TE, the further discharge of detritus will be detained in the embayed valleys, E, and reef-upgrowth may begin. But, as under these conditions strong cliff-cutting will have accompanied the erosion of deep valleys, a considerable measure of subsidence, placing sea-level at UV, will be eventually necessary to submerge the cliff-tops, L, if they are not seen to-day. Whether this supposition represents the actual history of reef-encircled islands or not, it certainly provides a more reasonable condition for reef-growth than any other supposition here considered.

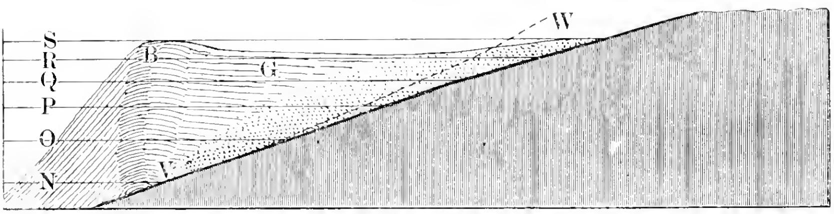

Fig. 6.

Various combinations of diverse conditions may be imagined. For example, the succession of events may be as follows: (1) Moderate cliff-cutting during a still-stand period before reefs are developed; (2) moderate submergence and reef-upgrowth; (3) a second still-stand period, resulting in the smothering of reefs by outwashed detritus, and renewal of cliff-cutting; (4) further subsidence and renewed reef-growth. Tahiti seems now to be approaching the third phase of this succession, for, if the present still-stand that is attested by the alluvial lowland around the island border endures as long as the earlier reefless period of valley- and cliff-cutting, the lagoon will be overfilled, the smothered reefs will be abraded, and a new attack will be made by the waves on the cliffs at a higher level than before.

In any event, the only way of developing a barrier reef around a deeply dissected and non-cliffed volcanic island seems to be either to allow it to subside rapidly to a great depth while its reef is growing up, or to allow it to subside to a less depth after strong cliffs have been cut around its shore. And inasmuch as Réunion, Tutuila and the Marquesas, and Tahiti exemplify the second of these alternatives, the first alternative is regarded as the less probable of the two.

Many more observations of reef-encircled islands are needed before the questions here raised can be settled; and the observations must evidently be directed much more to the islands than to the reefs around them. The various possibilities here outlined, and as many others as can be invented, should be critically reviewed by the observer while he is still on the ground, in order that he may give conscious attention to the details which are confirmatory of or contradictory to the different suppositions. The absence of records regarding significant details in many accounts of reef-encircled islands makes it impossible to use them in a settlement of the questions at issue.

SUBMERGENCE BY OCEAN RISE OR BY ISLAND SUBSIDENCE.

The changes of level involved in producing coasts of submergence or of emergence, and the changes in coral reefs therewith associated, may result from various causes. Chief among these are, first, a local movement of the earth's crust without significant alteration of ocean-level; secondly, an alteration of ocean-level due either to a distant movement of the earth's crust or to the general transfer of detritus from continents to ocean basins; and, thirdly, an alteration of ocean-level due to climatic change, whereby a considerable volume of water is withdrawn from or returned to the ocean in connection with the making or melting of continental ice-sheets.

As far as coral reefs alone are concerned, it is immaterial whether the changes of level upon which their formation or their emergence depend are caused by one of these processes or another; but when it is sought to assign coral reefs to their proper place in the history of the earth the causes of the changes of level with which they are associated must be determined as definitely as possible, and this is now the most difficult part of the coral-reef problem. In order to solve it, search must be made for the characteristics by which each kind of change of level may be recognized.

Crustal subsidence operating over large areas was accepted by Darwin and Dana as the whole cause of the subsidence with which coral reefs are so generally associated. Local subsidence of volcanic islands, as a result of their excessive weight, has been recently suggested by Molengraaff in explanation of mid-Pacific atolls. It may seem at first sight that either one of these processes would, if acting alone, cause a slight lowering of ocean-level, whereby coasts of emergence would be produced around continental shores; and in this case the resulting local submergence of the reef-encircled islands would be a little less than the local subsidence.

But a closer consideration leads to other conclusions: first, inasmuch as general crustal subsidence is presumably associated with compensatory uplifts of other areas, the changes in ocean-level thus caused may be neglected, and with all the more reason when it is noted that if a subsiding island is only partly submerged while a compensatory uplift of equal volume occurs on the ocean-floor without any emergence the result will be a small rise of ocean-level; secondly, if a large number of volcanic islands are built up in succession by eruption from the ocean-floor in such intervals of time that the earliest ones have subsided so far as to be crowned with atoll reefs when the latest ones are formed, the total effect on ocean-level will be not a fall, but a small rise (Davis, 1917B).

In this connection let it be noted that modern investigation gives little support to the old view that active volcanoes always occur in regions of elevation. There is much evidence to show that the reverse is often true. It is therefore desirable that the movements suffered by other islands in the neighbourhood of young volcanic islands should be independently worked out. It is certainly not legitimate to conclude, as has been done by an observer in the Australasian region, that a certain atoll could not have been formed by upgrowth during subsidence because an active volcano stands near it, especially when the supposition of upheaval based on the occurrence of the volcano is contradicted by the occurrence of embayments in the shore-line of another island not far away.

The chief characteristics of crustal subsidences, as well as of crustal upheavals, are that the submergences or emergences they produce may vary from place to place in rate, amount, and date; and in these significant respects they will differ from the submergences or emergences due to other causes, which must involve universal changes of ocean-level, everywhere the same in date, amount, and rate, except where they are complicated by contemporaneous local crustal movements. Evidently, then, it is important to examine all structural and physiographic features of coral reefs and of their encircled islands from which inferences may be made as to the rate, amount, and date of the changes of level that they have suffered, in order to learn how far they are everywhere alike, or how far they vary from place to place.

Extravagant Deformation is demanded by Large Changes of Ocean-level.—A few examples of results already gained in this direction will be given below. But let it first be noted that in order to produce the submergence or upheaval of an island by 1,000 ft. a local subsidence or upheaval of the island by that amount in an ocean of essentially constant level is a much more economical movement than the vast crustal deformations involved in a rise or fall of the ocean-surface by the same amount around a still-standing island: for such a change of ocean-level can be brought about only by a change of the same measure in the entire ocean-floor (except around the still-standing island), or by a ten times greater change in a tenth of the ocean-floor.

Indeed, if a change of ocean-floor level over a tenth of its area involve roughly compensatory changes of a similar area elsewhere, then in order to cause a rise or fall of the ocean-surface by 1,000 ft. the failure of compensation must be of the order of 10,000 ft.; and, great as these movements are, their whole measure must be accomplished in the same period of time as that required for the much smaller measure of local upheaval or subsidence of the island under discussion. It thus appears that in seeking to account for a local submergence or emergence of 1,000 ft. an economy of vertical movements in a reef-encircled island involves an extravagance of movements elsewhere. Hence while small, slow, wide-spread, and synchronous changes in the relative level of land and sea may be plausibly ascribed to changes in the level of the ocean as a result of ocean-floor deformation, large, rapid, and local changes are best accounted for by movements of the island or coast where they are recorded.

Nevertheless, some students of coral reefs have attempted to throw the responsibility for large submergences or emergences of the islands that they have described upon other unspecified parts of the world. Thus C. W. Andrews says, regarding the emergence of Christmas Island, a little-dissected high-standing atoll, 1,200 ft. in altitude, in the eastern Indian Ocean, "It seems very probable that it is the general level of the surface of the sea that has been altered, and not merely a local upheaval of a limited land area that has taken place." Inasmuch as in this case all islands and all continental shores that did not suffer emergence at the same time must have subsided with the ocean, an enormous terrestrial disturbance is involved in this method of accounting for the recently gained altitude of a single small island.

Suess was somewhat more warranted in ascribing the emergence of a number of Pacific atolls to a sinking of ocean-level, for, according to the records that he quoted, their altitudes were about alike; but a closer examination of the facts shows not only that the altitudes of these emerged islands vary greatly, but also that the amount of post-emergence erosion that they have suffered is very unlike. Hence their present altitudes must be explained by local upheavals, varying in date as well as in measure.

Diverse Measures and Dates of Submergences and Emergences.—Local differences in the measures and the dates of emergences and submergences are the best indications of local movements, and evidence of such differences is found on islands in many parts of the Pacific and Indian Oceans. In Fiji, for example, the uplifted limestones, which reach an altitude of 650 ft. on Vanua Mbalavu, in the eastern part of the group, are greatly dissected; Vatu Vara, an elevated atoll thirty miles to the west, is hardly dissected at all, though its height is 1,030 ft.; Naiau, another elevated atoll, 580 ft. in altitude, forty miles to the south, is also little dissected; several other barrier-reef islands, one hundred miles or more to the west, show no signs of elevation.

Again, Viti Levu and Vanua Levu, the two largest islands of the Fiji Group, show fringing or close-set barrier reefs in association with slightly elevated reefs on parts of their southern coast, while to the north-west they have distant barrier reefs, enclosing broad lagoons. The barrier reef on the north-west of Viti Levu is well formed near the island, but fails to reach the sea-surface farther away, where the lagoon has the unusual depth of 58 fathoms. Such a combination of features can hardly be explained without assuming a gentle tilting of the islands.

A similar tilting would seem to be demanded by the features of the Pelew Islands as described long ago by Semper, although that zoological observer, who knew nothing of embayed shore-lines or of unconformable reef contacts, thought tilting too improbable a process to be believed in. New Caledonia shows abundant signs of recent submergence to some such measure as 80 or 100 fathoms, while the Loyalty Islands, not far away to the north-east, are recently elevated atolls. In the Solomon Group, Fauro, previously mentioned, is surrounded by a submarine platform which appears to represent a submerged barrier reef, while New Georgia, farther east in the same group, is bordered for part of its circuit by a remarkably good example of an emerged barrier reef.

It thus appears clear that diverse emergences and submergences at different dates are indicated in various island groups. Hence, even if changes of ocean-level from any cause have from time to time produced universal and synchronous emergences and submergences of moderate measure, local movements of much greater measure are also demanded by the features of various islands, and these local movements are probably the chief causes of the strong submergence which the drowned valleys and outstanding barrier reefs of many volcanic islands call for. Further observations on many reef-encircled islands should be made in order to learn the relative values to be assigned to the various causes of emergence and submergence; and from what has thus far been said it is clear that the observations should, in this aspect of the coral-reef problem also, be directed more to the islands than to the reefs which encircle them.

Atolls.

Although sea-level atolls are, by themselves, inscrutable structures, it sometimes happens that they occur at moderate distances from barrier-reef islands: then the changes of level demonstrated for the barrier reef may be plausibly extended to the atoll also. Thus it has been possible to show good reason for ascribing certain small atolls in Fiji to upgrowth during submergence, and to show also that the submergence was probably due to relatively local subsidence (Davis, 1916d). The large atoll of Ongtong Java, north of the Solomon Islands, can hardly have been formed according to any of the still-stand theories, because the Solomon Islands show many signs of diverse vertical movements. Similarly, the uplifted Loyalty atolls have probably suffered other movements than that of their last uplift, for they are not far distant from New Caledonia, which has had many disturbances.

It may, of course, be urged that the atolls here mentioned, standing near disturbed island groups, should not be taken to indicate the origin of the more numerous atolls in the mid-Pacific; but it may be answered that, while the mid-Pacific region has very probably been less disturbed by subsidences and upheavals than its western archipelagoes, nevertheless the atolls which are associated with barrier reefs resemble mid-Pacific atolls so closely in all essential particulars that the chief differences between them are probably to be found less in the diverse conditions of their origin than in the absence of neighbouring information-giving barrier-reef islands in the one case and their presence in the other.

It has been argued by some students of the coral-reef problem that the uniformity of the depth of atoll lagoons is better explained in connection with a rise of ocean-level everywhere of the same amount than by the subsidence of the atolls, which must vary somewhat from place to place. In so far as the post-Glacial rise of ocean-level can satisfy the demands of the problem this argument may be accepted; but inasmuch as the depths of atoll lagoons, as far as they are known, vary in a manner more suggestive of varying than of uniform measures of submergence, perfect stability of the atolls is improbable. Moreover, the reef-encircled volcanic islands that occur in close association with certain atoll groups demand a greater measure of submergence to account for their drowned valleys than can be provided by Glacial changes of ocean-level. Finally, the evidence of the Funafuti boring is, as noted above, strongly in favour of subsidence during the formation of its reef rock.

Elevated Reefs.

Recently-elevated atolls not dissected sufficiently to disclose their structure give little more testimony regarding their origin than can be obtained from sea-level reefs. But if a recently-elevated fringing or barrier reef lie unconformably upon its foundation, and if its limestones enter into valleys between the ridges of its central island, as is manifestly the case with the elevated reefs of Oahu, Hawaii, submergence of an eroded land-surface must have taken place before the reef was formed. The measure of submergence can be inferred if the down-slope extension of the eroded land-surface beneath the reef can be determined.

If elevated reefs have been out of water long enough to suffer dissection, the details of their structure may be disclosed; but so abundant is the vegetation of tropical islands that observation of reef-structure is very difficult. It is of importance that the observer who has opportunity of examining a dissected reef should locate the structural details that he may discover with respect to the total reef-mass; it is also important that he should bear in mind the expectable structures of reefs formed according to the several chief theories of reef-origin, as shown in figs. 7 and 8, for he will thus be led to make special search for critical structures in their appropriate locations.

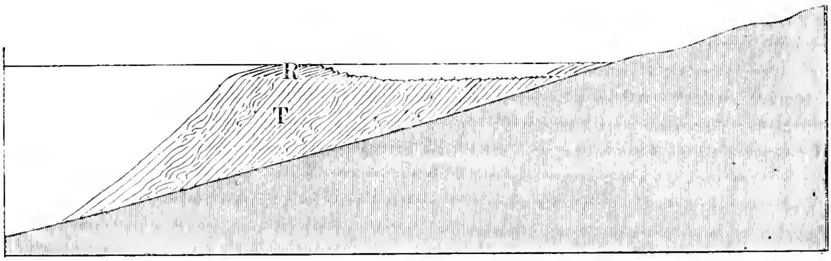

FIG. 7.

Thus if the great body of an elevated reef consist, as in fig. 7, of steeply sloping layers of reef detritus mostly free from admixture with volcanic sands and gravels, resting conformably upon a non-eroded volcanic slope, T, and more or less complicated by slides, the reef should be explained as a product of outgrowth during a prolonged still-stand period. Darwin clearly recognized the possibility of reef-formation in this manner, but regarded it as seldom occurring, because it would not result in the formation of a reef-enclosed lagoon from 20 to 40 fathoms in depth. Murray attempted to overcome this difficulty by assuming, as Semper had before him, that the lagoon-cavity would be excavated by solution; but the assumption is not supported by the features of lagoons, as has been noted above.

On the other hand, an elevated reef may show a three-part structure, as in fig. 8. The steeply dipping, exterior strata, T, may be formed of detritus chiefly derived from the reef, but with some fine sands and silts

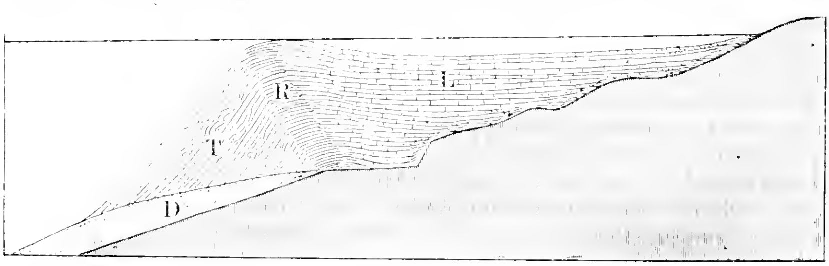

FIG. 8.

from the central island. The slanting layers may be sometimes complicated by slide-structure as in the preceding case; they may rest on a heavy deposit of volcanic detritus, D, which should be associated with a buried cliff. The intermediate wall-like structure, R, should contain much coral in place, as well as large and small fragments. The outward or inward slant of the wall appears to be dependent on the rate of subsidence during its formation (Davis, 1916c). The nearly horizontal interior strata, L, may contain coarse sand near the reef-wall, fine lagoon deposits in the middle, and volcanic sands and gravels near the central island; and the whole mass, with the exception of some of the outer slanting layers, may lie unconformably on a rock surface of subaerial erosion. In such a case reef-upgrowth during prolonged submergence probably due to subsidence would be inferred. Irregularities in the reef-wall, as in fig. 9, would indicate changes in the rate of submergence. A horizontal outgrowth, H,

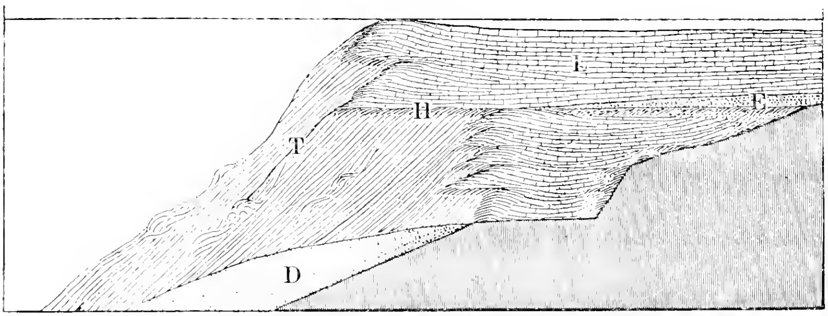

Fig. 9.

would occur during a long still-stand period, when delta plains, E, might almost fill the lagoon. The occurrence of a buried cliff and platform in the profile of the underlying rock, and an exterior detrital deposit, as shown in figs. 2, 4, 5, 8, and 9, would be of much theoretical interest.

In case dissected atolls are found, their structures should be studied with especial care: and if their rock foundation is disclosed it should be closely examined to see whether the atoll limestones lie on it conformably or not. Christmas Island, in the eastern Indian Ocean, merits renewed study in this respect, for basalt has been seen in ravines behind its limestones, but the nature of the limestone-basalt contact has not been fully described.

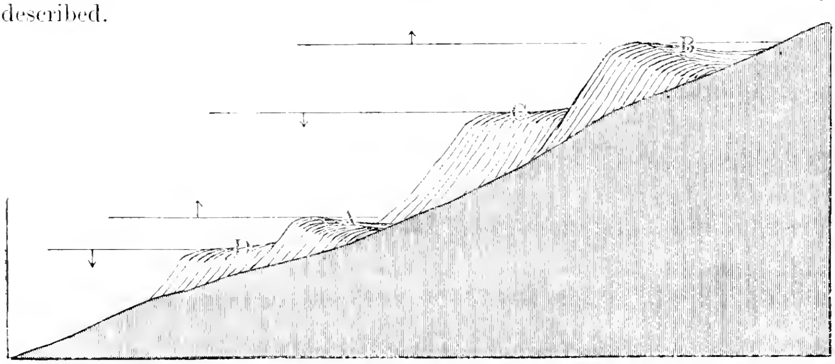

Fig. 10.

In case elevated reefs occur in terrace-like arrangement, one above the other, as on Cebú in the Philippines, and elsewhere, the structure of the successive terraces will indicate the sequence of formation of their reefs.

Following Gilbert's method of interpreting the terraces of Lake Bonneville, and assuming that the reefs rest unconformably on their rock foundation, a series of superposed reefs, one resting on the other, must have been formed during successive pauses in a long submergence and afterwards rapidly elevated; while a series of apposed reefs, one in front of the other, must have been formed during pauses in a long emergence, preceded by a rapid submergence. Such a structure as is shown in fig. 10 should be interpreted as meaning that reefs A and B were formed during pauses in submergence, while reefs C and D were formed during pauses in emergence. It is manifest that all details of reef-structure such as are here suggested should be critically observed.

Summary.

It is singular that the coral-reef problem, which has been so long under discussion, should not have been already so far standardized as to make the suggestions contained in this article unnecessary; but, as a matter of fact, neither the special reports by various investigators of coral reefs, nor the leading text-books of geology and of physical geography, present the problem in such a form as to emphasize the matters that are of the greatest importance in its solution. Factors so essential as shore-line embayments and unconformable reef contacts often receive no mention whatever. The meaning of unconformable fringing reefs has been almost universally overlooked. The forms of spur-ends on reef-encircled islands are hardly ever described. The disposal of the waste from a deeply-dissected, reef-encircled island has received no discussion. Elevated reefs, even if unconformable with their foundation, have nearly always been interpreted as having been formed during pauses in the movement of uplift by which they were elevated, and no recognition has been given to the manifest possibility of their formation during pauses in a preceding subsidence.

Several reasons for the neglect of these essential considerations may be suggested. One is that the investigators of coral reefs have often been zoologists, untrained in geological inquiry Another is that the physiographic principles which are involved in a critical study of the reef problem are not always familiar even to geological observers. A third and perhaps the most important reason is that few investigators of coral reefs appear to have taken the time necessary to think out the essential consequences of the several leading theories of reef-origin in order to discover which of the consequences are best supported by the facts. A fourth, as important as the third, is that observers have too often given their chief attention to the reefs, and have not attended sufficiently to the islands that they encircle. A fifth is that the origin of coral reefs is a very complicated matter, because many different factors may have a share in it, and many different solutions therefore appear possible.

It is in the hope of overcoming these deficiencies in the methods of reef-investigation that the preceding pages have been written. While it is recognized that the coral reefs constitute a wonderful field for zoological study, and that such study throws much light on the life-history of reefs in the past, it is urged that the geological and physiographic study of reef-encircled islands is necessary in order to discover the past inorganic conditions under which reefs were developed.

While it is fully understood that the observation of the visible zoological and geological facts of the present may absorb a large share of the attention of a reef-investigator, it is urged that he should frequently, while still in the field, take enough time from observational work to think out as carefully as possible the invisible conditions of the past according to each and every theory known to him, and that having done so he should return to an examination of the visible facts in order to discover which one of his theories they best support. New Zealand is favourably situated as a starting-point for the study of coral reefs; hence the scientific world must look to New Zealand students for new light on this old problem.

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ART. III.—*On the Occurrence of Two Unusual Blood-vessels in* Hyla aurea.

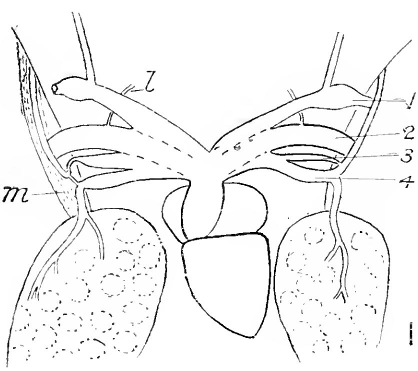
By Professor W. B. BENHAM, D.Sc., F.R.S., Hutton Memorial Medallist.

[*Read before the Otago Institute, 9th July, 1918; received by Editor, 17th December, 1918; issued separately, 14th May, 1919.*]

IN former days, when fixity of species was a tenet of biologists, any unusual occurrence in the anatomy of animals was spoken of as an "abnormality"; but nowadays biologists are familiar with the fact that no two individuals of a given species are absolutely identical in all their parts—every organ, both external and internal, may present some more or less profound difference when compared with other individuals, and these differences are known as "variations." In the blood-system, for example, although the main blood-vessels conform to a type in all the individuals of a species or even genus, yet the mode of branching, the number of the branches, their size and extent and distribution, are very rarely identical over a series of individual specimens. So it is with other organs or systems of organs: some of these "variations" are in the direction of loss of parts, or they may be of additions of parts—new structures which suddenly appear without any transition between them and the usual state of the organ. We call these "mutations" if they are hereditary, though in a large number of cases it is impossible to determine whether this is so or not. But others of the variations from the usual adult structure are due to the persistence of conditions which are present in the embryo or in some lower member of the group to which the species belongs, and which are usually lost during the development, so as to be absent in the adult. Such persistent embryonic structures are always of great interest. Two such cases were met with amongst the adult frogs, *Hyla aurea*, dissected in my laboratory during this session. Both of these conditions seem to be extremely rare, and, so far as I have been able to consult the literature at my disposal, they appear to be unique.

1. Persistence of the Third Branchial Aortic Arch.

On the 28th March one of my students called my attention to the presence in the specimen she was dissecting of four arterial arches on each side, in place of the normal three. The frogs had been injected so that the students should be able to trace out the arterial system, and in the



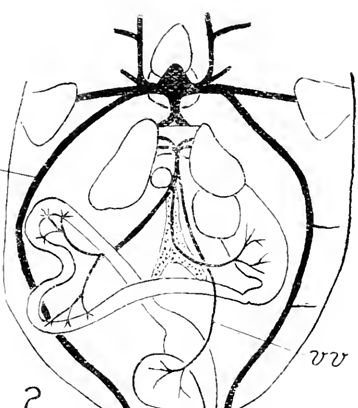


FIG. 1.—Arterial aortic arches (× 2) showing persistent third larval arch. *m*, portion of petrohyoid muscle; *l*, small laryngeal artery.

FIG. 2.—Visceral veins in abnormal frog (from drawing by E. W. Hunt). The heart is turned forwards to show the sinus venosus and the hepatic veins. *lv*, the unusual paired lateral (abdominal) vein; *vv.*, the vesicular vein entering the hepatic portal.

case under consideration the injection, performed by my assistant, Miss W. Farnie, was particularly successful, so that even small branches were distended with the injection mass, such as the laryngeal and pharyngeal arteries. The student had dissected out the arteries on the animal's right side with great care, and only the internal carotid had been ruptured. The other side she had scarcely touched when she directed my attention to its condition.

The arrangement is as follows: The carotid and systemic arches are normal, but the pulmo-cutaneous arch bifurcates close to its origin, the posterior branch of which has the usual relations dividing into the pulmonary artery and the cutaneous artery. It is the anterior of the two branches which is exceptional, and appears to be the persistent third branchial arterial arch of the tadpole. This anterior branch arises from the base of the pulmo-cutaneous soon after it leaves the synangium: it is equal in diameter to this arch, and runs parallel with the other arches nearly to the point at which the last arch divides to form the pulmonary artery and the cutaneous artery. But as it approaches this cutaneous artery its diameter decreases and it bends backwards towards the fourth arch, to which it is joined by a very slender vessel. It then bends forward again and is continued into the cutaneous artery alongside which runs as usual the petrohyoid muscle, to which it gives off twigs. The relation of this third arch to the cutaneous artery would suggest that the latter is derived from it, were it not for the precise account of the development of the latter given by Marshall. At the first bend of the arch is an angle as if a vessel or ligament passed forwards to the systemic arch, but I can find no trace of this. There is no connection between this third arch and either the systemic arch or the dorsal aorta.

On the left side I find that the condition of affairs is essentially the same, but the third arch is much more slender than on the right side. Less injection has penetrated the vessel, which suggests that possibly some resistance is exerted at the connection between it and the cutaneous artery. Nevertheless, the connecting vessel is distinctly red with injection, but is much narrower than its basal region. As on the right side, this third arch bends backwards (more abruptly than is shown in the drawing, for it is better seen when the arches are stretched apart) in order to reach the cutaneous artery, which on this side is normal and of equal diameter throughout its course.

The delicate pharyngeal artery, from the systemic arch, is plainly visible in the specimen below the third arch, but I have omitted it from the drawing for the sake of clearness.

According to Marshall,* during metamorphosis "the third aortic arch in the third branchial arch of the tadpole atrophies altogether. In young frogs of the first year it loses its connection with the aorta and then gradually shortens up, the distal end becoming a solid cord, and the proximal or cardiac part retaining for a time its lumen. Before the end of the first year this vessel has entirely disappeared."

In the larva this third afferent arch goes, of course, to a gill, and has no connection distally with the fourth arch: it is this union on the ventral surface that is rather puzzling in the present case, and especially the very slender union between the cutaneous artery and the parent fourth arch. It raises the question whether the ontogeny of the frog is really a true recapitulation of the phylogeny of the Anura, or whether the cutaneous artery is originally derived from the third arch, which in the embryology of those species of frog that have been studied has undergone some modification, leaving the third to become connected with the fourth arch at some stage in the history.

The cutaneous artery seems to be peculiar to the Anura, as no reference is made to such an artery in any description of the anatomy of salamander

* A. M. Marshall, *Vertebrate Embryology*, p. 178, 1893.

or newt to which I have access (*e.g.*, Bronn's *Thierreich*). In the salamander, as is well known, both the third and fourth arches persist, but unite with the systemic to form the dorsal aorta.

As I have noted, the third arch in the case under consideration is not connected on either side to the dorsal aorta or with the systemic arch.

2. Paired Lateral Abdominal Veins.

A frog dissected by one of my students on the 4th April rather worried him because there was no "anterior abdominal vein." and so he called my attention to it. I was surprised to find that in place of this median vein this frog possessed a pair of laterally situated veins each of which, arising from the femoral vein of its side and running forwards in the body-wall, quite laterally entered the precaval (anterior vena cava) of its side. On its way it received two musculo-cutaneous veins, which normally in this species enter the anterior abdominal vein at the level of the tendinous intersections of the rectus abdominis muscle. These lateral veins had no relation to the portal system, but the vesicular vein from the urinary bladder passed forwards to enter the hepatic portal at the spot at which the abdominal vein normally does so.

I can find no record of exactly this arrangement as occurring in the frog, though cases of a right or left vein of somewhat similar relations anteriorly have been described.

Buller* found an abdominal vein which after a normal course from the hinder part of the body as far as the liver, to which it sent a small branch, bent outwards to the right side and entered the right superior vena cava, or, as the figure shows, the subclavian.

The next case is that of Woodland,† where the abdominal vein is median posteriorly but passes outwards to the left precaval (or subclavian). It gives no branch to the liver.

In the next year O'Donoghue‡ described a frog with an abnormal heart and with an abdominal vein similar to that described by Woodland.

These are the only instances of an abnormal condition of the abdominal vein which I can find. In each of them the hinder end arises quite normally from the union of the two femoro-abdominal or "pelvic" veins. Each of these authors refers to the condition in *Ceratodus*, while Woodland carries the comparison back to the paired lateral veins of the dogfish, which homology was first suggested by Hochstetter in 1894.

In the present case this resemblance is very evident and precise. Here, too, is an instance of the persistence of a larval condition, though with certain differences in detail. Marshall§ writes thus: "The anterior abdominal vein is at first paired and is in connection not with the liver, but with the heart. The pair of vessels appears first in the ventral body-wall, extending backwards a short distance from the sinus venosus; they soon extend farther backward and acquire a communication with the veins of the hind legs and of the bladder. At a later stage the two veins unite at the hinder end in front of the bladder, while farther forward the vein of the right side disappears and the left one alone persists; later still the

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* A. H. R. Buller, *Journ. Anat. and Physiol.*, vol. 30, p. 211, 1896.
† W. Woodland, *Zool. Anz.*, vol. 35, p. 626, 1910.
‡ C. H. O'Donoghue, *Zool. Anz.*, vol. 37, p. 35, 1911.
§ *Loc. cit.*, p. 184.

anterior abdominal vein loses its direct connection with the sinus venosus, and acquires a secondary one with the hepatic portal system."

In the European frog *Bombinator*, which is closely allied to the New Zealand frog *Liopelma*, Goette* had already described a similar course of events, while Hochstetter† found in the larva of the salamander that the two abdominal veins are at first separate for the greater part of their length, but unite near the liver to form a median vein which enters the left precaval vein; but with the absorption of the yolk this communication is lost and a new one established with the hepatic portal system.

The occasional persistence in *Rana* of either a right or a left connection with the sinus venosus by way of a precaval has already been emphasized by Woodland and O'Donoghue.

That the present instance is not an exact recapitulation of the larval condition is seen by the fact that the anterior end of the lateral vein on each side is not connected with the sinus venosus but with the precaval, which is apparently an earlier condition, as seen in the Elasmobranchs.

Art. IV.—*Some Earthworms from Stephen Island and D'Urville Island.*

By Professor W. B. Benham, D.Sc., F.R.S., Hutton Memorial Medallist.

[*Read before the Otago Institute, 10th December, 1918; received by Editor, 30th December, 1918; issued separately, 14th May, 1919.*]

During the present year Dr. J. Allan Thomson visited these islands in Cook Strait, and amongst the animals collected by him were a few earthworms, which he was good enough to send to me for identification.

No earthworms have hitherto been recorded from D'Urville Island, though we are already acquainted with three species from Stephen Island. Some were collected by Schauinsland during his visit in 1896–97, and others by Thilenius; and they have been described by Michaelsen (1) and by Ude (2) respectively.

These three worms are *Octochaetus thomasi* Beddard, *Maoridrilus tetragonurus* Michaelsen, and *Dinodrilus gracilis* Ude. The first of these species is a well-known and widely distributed South Island form, which was one of the earliest of the New Zealand worms to be accurately described (3); the other two species are so far confined to Stephen Island, though they belong to genera which are known in the South Island and the North Island.

The present collection contains two out of these three species, and in addition two new species of *Maoridrilus*, one from each of the islands, together with a new species of *Pericodrilus*, a genus hitherto known only from the mountains of the west coast of the South Island. So, as one would expect, the Oligochaet fauna of the two islands is mainly derived from the South.

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* A. Goette, *Entwickel der Unke*, 1875.

† F. Hochstetter, *Morphol. Jahrbuch*, vol. 21, p. 19, 1894.

Octochaetus thomasi Beddard.

Three individuals of this common South Island species were included in the collection from Stephen Island.

Maoridrilus tetragonurus Michaelsen.

This handsome species is evidently tolerably common on Stephen Island, as Michaelsen obtained four specimens. Ude speaks of several, and Dr. Thomson sent me seven individuals collected during his brief visit.

The largest specimen in this last gathering measures 210 mm. in length, which is not so long as those described by Ude, which attained as much as 280 mm.

I have nothing to add to the two accounts given by these two zoologists.

M. megacystis n. sp.

A single specimen of a small worm measures 90 mm. in length, with a diameter of 5 mm.; but it is poorly preserved, so that its dimensions are not accurately indicated by these figures.

Its colour is greyish-purple when preserved, and the clitellum has a redder tone.

The clitellum is fairly well marked over segments 14–22: that is to say, the segments themselves are glandular, but the intersegmental furrows still remain distinct.

The chaetae have the arrangement usual in the genus: the spaces *aa*, *bc*, and *dd* are practically equal, though *aa* is rather less than *dd* or *bc*—at any rate, behind the clitellum. Owing to the softness of the worm, it does not show the squareness of the tail which is so common in the genus.

Porophores are but feebly developed, and the ventral region of the segments 17 and 19 between the porophores is depressed so that in the 18th segment a slight transverse pad is left on the ventral surface. The spermatic grooves are convex mesially, and lie mediad of the ventral chaetae, which are quite distinct here, and are not thrust out of line of those in the neighbouring segments (as are those in the next species).

Internal Structure.—The septa separating the segments 8–14 are more or less thickened.

The dorsal vessel is single throughout the worm; the last heart is in the 13th segment.

The gizzard lies in the 6th. This is its true or "morphological" position, but, as is usually the case, it gets pushed backwards owing to the fact that the preceding region, like the gizzard itself, is longer than the segments to which it belongs.

There are large oesophageal glands in the 15th and 16th segments, and a smaller pair in the 14th. They are subspherical dilatations of the tube on each side, and the anterior two pairs meet their fellows above the gut.

The reproductive organs lie in the usual segments and in their normal positions.

Each spermatheca (fig. 1) has a relatively enormous diverticulum, which is as large as the ampulla—so large, indeed, that at first one thinks there are four spermathecae. The diverticulum, further, is not racemose, as usual, but has a smooth wall and a nearly globular form. When mounted, however, and viewed under the microscope one can see the outlines of the characteristic chamberlets into which its cavity is divided; but these walls do not affect the surface.

Another peculiar feature is that the duct of each of the two sacs opens into a large muscular "atrium," which in its turn opens to the exterior.

The penial sacs are large, and the penial chaetae long. These are bluntly pointed, and the edges are curved upwards so as to form a short shallow furrow extending a short distance from the apex (fig. 2). These edges are ornamented with a few short bluntly pointed processes, but the rest of the chaeta is smooth. I examined not only a fully developed chaeta, but also one of the reserves, which exhibit precisely the same features, so that the processes are not produced by wear of the edges.

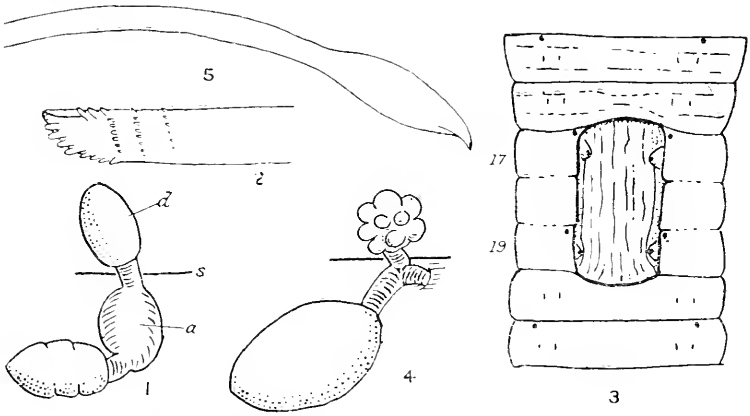


Fig. 1.—*Maoridrilus megacystis.* Spermatheca. *a*, muscular "atrium" common to the ducts of the ampulla and the diverticulum (*d*); *s*, septum.
Fig. 2.—*M. megacystis.* Tip of a penial chaeta, under a high power.
Fig. 3.—*Maoridrilus thomsoni.* View of the ventral surface of segments 15–21 (× 4½), showing the characteristic "trough" and the position of the ventral nephridiopores.
Fig. 4.—*M. thomsoni.* Spermatheca.
Fig. 5.—*M. thomsoni.* Penial chaeta.

Locality.—Stephen Island.

Remarks.—The only species at present known in which the dorsal vessel is single throughout the body is *M. michaelseni* Ude (2), which was collected at Westport; but in that species the diverticulum of the spermatheca is quite small, its duct is narrow, and there is no "atrium": further, the penial chaetae are quite different. The size of the diverticulum suggests the specific name.

M. thomsoni n. sp.

Of this species also there is but a single individual, which seems to be of about the same size as the previous species, but is in even a worse state of preservation than it. It is damaged just behind the clitellum, and is very soft. Its posterior end is missing, and there is as yet no sign of tapering. We do not know, therefore, what is its length. The fragment contains 198 segments and measures 65 mm. in length. The first 24 segments contribute 10 mm. to this.* Its diameter behind the clitellum is

* In the previous species this anterior region accounts for 25 mm., but I did not make corresponding measurements of the other features, for I had opened it before studying the present worm.

5 mm., but, as usual, is somewhat less at about the 7th segment, which is but 4 mm. across, and less again at the genital region, which is only 3 mm. It is evident that these measurements do not give a true idea of the dimensions.

The chaetae are equally spaced, so far as one can see on the animal.

The clitellum, though not yet thickened, seems to cover segments 16–20, for the intersegmental furrows are evanescent. Probably when the worm is mature the clitellum extends farther forward than this.

The spermathecal pores are conspicuous owing to their tumid lips.

There is one external feature in which this worm seems to show a marked peculiarity. On the ventral surface of the segments 17–19 there is a rather deep rectangular trough, with well-defined lateral and terminal boundaries, while the non-glandular floor is marked by longitudinal foldings. The appearance is that this ventral region is withdrawn by internal muscles (fig. 3).

The longitudinal margins correspond to the level of the ventral couples of chaetae, but on these segments, owing no doubt to the retraction of the ventral region, which results in the formation of the trough, the ventral chaetae and the nephridiopores are carried mediad of the line formed by these structures in the neighbouring segments. Under a dissecting-lens the chaetae themselves are not visible on these three segments, but the ventral nephridiopores of segments 17 and 19 are quite conspicuous and are out of the line.

The porophores lie within this lateral margin, and are not prominent. They project rather into the trough from the sides than from its floor, so that the pores face inwards towards the middle line.

The spermatic groove is very evident: its outer lip is formed on each side by the edge of the lateral wall of the trough; the inner lip is seen lower down this wall.

Internal Structure.—I did not note any specially thickened septa, as everything is so soft.

The dorsal vessel is single throughout the worm; the last heart is in the 13th segment.

The gizzard belongs morphologically to the 6th, for the septum 5/6 is inserted at its hinder end; but its "apparent" position is in the 8th and 9th segments—that is, a transverse line across the body as dissected, passing over its anterior end, cuts through the intersegmental furrow 7/8, and its posterior end lies at the transverse line through 9/10.

Oesophageal glands are large and spherical, and meet above the tubes in 14th and 15th, while in the 16th is a smaller gland; the intestine commences in segment 20.

The spermatheca has a large ampulla (larger actually than that of the previous species) with a narrow duct, which carries a small racemose diverticulum of the form usual in the genus (fig. 4).

The penial sac, and consequently the copulatory chaetae, are not nearly so long as usual. This, I think, is to be accounted for by the external trough, which probably aids in the process of copulation in this species, as it appears to do in certain other families of worms. But I can detect no "arcuate" muscles in these segments. The penial sac is not only relatively, but absolutely, smaller than in the previous species. Here it is scarcely longer than the length of the segment, whereas in *M. megacystis* it extends across the body-wall half-way towards the dorsal mid-line.

The penial chaeta (fig. 5) is slender, curved, and slightly swollen just below the apex, whose sharp point is slightly bent up to form a hook; it has no perceptible furrow. The sides are not ornamented by rows of minute teeth as in *M. michaelseni*, but in certain lights some five or six faint transverse lines can be made out just below the swollen region.

Locality.—D'Urville Island.

Remarks. This species certainly has some resemblances to *M. michaelseni*, especially in the possession of a depression on the segments 17–19. But from it the present species differs in one or two features that seem to be specific. The gizzard, which in that species is said to occupy the two segments 6 and 7, here lies only in the 6th. I was careful to trace out the septa as above described.

The oesophageal glands, four in number, are said by Ude to be "small." The penial chaetae are described as "long," "spoon-shaped," and ornamented with very fine teeth in transverse rows; and, though the tip is curved, its curvature is in the other direction, and there is no swelling below the apex. Thinking that perhaps this last feature was due to pinching with the forceps, I examined a "reserve," or undeveloped, chaeta, which I find exhibits the same subterminal enlargement.

Ude also speaks of the penial sac as being "absent." I have noted its very small size, and it may be that in a well-hardened specimen it would not project within the body-wall.

Had it not been, however, for the distinctness between the form of the penial chaetae in the two forms, I should have regarded this as merely a variety of Ude's species.

Perieodrilus durvilleanus n. sp.

A single individual was received, which unfortunately is immature.

A brick-red worm, with its mid-dorsal line of much deeper tone than elsewhere; each segment is marked by a number of white spots, in each of which is a chaeta.

Length, 108 mm.; diameter, 6 mm.; with 117 segments. The body is cylindrical, with scarcely any tapering at the hinder end.

The prostomium is tanylobic.

There are some 20–24 chaetae on each side of each segment. They are not in definite couples, but are more or less equidistant, though here and there a chaeta is absent.

The dorsal "gap" is about one-third the width of the ventral gap.

Dorsal pores are present, but I failed to note at what segment they commence. No nephridiopores are visible under the dissecting-lens, owing, I believe, to the softness of the wall.

There is no sign of a clitellum. On the 17th and 19th segments, outside the ventralmost chaeta on each side, is a faintly expressed papilla, recognizable in its immature condition by its pink colour in contrast with the nearly white colour of the surrounding skin. No spermatic groove is as yet present.

Internal Structure.—The septa behind the segments 9 to 13 or 14 are thicker than the rest

The dorsal vessel is double throughout the worm; enlarged hearts in 10th to 13th segments.

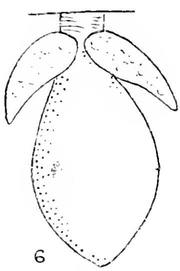
The gizzard is long, lying apparently in the 7th and 8th, but in reality it belongs to the 6th and possibly partly to the 7th.

The oesophageal pouches or glands are four pairs, in segments 10, 11, 12, and 13: each is a subglobular outgrowth marked by a series of vertical lines which indicate the attachment of internal folds or lamellae. They are quite lateral in position and do not overlap the gut.

The intestine commences in the 18th segment.

The gonads occupy the usual position on the hinder face of the septa of their respective segments, inserted close to the attachment of the septa to the body-wall. The prostates are as yet very small but quite distinct under a lens, and are of the usual form; the muscular ducts are recurved. There are no penial sacs, and at present no transverse muscles in these segments such as are present in the mature stage of the other species.

The spermathecae occupy the usual position: each consists of a pointed ovate sac, or "ampulla," with a short stout duct, into the anterior face of which opens a bifid diverticulum, the free ends of which lie at the right



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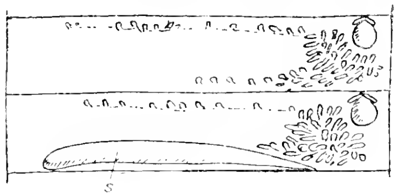

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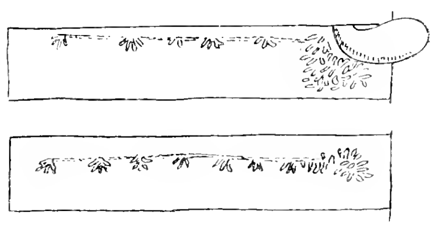

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Fig. 6.—*Periodrilus durvilleanus.* Spermatheca. The dotted circles on the diverticula indicate the chamberlets, which are visible only when the organ is cleared.

Fig. 7.—*P. durvilleanus.* The left side of segments 8 and 9, showing the spermathecae, nephridial tuft and its lateral extension, and in the latter segment the sperm-sac (*s*). The median line is towards the right side.

Fig. 8.—*P. durvilleanus.* The left half of segments 12 and 15, showing the gradual dissolution of the nephridial tuft and its extension dorsalwards.

and left sides of the ampulla (fig. 6). Externally they appear simple, but when mounted and viewed as transparent objects the internal chamberlets are visible. In this condition the diverticulum appears as a semicircular collar round the duct, much as I have figured it for *P. ricardi* (5); but seen in the animal the distinctness of the two long processes of the diverticulum is very evident.

There are four pairs of sperm-sacs, in segments 9, 10, 11, 12. The two anterior sacs have at present the form of long white slender cylindrical tubes resting against the hinder septa of the segments (fig. 7); each terminates upwards in a rounded end, and is attached ventrally to the septum close to the body-wal' and nerve-cord. The two posterior sacs are shorter, wider, and lie along the anterior wall of their segments (fig. 8): in short, they have the usual position, but are at present only commencing to form.

The Nephridia.—From the 2nd to the 14th segments, inclusive, the nephridium is represented by a conspicuous tuft of minute looping tubules arranged in such a way as to form a sort of "rosette" close to the nerve-cord and occupying nearly the whole length of its segment. It is thus a more or less rounded or quadrate mass of tubules. These tufts are much larger in the more anterior segments, and in the 2nd, 3rd, and 4th seem to represent the entire organ, but farther back one sees that the tubules are not confined to these tufts but extend outwards along the body-wall for a short distance as a linear series of isolated loops near the septa (fig. 7). In about the 7th–11th I believed that under a high-power dissecting-lens I could detect a duct or tube passing outwards, and ending apparently on the body-wall about half-way up the side of the body. I therefore cut out, stained, and mounted a portion of the side of the body, including the segments 7–11, in the hope of being able to satisfy myself as to the locality of the pore; but I was unsuccessful. The body-wall is too soft to allow such a small aperture to be recognized.

I then mounted the cuticle of these segments, but was no more successful, for, though the large spermathecal pores and the linings of the chaetiferous follicles are perfectly evident, there is no pore that I could interpret as being the nephridiopore.

Sections were equally useless, owing, as I believe, to the soft condition of the specimen.

To continue the internal appearance: The dissolution of the tuft of the tubules, which commences about the 7th segment, continues till at the 15th almost all the loops are arranged in the linear series (fig. 8), and by the 17th I fail to see any tuft or rosette. At the 20th I am unable to detect any loops under a lens, but by picking up at random the tissue that lies between the septa I find under the microscope that it consists of minute nephridial tubules with accompanying blood-vessels.

I was unable to detect any funnel, but the poor state of the tissue has rendered it difficult to make as thorough an investigation on this important point as is necessary.

However, it is clearly, I think, a "meganephric" worm such as I have previously described.

Locality.—D'Urville Island.

Remarks.—The genus *Pericodrilus* (which Michaelsen has separated from my *Plagiochaeta*) (4) is so far confined to the mountains of the West Coast: it is therefore not surprising that a representative occurs in this island.

It is evident that the present species is nearly related to *P. montanus* and to *P. ricardi* (5), but from each it differs in one or more features. Externally its coloration recalls that of the former, as also in the concentration of the nephridial loops near the ventral region of the body (6); but in *P. montanus* the gonads are situated on the posterior wall of their segments, in *P. ricardi* they are on the ventral wall midway between the septa. Only in *P. lateralis* are they in their normal anterior position as in the present species, but in that worm there are no oesophageal glands and only two pairs of sperm-sacs. In the two other species, while there are four pairs of sperm-sacs, there is only one pair of oesophageal glands. The form of the spermathecal diverticulum likewise differs from that in the known species.

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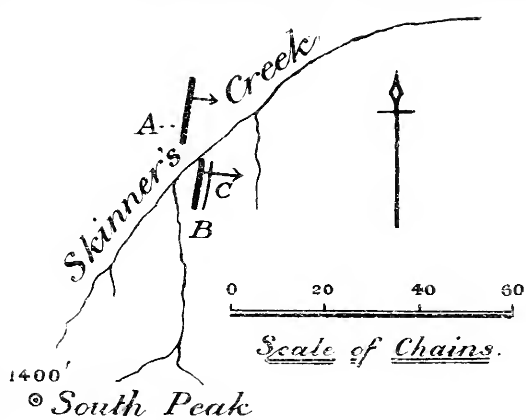
Art. V.—*On the Occurrence of Three Bands of Marble at South Peak, near Hampden, Otago.*

By Professor James Park, F.G.S.

[*Read before the Otago Institute, 10th December, 1918; received by Editor, 27th December, 1918; issued separately, 14th May, 1919.*]

In the early part of last November, while investigating the extension of the Shag Point beds to the landward side of Hampden, I was informed by Mr. A. Craig, of that place, that an attempt had been made some twenty years ago to burn limestone in a kiln somewhere near the upper end of Baghdad Road. As the result of two days' search, with the assistance of Mr. Craig, I found a small outcrop of a grey crystalline limestone on the north side of Skinner's Creek, at an altitude of 450 ft. above the sea, at a point about 300 yards from Baghdad Road. The outcrop had been opened out by blasting, and I concluded that this was the place from which the material for the experimental burning had been excavated. I continued the search towards South Peak, and succeeded in discovering three well-defined bands of limestone, two on the south side of Skinner's Creek and one on the north. These bands are interbedded in the altered argillite that forms the core of the coastal range lying behind Hampden. They strike almost north and south (true), and dip east at angles that vary from 50° to 65°.



A, B, and C, lenses of limestone.

Band A is about 5 ft. thick; band B, 12 ft.; and band C about 2 ft. Bands B and C are separated from one another by 32 ft. of argillite. Band A, geologically the lowest, is perhaps 200 ft. below band B.

When traced along the outcrop the limestone bands are found to occur as short lenses. Band A is a lens about 450 yards long, and bands B and C peter out in a distance of 70 yards.

Like the blue crystalline limestone at Dunback, the Hampden limestone bands occur in the semi-metamorphic rocks of the Kakanui series of Hector, the age of which is still unknown. The relationship of the Hampden and Dunback limestones can be determined only by a detailed survey.

The Hampden limestone is a fine-grained grey marble of good quality. The larger blocks will form good building-material, and the small pieces may be utilized for grinding into material for agricultural purposes.

An average sample of marble from the lens marked A on the accompanying sketch was analysed at the Dominion Laboratory, Wellington, with the following results:—

Insoluble in acid	0·86
Alumina and iron oxide	0·55
Magnesium carbonate	0·56
Calcium phosphate	0·17
Calcium carbonate ($CaCO_3$) by difference ..	97·86
	100·00

I am indebted to the Director of the Geological Survey for obtaining the above analysis for me.

Art. VI.—*A Preliminary Investigation of the Age and Manner of Growth of Brown Trout in Canterbury, as shown by a Microscopic Examination of their Scales.*

By M. H. Godby, M.A., B.Sc.

[*Read before the Philosophical Institute of Canterbury, 4th September, 1918; received by Editor, 20th September, 1918; issued separately, 14th May, 1919.*]

Plates I–VI.

The possibility of determining the age of fish by a microscopic examination of their scales was first demonstrated in 1899 by Hoffbauer (3), who made a special study of carp-scales.

The same principle was applied to salmon-scales by Johnston (4) in three papers published in the 23rd, 25th, and 26th Annual Reports of the Fishery Board for Scotland. Johnston further demonstrated that it was possible to trace the whole life-history of a salmon from its scales, and to say with tolerable certainty how long the fish had spent in fresh water as a "parr," at what age it had become a "smolt" and migrated to the sea, whether it had re-entered fresh water to spawn, and, if so, the approximate dates of its re-entries and returns to the sea.

Working on the same lines, Dahl (1) made a most careful study of salmon and trout scales in Norway, and showed that, in addition, it was possible to calculate with considerable accuracy the length attained by the fish each year of its existence.

The fundamental fact on which these investigations are based is that carp, salmon, and trout—and, indeed, most if not all kinds of fish—each year pass through a period of rapid growth followed by a period of comparative stagnation. This periodic growth has generally been attributed to changes of temperature and corresponding changes in the abundance of food-supply; and in regard to many species of fish it has been demonstrated that the maximum rate of growth roughly coincides with the maximum temperature of the water. There is evidence, however, to show that this periodic growth is well marked in the scales of some deep-sea fish, which can hardly be subject to any marked seasonal changes of temperature, and in the case of the squeteague (*Cynoscion regalis*) Taylor (6) has shown that the period of stagnation roughly coincides with the spawning season in midsummer. It seems probable, therefore, that the period of stagnation is determined more by a voluntary fast during the spawning season than by any actual shortage of food, and that individuals which have not arrived at sexual maturity subject themselves to this annual fast, though not to the same extent as the mature specimens. This voluntary-fast theory is further borne out by the observations of Masterman (5), who in a most careful critique of the previous work on salmon points out that a certain number of salmon captured at sea throughout the summer show no evidence of summer feeding. He concludes that some salmon start their spawning-fast many months before entering fresh water. This may cause the age of salmon to be underestimated in some cases, and certainly throws grave doubt on Johnston's claim that he can tell approximately the month of entering fresh water. In the case of trout there is no evidence of prolonged fasts, except during the spawning season, which occurs in midwinter, and it is of little importance whether the cause be lack of appetite or lack of food. There is some evidence to show that in Canterbury the maximum rate of growth, especially amongst the larger fish, occurs in spring rather than in summer. It is probably quite safe to assume, however, that the period of stagnation occurs in the winter.

Roughly speaking, a trout-scale (Plate I, fig. 1) consists of a transparent plate of more or less elliptical form, having its centre of growth approximately at one of the foci. Surrounding this and roughly concentric with the outer edge of the scale are a number of lines or "circuli." The scale grows by the addition of these circuli round the periphery, which are added in greater numbers and more widely spaced during the periods of rapid growth. This alternate spacing and crowding produces light and dark zones, one light and one dark corresponding to a complete year's growth. The dark zones are called "annuli," or "winter bands."

In the case of spawning fish the stagnation is more complete, and the winter band is narrower and more clearly defined. In salmon (*Salmo salar*) the act of spawning leaves a clearly defined scar or "spawning-mark" on the scales, due to disintegration or reabsorption of the scale, especially along the lateral edges and the outer surface containing the circuli. A true spawning-mark is not very common in trout, but the character of the winter bands gives a fairly reliable indication of spawning. Plate I, fig. 1, shows one such winter band.

The exact cause of the spawning-mark in salmon is still in dispute. Johnston (4) attributed it to the vicissitudes of river life, whereby the fish shrank in girth, and says, "The compression of imbricated scales tends to increase the amount of overlap, and from this or dermic influences we find that their margins become ragged or frayed." Masterman (5) has shown that this fraying or erosion in many cases starts long prior to the fish's entry into fresh water, and concludes that the phenomenon is one of "erosion or absorption by the living tissue which is known to envelop the scale." Two possible explanations are suggested: "The process may be an anticipatory reduction of the size of the scale to meet the approaching reduction in the girth of the body, or it may be connected directly with the formation and development of the ova."

In Canterbury the spawning-mark is by no means so uncommon in trout as it appears to be in England and Norway. With male fish of considerable size (say, over 24 in.) it is rather the exception to find scales that do not show a definite spawning-mark—at any rate, in the Selwyn River (see Plate III, fig. 2). In females the act of spawning seems to leave a less decided scar, and most of the cases come within the region of uncertainty mentioned by Masterman, and introduce the personal element. In handling a large number of spawning fish this year, whilst collecting scales, I found that I could in almost every case detect the males by the texture of the skin. The males had a thick tough outer skin, and great difficulty was experienced in removing the scales, whilst no such covering was present in the females, and the scales were easily removed. Under the microscope the scales themselves were in many cases readily distinguished, those of the males being very much more eroded than those of the females. The ripe testes form a very much smaller proportion of the total weight of a male than the ripe ova of a female, so it is natural to suppose that the wastage of tissue in producing the former would be less than in producing the latter, and the shrinkage in milting is certainly less than in spawning, yet the scale-erosion is greater in males. All this seems to suggest that scale-erosion at spawning-time, in trout at any rate, is intimately connected with the production of the thick tough skin assumed by the males. Dahl has noticed that the erosion of scales in spawning salmon is more pronounced in the males, but apparently attaches no significance to his observation. In many cases it is a matter of opinion whether there is a spawning-mark corresponding to any particular winter on a trout-scale, but of the thirteen tagged fish from which I have scales every one shows, if not a distinct spawning-mark, at least a sharply defined winter band, such as the third winter band in Plate I, fig. 1, corresponding to the winter when the fish was stripped and tagged. I think it is probable that such winter bands are tolerably reliable evidence of spawning, but there is an almost perfect gradation from the broad ill-defined bands of the first two winters in Plate I, fig. 1, and many cases must always remain doubtful.

Dahl (1) assumed that the scales grew in the same proportion as the fish, and consequently that the distances from the centre of growth to the successive winter bands would be in the same ratio as the lengths attained by the fish in each successive winter. This assumption was almost in the nature of a corollary from what was previously known of the formation of winter bands, but experimental proof was desirable. Dahl and others have collected such a wealth of indirect evidence in favour of this hypothesis that there is little danger in accepting it as the basis of my investigations. Direct evidence, however, is difficult to obtain, and is meagre. As the whole of the present investigation depends on the truth of Dahl's hypothesis, it will be as well to add my small quota, more especially as Masterman and others have raised the objection that direct evidence is almost, if not entirely, lacking.

The North Canterbury Acclimatization Society annually strips a number of trout in the Selwyn River for piscicultural purposes, and takes the opportunity to tag two or three hundred fish each year with a small silver label bearing a distinctive number; at the same time particulars of length, weight, and sex are recorded. Through the kindness of the society, and of anglers who have had the good fortune to recapture tagged fish, I have secured scales from thirteen of these fish when recaptured, and have calculated from these scales the length of each fish when tagged.

The following table shows the length when recaptured: the length (*a*) actual, measured at time of tagging, and (*b*) calculated from the scales; together with the difference in each case between the calculated and the measured lengths:—

Log No.		Tag. No.	Length when recaptured.	Tagged Length. (*a*) Measured.	Tagged Length. (*b*) Calculated.	Difference
			Inches.	Inches.	Inches.	Inch.
B 25	..	1101	21½	19½	20	½
B 26	..	1074	21	20	19¾	¼
B 27	..	1037	21	20	19½	½
B 28	..	1088	22½	20	20	0
B 136	..	1374	23	21½	21½	0
B 147	..	1401	28	27	27¼	¼
B 159	..	1398	21	20	20	0
B 236	..	1095	21½	19	19¼	¼
B 246	..	1352	22½	21	21	0
B 253	..	1346	22½	21	21¼	¼
B 277	..	1428	20½	19	18¾	¼
B 278	..	1380	22¼	21¼	21¾	½
B 284	..	1304	21	19	19¼	¼

In no case is the difference between the calculated and the measured length more than ½ in., and in only three cases is it so much, whilst in four cases the agreement is exact. Considering the difficulty of measuring two or three hundred live fish accurately, these results may be taken to fall well within the limits of experimental error in measuring. In practice the fish are generally measured to the nearest ½ in., and an error of ¼ in. at time of tagging and another ¼ in. when recaptured would be sufficient to account for the largest discrepancy of ½ in.

Two scales taken from one of these fish (tag No. 1374) at different times are shown (Plate II, figs. 1 and 2). The scale in Plate II, fig. 1, was taken on the 17th June, 1917, when the fish was tagged, and measured 21½ in. The scale in Plate II, fig. 2, was taken on the 28th October, 1917, when the fish was recaptured, and measured 23 in. The lengths each winter, calculated from a set of scales taken in June and a set of scales taken in October, are as follows:—

Winters	..	..	1	2	3	4	5	6	7
June scales (inches)		..	5	8½	14½	17¼	19¼	21½*	..
October scales (inches)		..	4½	8¼	14¼	17	19	21½	23*

* Actual measured length.

Two fairly well-defined spawning-marks are shown in Plate II. fig. 2, and the space between the outer spawning-mark and the edge of the scale represents the growth of the fish between June and October. This growth ($1\frac{1}{2}$ in.) certainly appears large as against $2\frac{1}{2}$ in. for the whole of the previous year. It seems, however, to be a pretty general rule that the most vigorous growth takes place in the spring, and very little after midsummer, except perhaps in quite young fish. It should also be noted that the posterior end of this scale is well developed. This is usually a characteristic of vigorous growth, and this portion of the scale is usually the first to be eroded when deterioration sets in.

It has been objected that scales are not permanent, but are shed and replaced by new scales. There may have been something in this objection until Dahl pointed out that scales with the so-called "expanded centre of growth" were in reality "replacement scales," and supplied the connecting-link in a drawing of a scale which had been displaced in its socket but not actually lost. Plate I. fig. 2, shows a particularly fine example of such a "displacement scale," and is of itself almost convincing proof that normally scales are retained throughout a trout's life, and grow with the fish by additions round the outer edge.

The Material.

The material examined consists of three samples comprising respectively 33, 140, and 65 fish taken from the Selwyn River on the occasion of the annual stripping by the Acclimatization Society in 1915, 1917, and 1918 respectively, and smaller samples from several other rivers and lakes I shall deal with each separately.

Selwyn River.

Table I (A) gives the complete figures for thirty-three fish, all males, stripped in the Selwyn in June, 1915. The scales were collected by Dr. C. Morton Anderson, who kindly handed them over to me. It is interesting to note that these scales had been simply folded up in paper for nearly two years when I received them, and had not deteriorated during that time.

The second parcel of scales was taken by myself on the 17th June, 1917, and consists of scales from 140 fish, all being females except one, a particularly large male weighing 10 lb. The full figures are given in Table I (B).

The average growth-curves are shown in fig. 1. The curve for the 1915 fish is a broken line, and that for the 1917 fish a continuous line. On the same diagram are also shown the curves for 173 fish from Lake Mjosen, in Norway, plotted from figures given in Dahl's book. The broken line again is the curve for males, the continuous line for females. In each case the males continue vigorous growth for a longer period than the females, and eventually outstrip them. As the males were from fish taken in 1915 and the females from fish taken in 1917, I thought it desirable to test this apparent difference between the sexes further, and with that object collected scales from twenty-nine males and thirty-six females at the annual stripping this winter (1918). The full figures are given in Tables I (C) and I (D). The average growth-curves are shown in fig. 2. Again the males continue vigorous growth longer and attain a greater size than the females.

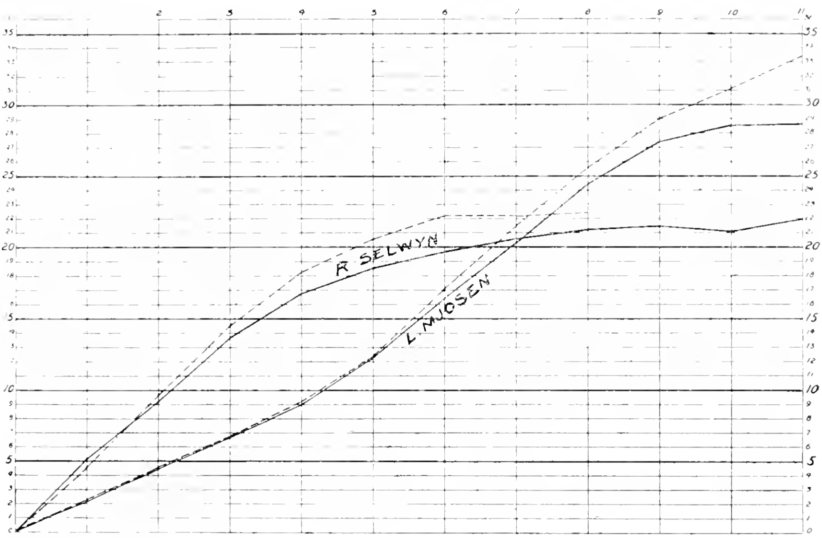


FIG. 1.

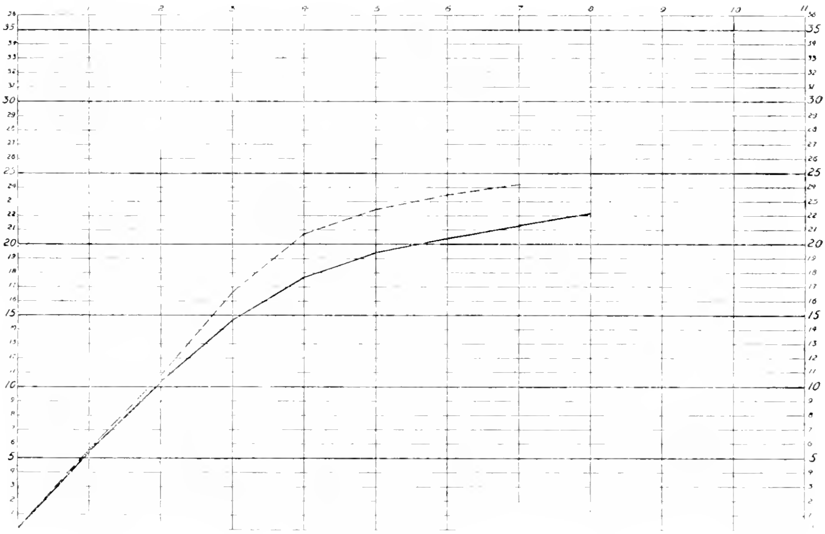


FIG. 2.

From the Acclimatization Society's records I have calculated the average length of the fish tagged each year since 1915. The figures in parentheses give the number of fish measured :—

1915—Males, 20·8 in. (100) ; females. 20·1 in. (98).
1916—Females, 19·3 in. (199).
1917—Females, 20·4 in. (140).
1918—Males, 22·6 in. (66) : females, 21·5 in. (156).

In the years 1915 and 1918, when both sexes were tagged, the males averaged about 1 in. longer than the females. The average lengths of the samples from which I took scales are as follows :—

1915—Males, 21·3 in. (33).
1917—Females. 20·4 in. (140).
1918—Males, 22·5 in. (29) ; females, 21·7 in. (36).

These figures agree closely with the averages for the total fish measured, so the samples were in all probability fairly representative. The year 1918 was remarkable both for the number and large size of the spawning fish. The average ages [see Tables I (A) to I (F)] indicate that the males either have a shorter life, or cease to run up the river at an earlier age. This bears out the general belief that the spawning mortality is greater amongst the males.

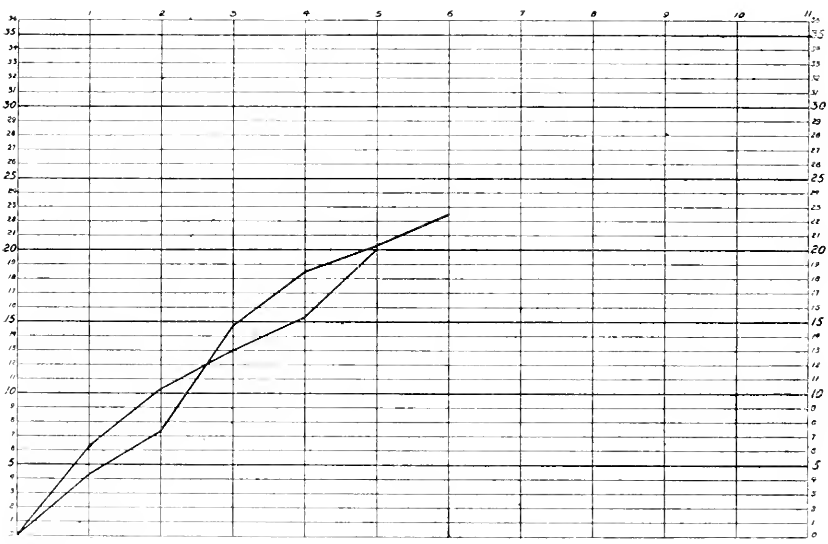


Fig. 3.

A point to notice in these curves is that they are nearly straight lines for the first four years. This does not mean that each individual fish increases in length by approximately the same amount each year up to four years old. So far as my experience goes, growth of this character is almost unknown amongst trout in Canterbury, although such apparently is not the case in Norway. In Canterbury I have found that unless some outside influence is at work the rate of growth almost invariably starts to decrease quite appreciably in the third year, and this decrease is

1

2

Fig. 1. Brown trout, ♀, 20 in., 4 years; Selwyn River, 17th June, 1917; B 48 [Table 1 (B)].
Fig. 2. "Displacement" scale, from Rakaia River; taken from the same fish as fig. 2 of Plate IV.

Face p. 48.]

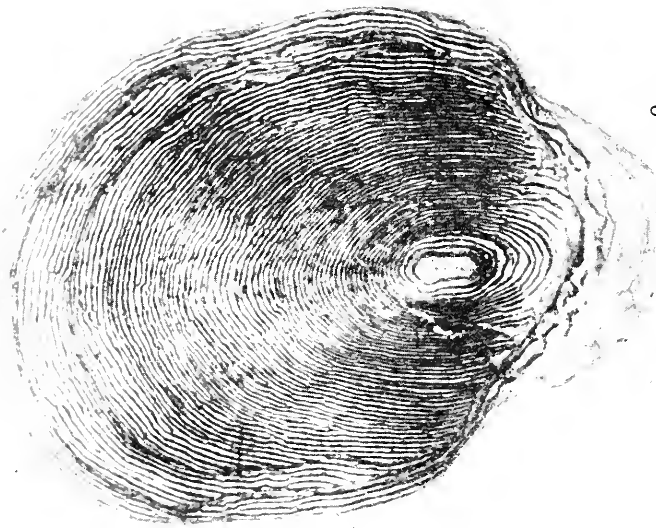


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FIG. 1. Brown trout, ♀, 21½ in., 6 years; Selwyn River, 17th June, 1917; B 105 [Table I (B)]. (First and second winter bands not well shown in photograph.)

FIG. 2. Brown trout, ♀, 23 in., 6 years 4 months; Selwyn River, 28th October, 1917; B 136 [Table I (E)]. (Taken from the same fish as fig. 1 of this plate. Note the new growth, corresponding to 1½ in. increase in length.)

1 2

Fig. 1. Brown trout, ♀, 22½ in., 6 years; Selwyn River, 17th June, 1917; showing migration after second winter: B 107 [Table I (B)].

Fig. 2.—Brown trout, ♂, 22 in., 5½ years; Lake Ellesmere, 17th November, 1917; showing migration after fourth winter, and pronounced spawning-mark in fifth winter: B 151 [Table I (E)].

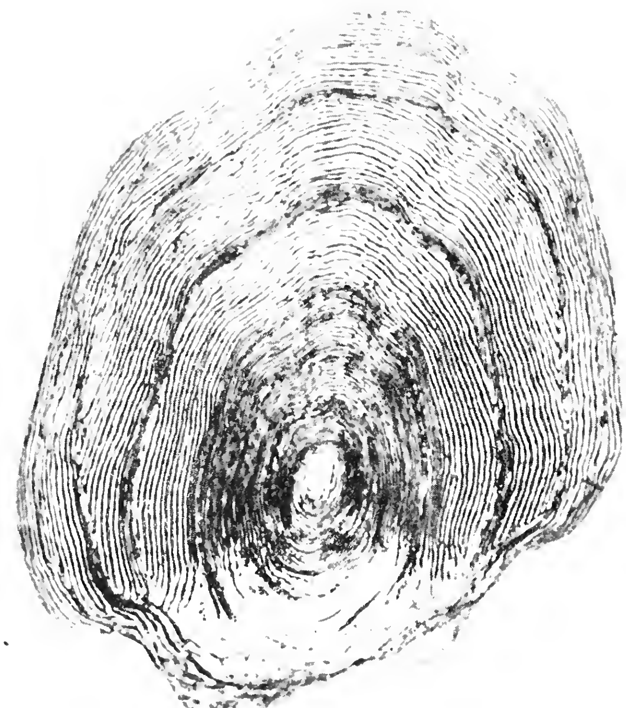

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Fig. 1. Brown trout, ♀, 26½ in., 8 years (nearly): Opihi River, 28th March, 1918: showing 4 years of poor growth in river followed by 4 years of vigorous growth subsequent to migration. Length at completion of each winter, 4¾ in., 7¼ in., 9 in., 10½ in. 16 in., 21½ in., 24¼ in., 26½ in..

Fig. 2. Brown trout, ♂, 25 in., 4½ years: Rakaia River, 12th January, 1918; second winter band divided: B 190 [Table III]. (From same fish as fig. 2 of Plate I.

more marked in the fourth year. A close examination of the figures in Tables I (A) to I (F) will show that in practically every case there is one year for each fish in which it has made more than normal growth; it may be the second, third, fourth, or fifth year, but in almost every case there is this break in the growth-curve. This sudden jump or break is generally attributed to migration to more favourable surroundings, and there is every reason to believe that this is the case with the Selwyn fish. Practically all the spawning in the Selwyn takes place in the shallow, shingly part. Except in the spawning season, fish of any considerable size are rare in this part of the river. The traps are set just about the junction of the shallow water and the deep, to catch the fish working up to the spawning-beds. Consequently every fish caught has come from the deep water. Probably every fish was hatched and spent its early youth in the shallow part of the river; therefore at some period it must have migrated to deep water. An examination of its scales will generally disclose when that migration took place. The average curves, therefore, are really compounded of a number of different curves representing one-, two-, three-, four-, and possibly five- and six-year-old migrants. In fig. 3 are shown typical curves for a two-year-old and a four-year-old migrant. Plate III, figs. 1 and 2, show scales from these fish respectively, in which the period of better growth subsequent to migration is very distinctly shown. Whenever an average growth-curve closely approximates to a straight line for four or five years it is a fairly definite indication that the fish from that locality are migratory.

Table I (E) shows the figures for thirteen trout caught last summer with rod and line at the mouth of the Selwyn and other streams running into Lake Ellesmere. The average rate of growth is about the same as that of the 1915 males, or intermediate between those of the 1918 males and females.

In order to ascertain whether results in any way reliable could be obtained from smaller samples I calculated the average growth for the first, second, third, &c., twenty fish in Table I (B). Considering the very complex nature of the water, the agreement is quite satisfactory, and indicates that results of some value can be obtained from quite small samples.

Trout in the Selwyn, whatever the mode of growth, seem to have a more or less fixed limit of growth at about 23 in., which is rarely exceeded. Other waters also seem to show a maximum size-limit. It is curious, however, that this limit is occasionally considerably exceeded, and not necessarily by very old fish. These abnormally large fish, so far as I can ascertain, show no peculiarity of growth common to all, but their scales seem on the average unusually broad in proportion to their length, though I am at present unable to state this definitely. Whether the large size is determined by heredity or by unusually favourable environment I cannot say, though I am inclined to attribute it to the former. It is certainly a point worthy of further investigation. Particulars of five of these abnormally large fish are given in Table I (F).

Rivers.

From the angling point of view the rivers of Canterbury may be divided into two classes—snow rivers and rain rivers. The former contain large trout, for the most part, of sea-going habits; the latter comparatively small trout, which are not as a general rule migratory.

The material which I have examined up to the present consists of a quite inadequate number of fish from several rivers of each class.

In Table II particulars are given of thirty-five fish from the Cam, North Branch of the Waimakariri, Styx, Selwyn No. 2, Opihi, and Tengawai, all of which I class as rain rivers. There are individual differences, but the average rate of growth in all these is very similar. The average for the whole thirty-five fish is—

Winters	1	2	3	4	5	6
Inches	4·6	9·0	12·0	13·7	14·7	17·7

In Table III particulars are given of nineteen fish from the Ashley, Waimakariri, and Rakaia. The figures for the Ashley and the Rakaia agree very closely, but the figures for the Waimakariri are nearer to those for the rain rivers. The probable reason for this is that four out of the seven fish were taken from the Belfast branch of the river, which is frequently very low, and probably contains only a small percentage of sea-going fish. The average for the whole nineteen fish is—

Winters	1	2	3	4	5	6	7	8	9
Inches	4·7	9·7	14·3	17·1	19·7	21·1	19·5	21·5	22·7

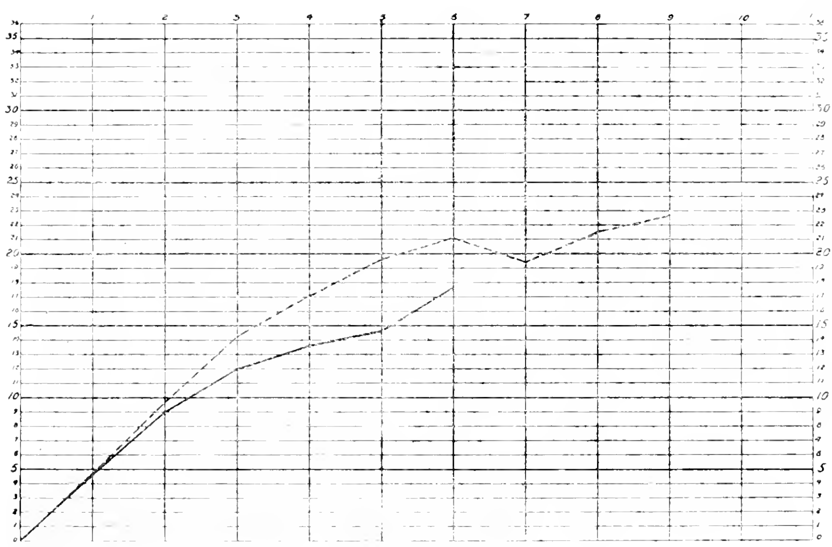

Fig. 4.

The averages for seven-, eight-, and nine-year-old fish are the figures for one fish only, an old jack from the Rakaia, which showed no sign of ever having been in the sea. The growth-curves plotted from these figures are shown together in fig. 4 for comparison—the rain-river fish by a continuous line, the snow-river fish by a broken line.

The points to notice are that, although the rate of growth is approximately the same in each class for the first two years, the rain-river fish fall off rapidly in the third, fourth, and fifth years, whilst in the snow-river fish a good growth is maintained. The growth-curve for the snow-river fish is a typical curve for a sample of which the individuals have migrated to more favourable surroundings at varying ages. Probably no individual fish has a growth-curve of this type, but the average curve is compounded of several different types representing the one-, two-, three-, and four-year-old migrants respectively. The sudden jump during the sixth year in the rain-river curve is the result of two fish only, and no importance attaches to it.

It may seem rather arbitrary to include the Opihi as a rain river and the Ashley as a snow river. Each of these rivers is more or less on the border-line. Sea-going fish frequent each, and each contains a large number of small fish which have not been to sea, though possibly they may go later. It so happens that all my examples from the Opihi, which were caught in November, 1917, near the junction with the Tengawai, belonged to this latter class, whilst all the Ashley fish were largish fish which had probably been to sea.

In view of the exceptionally poor growth of the Opihi and Tengawai fish, it would be most interesting to get scales from some of the large sea-run fish for which the Opihi is so famous, and to see whether these represent a later stage in the development of fish which as three- or four-year-olds had averaged only 10 in. to 12 in., or whether they belong to a different race. The matter is of some importance to the South Canterbury Acclimatization Society. If these poorly developed three- and four-year-olds are practically the "parr" stage of the larger sea-going trout the present condition of the Opihi is healthy; if not, then in my opinion it is carrying a stock far in excess of its food-supply.*

Plate IV, fig. 2, shows a scale from one of the Rakaia fish, and is an example of a very clearly marked scale, which is none the less difficult to read. The first winter band is clearly shown, and so is the second; but immediately outside the latter is another darkening; there is then a space indicating rapid summer growth, and the rest of the scale is normal. If this peculiarity existed in one scale only it might be attributed to some accident to or displacement of that particular scale. I have ten scales from this particular fish, and every one of them shows the same peculiarity. It has some meaning if one could only find it out. With some diffidence I offer the following explanation: The fish lived in the stream where hatched—probably the Rakaia—throughout the first year and the second summer and autumn; when the second winter band was nearly complete it migrated to the sea, and immediately responded to the stimulus of sea-water. The stimulus, however, was short-lived, and winter stagnation again set in, causing the third check. So the second and third checks are really one winter band divided by a short period of rapid growth in winter, due to the tonic effect of sea-water. I have met this same peculiarity in one or two other fish from the Rakaia.

Peculiarities such as this are not uncommon, and when they occur in one scale they invariably occur in every scale from the same fish, showing

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* Since writing the above I have received scales from two of the large sea-run fish of the Opihi, 26 in. and 26½ in. in length. The former appears to have migrated as a yearling when about 6 in. long, the latter as a four-year-old (possibly three-year-old) when about 10½ in. long. The early growth of this latter corresponds closely with that of the small Opihi fish previously mentioned. A scale from this fish is shown in Plate IV, fig. 1.

that they are the result of some peculiarity in that fish's growth. Whilst very puzzling, these peculiarities are encouraging, for they open up possibilities for fresh discoveries in scale-reading.

The Back-country Lakes.

The material examined comprises ten fish from Marymere, fifteen from Lake Heron, three from Lake Coleridge, and two from Lake Alexandrina.

Marymere.—The average growth in this lake is as follows:—

Winters	1	2	3	4	5	6	7	8	9
Inches	5·4	12·6	17·2	19·7	21·5	22·7	23·4	24·2	24·4

The full figures are set out in Table IV (A), and the growth-curve is shown in fig. 5. The most striking feature of the curve is the large growth made during the second year, which exceeds even that of the first year; and not only is this the case in the average curve, but it is true of every

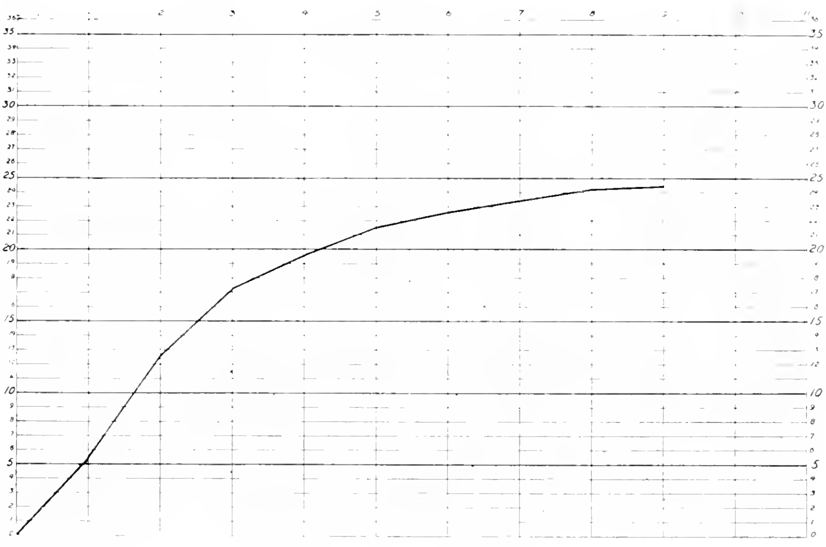

Fig. 5.

one of the ten fish examined, except one, in which the growth was equal for the first and second years. Such a state of affairs would generally be explained by saying the fish migrated at one year old to more favourable conditions. This cannot be the explanation in Marymere, as there are no streams running either into or out of the lake. It must be remembered, however, that the insects in our back-country districts are mostly large in size, and it seems probable that the true explanation is to be found in the fact that the main bulk of the food-supply is of a nature more suitable to fish after they have passed the yearling stage. Gilbert (2) has shown that quinnat and sockeye salmon which have migrated to the sea as fry a few months after hatching have very similar scales.

No brown trout have been liberated in Marymere since 1908, and so it is clear that they must breed in the lake itself, as three of the ten fish appear to have been hatched in 1914. It is curious that the next-youngest fish seems to have been hatched in 1911. In dealing with such small samples it is dangerous to generalize, but it certainly looks as if 1914 was an exceptionally favourable breeding season. Plate V, fig. 1, shows a scale from one of these fish hatched in 1914, and Plate V, fig. 2, a scale from one of the older fish. The latter illustrates clearly the difficulty in determining the age of old fish, owing to the way in which the winter bands are crowded together towards the edge of the scale. It is probable that the percentage of ova hatched in Marymere, except in very favourable seasons, is abnormally low, and that the stock of fish is maintained mainly by the greater average age attained. Whether this latter is due to natural causes or to the limited amount of angling I am unable to say, but it is a characteristic not only of Marymere but also of other back-country lakes. The average age is 6·4, calculated to last winter: and as these fish would probably all have survived until next spawning season their average age would then have been 7·4 years, or about $1\frac{1}{2}$ years older than the Selwyn fish.

Lake Heron.—The average growth is as follows:—

Winters ..	1	2	3	4	5	6	7	8	9	10
Inches ..	4·4	9·0	14·4	18·2	20·4	21·5	22·6	23·0	23·7	23·7

The full figures are set out in Table IV (B), and the growth-curve is shown in fig. 6 as a continuous line, the Marymere curve being reproduced

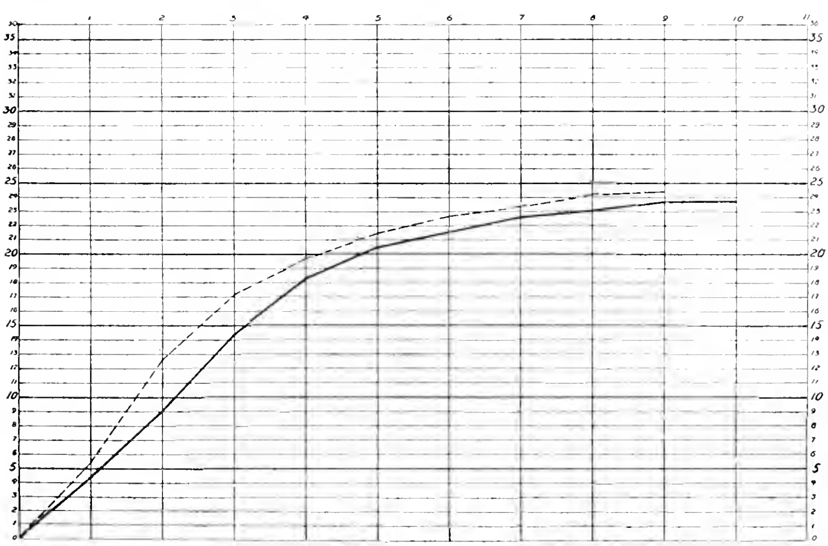

Fig. 6.

as a broken line for comparison. Although the size of the older fish approximates fairly closely to that in Marymere, the average length of the younger fish is distinctly lower, especially at two, three, and four years old. It is also noticeable that the curve is nearly a straight line for the first four years, and that even in the fifth year the falling-off is not very pronounced. In dealing with the Selwyn fish I pointed out that a curve of this character was to be associated with a sample of fish containing individuals which probably migrated to more favourable conditions at varying ages. An examination of the figures in Table IV (B) shows the characteristic increase of growth to have taken place in every case, and examples can be found of one-, two-, three-, and four-year-old migrants. Lake Heron differs from Marymere in that there are several small tributary streams flowing in and one fair-sized stream flowing out of it. In the spawning season these are packed with spawning trout. No doubt also a large number of trout spawn in the lake itself. I have selected five fish from the fifteen which appeared to have scales similar in character to the Marymere fish, and calculated the average rate of growth as follows:—

Winters	1	2	3	4	5	6	7
Inches	5·1	12·2	18·2	20·5	21·7	22·3	23·0

Fig. 7 shows the growth-curve for these, and the broken line shows the growth-curve for the Marymere fish. There is a difference of 1 in. at three years and 0·8 in. at four years old: elsewhere they agree to within 0·5 in.

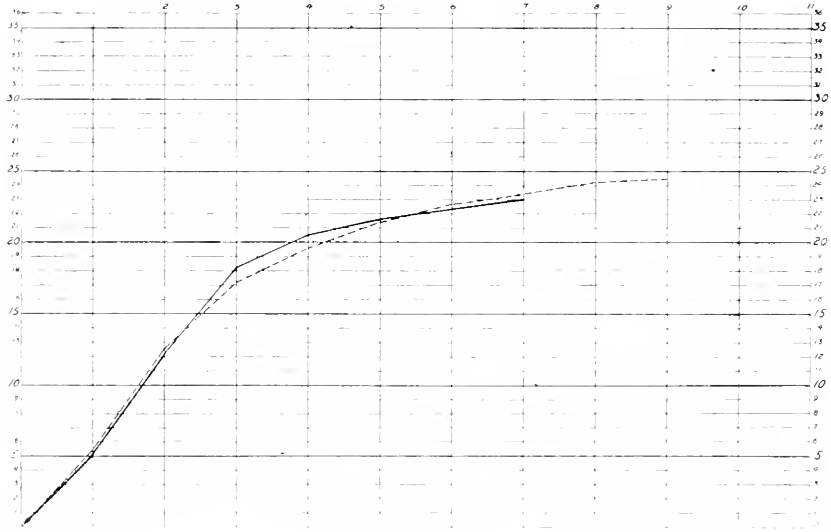

Fig. 7.

In dealing with such small samples the agreement is most remarkable, and suggests the probability that these fish were bred in the lake itself or migrated as fry.

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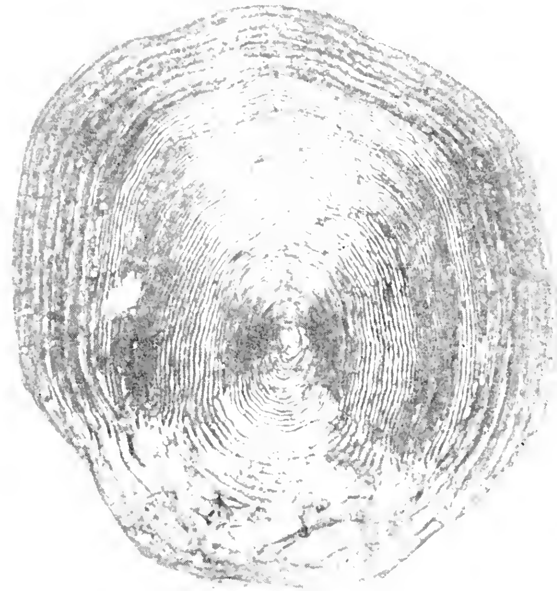

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Fig. 1. Brown trout, ♀, 21½ in., 4½ years; Marymere, 24th December, 1917; B 178 [Table IV].
Fig. 2. Brown trout, ♀, 26 in., 9½ years; Marymere, 25th December, 1917; B 189 [Table IV].

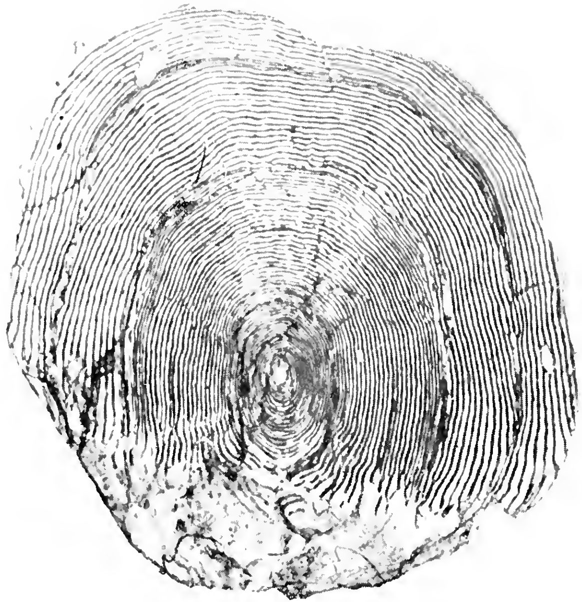

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Fig. 1. Brown trout, ♀, $10\frac{1}{2}$ lb., probably about $27\frac{1}{2}$ in., 3 years 5 months; Lake Coleridge, 5th November, 1917; B 141 [Table IV].
Fig. 2. Brown trout, ♀, $34\frac{1}{2}$ in., 17 lb., 4 years' poor growth followed by 4 years' vigorous growth and (probably) another year of little or no growth; Lake Coleridge, 10th March, 1918; B 218 [Table IV]

The average age—6·93 last winter or 7·93 at next spawning—is again high—higher than Marymere.

Lake Alexandrina.—This lake contains some very large fish, and the average size is certainly greater than in either of the last two lakes. Unfortunately, I have been able to obtain scales from only two fish: the figures for these are shown in Table IV (C).

Lake Coleridge.—This lake was first stocked with brown trout in 1868, and has for many years been noted for the exceptionally large size of its trout. I have been able to obtain scales from three fish only from this lake, but two of them are so remarkable that I have included a photograph of a scale from each fish. Plate VI, fig. 1, shows a scale from a fish of 10½ lb. captured about the 5th November, 1917. The length of the fish was not supplied to me, but would probably be about 27½ in., and I have made my calculations on this assumption. The fish seems to have been three years old in the winter of 1917, and shows a most remarkable growth since the last winter. The figures for each year are as follows:—

Winters	1	2	3
Inches	7	15¾	23½

This scale apparently belongs to the Marymere type, and the fish was probably bred in the lake. It is considerably larger than any three-year-old I have ever heard of. The second fish was captured on the 10th March, 1918. A photograph of one of these scales is shown in Plate VI, fig. 2. The fish weighed 17 lb. and measured 34½ in. in length. The scales are, I think, the most beautifully marked and at the same time the most interesting in my collection. Surrounding the centre of growth are four winter bands close together, denoting four years of poor growth. These are followed by a year of growth which, so far as I know, is quite unique. There is another year of good growth, and then two years of moderate growth. The last winter band is right at the edge of the scale, and it is perhaps open to question whether this represents the winter of 1917 or the beginning of the 1918 winter. The difficulty of reading the scale is increased by the fact that every scale is more or less broken or worn at the edge. The fish was an egg-bound female, and in this abnormal state it is unlikely that she would grow much. On the whole, I think it more probable that the winter band right at the edge of the scale represents the winter 1917, and that there has been practically no growth since then (represented by one or two rings only), and that the fish was going back in condition when caught, as is evidenced by the frayed lateral edges of the scale. On this assumption the figures are as follows:—

Winters	1	2	3	4	5	6	7	8
Inches	2½	4	8	10½	24	30	32½	34¼

The individual growth-curves for these two fish are shown in fig. 8. It is a fortunate coincidence that in three fish from this lake I should have hit on two such striking and extreme examples of different types of growth. The probable weight of the 17 lb. fish each year would be about—

Winters ..	1	2	3	4	5	6	7	8
Weight ..	1 oz.	4 oz.	4 oz.	8 oz.	$5\frac{1}{2}$ lb.	11 lb.	14 lb.	$16\frac{1}{2}$ lb.

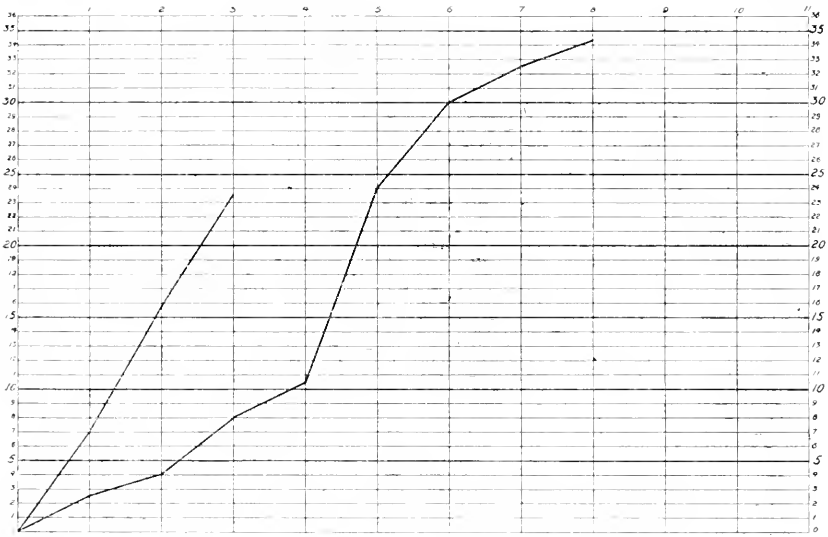

Fig. 8.

Conclusions.

1. The scales of a trout give fairly reliable evidence of age and length attained by the fish each winter.

2. Some scales are difficult to read, and errors may occur mainly in three ways: (*a*) The first one or two winter bands are often very indistinctly marked; (*b*) in very old fish the winter bands may be so crowded together towards the edge of the scale as to be indistinguishable—possibly in some cases the scale may cease growing altogether; (*c*) some scales, whilst clearly marked, are at present difficult to read: when this is the case all scales from the same fish present the same peculiarity.

3. A true spawning-mark is not uncommon amongst the large males, and is probably formed by absorption of the scale, especially the outer surface, in formation of the tough skin assumed by the males at spawning-time. In other fish the character of the winter band gives in many cases a tolerably reliable indication of spawning.

4. Under normal conditions trout increase but slowly in length after the third winter. Growth is most rapid in the first two years, and generally the first year shows the best growth of all.

5. Very rarely does a trout growing in this manner attain a large size (say, over 2 lb.). Large trout almost invariably show a break in the growth-curve when a year of rapid growth succeeds slower growth. After the rapid

growth has set in the growth follows the normal curve again, getting less every year. This break or jump is probably caused by migration to more favourable surroundings.

6. Trout which have been stunted by unfavourable conditions for four or even five years, and possibly longer, are still capable of rapid growth.

7. Any particular water seems to have a fairly definite maximum size of fish. In waters where this is large, such as Lake Ellesmere and the back-country lakes, the maximum size will be reached no matter what the age of migration, and the age of migration seems to have little or no effect upon the size ultimately attained.

8. Lake Ellesmere has a maximum size in the neighbourhood of 23 in., but some fish considerably exceed this. Whether this is due to an inherited tendency to rapid growth or to some specially favourable circumstances I cannot at present say. It is certainly a point worthy of investigation.

9. In Canterbury trout grow much more rapidly in the early stages than in Norway, but the growth slows down earlier. The very large Mjosen trout are mostly very old, and still growing vigorously. The average age of migration is also much higher there than in Lake Ellesmere, for instance.

10. Yearling trout average about 5 in. in Canterbury, as calculated from the scales. From Victoria Lake 112 yearling trout averaged 6 in., but the conditions there are certainly more favourable than the average. In Norway yearling trout average about 2 in. (Dahl).

11. Lake Coleridge seems to favour the most rapid growth of all. The sea is slightly more favourable than Lakes Heron, Marymere, and Ellesmere, which are about the same.

12. Except in very complicated waters, a fair idea of the average growth can be obtained by examining small parcels of ten to twenty fish, provided they are of fair age and fairly representative.

I take this opportunity of expressing my thanks to Dr. Chilton for much kindly instruction in microscopy, and to the North Canterbury Acclimatization Society and many anglers for assistance in collecting scales. The photographs are by Messrs. Leghorne and Colgan, of the Radia Studio, to whom I am much indebted for their infinite pains and trouble to secure the best possible results.

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Table I (A).

Thirty-three Trout from Selwyn Stripping, June, 1915.

Log No.			Sex.	Length each Winter. 1	2	3	4	5	6	7	8
				In.	In.	In.	In.	In.	In.	In.	In.
A 11	..	..	M	3½	6½	11	18	20	22	..	..
A 12	..	..	M	5	10	14	22	23½	..	..	..
A 13	..	..	M	6¾	13½	17¾	20¼	22	22½	..	..
A 15	..	..	M	3¼	5¾	10	19	21¼	23¼	..	..
A 16	..	..	M	3½	7	11½	15¾	20½	22½	..	..
A 17	..	..	M	3	6¼	12½	14¾	20½	21¾	25	..
A 21	..	..	M	4½	8	14½	16½	19	..	..	..
A 22	..	..	M	5	10½	14¾	18¾	21¼	22½	..	..
A 23	..	..	M	7¼	12	17	..	..	..	..	..
A 24	..	..	M	3½	6½	12¾	16½	20½	22	..	..
A 25	..	..	M	3	6	12¾	18½	21¾	23	..	..
A 26	..	..	M	6¼	9¾	14¼	17¾	21	..	..	..
A 27	..	..	M	5	8½	10¾	15	19½	20¼	21	22½
A 30	..	..	M	6¼	12	18	20	20¾	22	..	..
A 31	..	..	M	6	14¼	18¼	20	..	..	..	..
A 32	..	..	M	6	10¾	18½	23	25	..	..	..
A 33	..	..	M	6½	14½	17	20	21¾	23½	..	..
A 34	..	..	M	4½	7½	9½	12	16	..	..	..
A 35	..	..	M	4	15¼	18	19	20½	21½	22	..
A 36	..	..	M	6	14	18¼	19½	21¼	22½	..	..
A 37	..	..	M	3½	6½	13½	17	19¾	22	23	..
A 38	..	..	M	3½	6¼	12	18½	19½	..	..	..
A 39	..	..	M	3½	9½	18½	..	..	..	..	..
A 40	..	..	M	5¾	10	18½	23	..	..	..	..
A 41	..	..	M	5½	12¾	17½	20¼	23½	25	..	..
A 42	..	..	M	3½	7	12½	15½	17¾	21	..	..
A 43	..	..	M	3¼	7½	10½	15½	17½	..	..	..
A 44	..	..	M	6¼	12	18½	21½	23	..	..	..
A 45	..	..	M	4½	10½	13	18¼	21¾	..	..	..
A 46	..	..	M	4¾	11½	18½	..	..	..	..	..
A 47	..	..	M	6	12½	18½	20½	..	..	..	..
A 48	..	..	M	3¼	8¼	12½	16½	19	19½	20	..
A 49	..	..	M	4¾	7	11½	17½	..	..	..	..
Averages		..	..	4·7	9·7	14·7	18·3	20·7	22·2	22·2	22·5

Average age .. .. 5·4
Average length .. .. 21·3
Average length of 100 males marked in 1915 .. .. 20·8

TABLE I (B).

140 Trout from Selwyn Stripping, 17th June, 1917.

Log No.	Sex.	Length each Winter.										
		1	2	3	4	5	6	7	8	9	10	11
		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
A 50 ..	F	7½	13	15	17¾	20¼	21	21½	..	..	..	..
A 51 ..	F	4	7½	12½	18½	20	..	..	..	..	..	..
A 52 ..	F	5¾	8¼	13½	16½	18¾	21¾	..	..	..	..	..
A 53 ..	F	4¼	7¾	17	20½	..	..	..	..	..	..	..
A 54 ..	F	4½	7½	13¾	18½	21	..	..	..	..	..	..
A 55 ..	F	3½	7¼	11½	15½	17¾	19	20¼	..	..	..	..
A 56 ..	F	6½	12	18½	20½	21¾	23	..	..	..	..	..
A 57 ..	F	4¾	7¾	12	17¼	20	21½	23	..	..	..	..
A 58 ..	F	4	7½	9¾	13	14¾	17	19	20½	21½	..	..
A 59 ..	F	3½	7	11	13¾	16¾	18¼	19½	..	..	..	..
A 60 ..	F	6¾	12½	18½	..	..	..	..	..	..	..	..
A 61 ..	F	6¾	10¼	14	18½	21	..	..	..	..	..	..
A 62 ..	F	4½	8¼	12¼	14½	17½	19½	20¾	..	..	..	..
A 63 ..	F	4½	7¾	13½	16	17¾	19	..	..	..	..	..
A 64 ..	F	5½	10	13½	16	18	19½	..	..	..	..	..
A 65 ..	F	6½	11	14½	16¾	18	19	19¾	20½	..	..	..
A 66 ..	F	5¾	12	18	..	..	..	..	..	..	..	..
A 67 ..	F	5¾	10	14½	18	19¼	20¼	21	..	..	..	..
A 68 ..	F	5¾	10½	14¼	16½	18½	20½	..	..	..	..	..
A 69 ..	F	7	10½	13¾	17	18¾	20½	..	..	..	..	..
A 70 ..	F	7	14¾	17½	18½	20½	..	..	..	..	..	..
A 71 ..	F	4½	9	12¼	16	18¼	20½	..	..	..	..	..
A 72 ..	F	3½	7½	12½	19	..	..	..	..	..	..	..
B 1 ..	M	5	8½	17	22½	27	..	..	..	..	..	..
B 2 ..	F	6½	12½	18½	..	..	..	..	..	..	..	..
B 3 ..	F	6½	12	14½	16	17¼	18	18¾	19½	20½	..	..
B 4 ..	F	5	8	10½	14¼	16¼	19¼	20¼	21	..	..	..
B 6 ..	F	4	7½	10½	16¾	20	23	..	..	..	..	..
B 7 ..	F	4½	9½	16½	18	19	20	20¾	21½	22	..	..
B 8 ..	F	4	9	14½	17	19¼	20½	22¼	..	..	..	..
B 9 ..	F	7	13	16	18½	..	..	..	..	..	..	..
B 10 ..	F	6¼	9¼	13¼	17½	..	..	..	..	..	..	..
B 11 ..	F	5¾	13½	19	..	..	..	..	..	..	..	..
B 12 ..	F	4½	10¼	14¼	17¼	19½	..	..	..	..	..	..
B 13 ..	F	4½	8	14	16	18½	20	..	..	..	..	..
B 14 ..	F	5	14	19½	..	..	..	..	..	..	..	..
B 15 ..	F	3	7	12¾	16½	18½	..	..	..	..	..	..
B 16 ..	F	6	10	17¼	19	21	..	..	..	..	..	..
B 17 ..	F	7½	13¼	18	..	..	..	..	..	..	..	..
B 18 ..	F	4¾	8¾	15	17¼	18½	21	..	..	..	..	..
B 19 ..	F	4	8½	12	17½	..	..	..	..	..	..	..
B 20 ..	F	6¼	11½	15¾	18¾	20	21½	..	..	..	..	..
B 21 ..	F	5	9	13	16½	18¼	20	..	..	..	..	..
B 23 ..	F	7	13¾	16¾	18¾	20	21¼	22	22½	..	..	..
B 24 ..	F	5	10¼	18	19¼	21	..	..	..	..	..	..
B 25 ..	F	6¼	10¾	15	18	20	21½	..	..	..	..	..
B 26 ..	F	7¾	11¾	15	17¾	19¾	21	..	..	..	..	..
B 27 ..	F	6¾	12½	15¼	18	19½	21	..	..	..	..	..
B 28 ..	F	6	9¾	12	14¾	18½	20	22½	..	..	..	..
B 29 ..	F	4	7¼	13½	19	..	..	..	..	..	..	..
B 30 ..	F	5½	9	11½	14	16½	20½	..	..	..	..	..
B 31 ..	F	4¾	9½	12½	14½	17¼	19	..	..	..	..	..

TABLE I (B)—*continued.*

140 Trout from Selwyn Stripping, 17th June, 1917—continued.

Log No.	Sex.	Length each Winter.										
		1	2	3	4	5	6	7	8	9	10	11
		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
B 32 ..	F	7	11¼	14¼	17½	20	..	..	..	..	..	..
B 33 ..	F	5½	10¾	16	19¾	21¼	..	..	..	..	..	..
B 34 ..	F	6¼	12½	18½	..	..	..	..	..	..	..	..
B 35 ..	F	6¾	12¾	16¼	17¾	18¾	20	21	..	..	..	..
B 36 ..	F	5½	7¼	13¼	19	..	..	..	..	..	..	..
B 37 ..	F	7¼	12¼	16¼	18½	..	..	..	..	..	..	..
B 38 ..	F	6¾	13¼	18½	..	..	..	..	..	..	..	..
B 40 ..	F	3½	7¾	13½	17½	19½	21½	..	..	..	..	..
B 41 ..	F	7	11¾	14¾	18	19½	..	..	..	..	..	..
B 42 ..	F	8¼	11	14½	17	19½	21	..	..	..	..	..
B 43 ..	F	5½	7¾	8¾	14¾	16½	20½	21¼	22	23	..	..
B 44 ..	F	6½	11	15¼	17½	20	..	..	..	..	..	..
B 45 ..	F	7¼	11¼	14¾	17	18¼	19½	20½	..	..	..	..
B 46 ..	F	3½	7	14½	17	18½	20½	..	..	..	..	..
B 47 ..	F	3¾	6¾	9½	12½	15½	18	19¼	21¼	..	..	..
B 48 ..	F	5½	11¼	17	20	..	..	..	..	..	..	..
B 49 ..	F	3¾	7¼	11¼	15¼	19	20½	..	..	..	..	..
B 50 ..	F	6¼	12	16¾	18¾	19½	21	..	..	..	..	..
B 51 ..	F	4	7¼	13	18¼	21	..	..	..	..	..	..
B 52 ..	F	4½	11	17	18¾	20½	..	..	..	..	..	..
B 53 ..	F	4½	10¾	15½	17¾	18½	19	20	..	..	..	..
B 54 ..	F	3½	6	9¼	12¾	16¾	18½	..	..	..	..	..
B 55 ..	F	5½	8½	11½	15¾	19½	21½	..	..	..	..	..
B 56 ..	F	5	8¼	13¼	18½	..	..	..	..	..	..	..
B 57 ..	F	3½	7¾	11¼	15	18	19½	21	..	..	..	..
B 58 ..	F	5½	12	16½	19½	20½	21	22½	23	..	..	..
B 59 ..	F	5¾	8¼	13¾	16	18	19¼	20½	..	..	..	..
B 60 ..	F	5	12½	17	19	..	..	..	..	..	..	..
B 61 ..	F	6¼	8½	12¼	17	19¼	20½	..	..	..	..	..
B 62 ..	F	3¾	6¼	9	16¼	19¼	20	20½	20¾	21¼	21½	..
B 63 ..	F	4½	7¼	10¾	14¾	20½	..	..	..	..	..	..
B 64 ..	F	5¼	9½	14½	18¼	20½	..	..	..	..	..	..
B 65 ..	F	4¼	7¾	12¼	18	..	..	..	..	..	..	..
B 66 ..	F	5½	8¼	11½	15½	19¼	20¾	22½	..	..	..	..
B 67 ..	F	4½	8¾	13¾	16	17½	19¼	20½	..	..	..	..
B 68 ..	F	5¾	11¾	13¾	16½	18½	19¼	20½	..	..	..	..
B 69 ..	F	3¼	9	13	17	20½	..	..	..	..	..	..
B 70 ..	F	4¾	8¾	11½	18	..	..	..	..	..	..	..
B 71 ..	F	4½	9	13½	15½	17¼	19	..	..	..	..	..
B 72 ..	F	4¾	8½	13¼	17¼	19¾	21¼	23	..	..	..	..
B 73 ..	F	4¾	8¼	14	19	..	..	..	..	..	..	..
B 74 ..	F	3¼	5½	9	12¾	15¼	17¼	19	..	..	..	..
B 75 ..	F	6½	10¼	18	19½	21	..	..	..	..	..	..
B 76 ..	F	4½	7¾	12	18½	..	..	..	..	..	..	..
B 77 ..	F	5	8¼	11	13	15¼	17	19	20½	..	..	..
B 78 ..	F	4¼	8¼	13¾	18½	..	..	..	..	..	..	..
B 79 ..	F	3¼	5½	9¼	13¼	16	18	20	..	..	..	..
B 80 ..	F	5½	10½	11¾	19¼	21	..	..	..	..	..	..
B 81 ..	F	5¼	8¼	12¼	17	20½	21½	..	..	..	..	..
B 82 ..	F	3½	6½	9¾	13½	16¼	18½	21	..	..	..	..
B 84 ..	F	3½	8½	13¼	16½	18¼	20¼	..	..	..	..	..
B 85 ..	F	5¼	11	13¾	19	..	..	..	..	..	..	..
B 86 ..	F	5½	9½	11¾	15¾	18½	19¼	21	..	..	..	..

Table I (B)—*continued.*

140 Trout from Selwyn Stripping, 17th June, 1917—continued.

Log No.	Sex.	Length each Winter.										
		1	2	3	4	5	6	7	8	9	10	11
		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
B 87 ..	F	3¼	5½	10½	14¼	16½	18¼	19½	..	..	..	..
B 88 ..	F	3¾	9¾	15¼	17¾	19¼	21¼	22¼	23½	..	..	..
B 89 (*a*)	F	6¼	9	11¾	14½	17	18½	20	..	..	..	..
B 89 (*b*)	F	5¼	8¼	14½	19¼	21¾	22¼	23½	..	..	..	..
B 90 ..	F	4	6¾	13¼	17	17¾	19½	20	20½	..	..	..
B 91 ..	F	4¾	7	10	14¼	16	18	20½	..	..	..	..
B 92 ..	F	6	13	16	18¼	21½	..	..	..	..	..	..
B 93 ..	F	4	7½	11½	13¾	15½	17¼	18¾	19½	20	..	..
B 94 ..	F	5½	9¾	14¾	17	19¼	20	21¼	22	..	..	..
B 95 ..	F	4	7½	12¾	17½	19½	21	22½	..	..	..	..
B 96 ..	F	3¼	6	13¾	20	..	..	..	..	..	..	..
B 97 ..	F	3½	6½	13	15½	17¼	18¼	20	21¼	..	..	..
B 98 ..	F	5	8¾	11¼	13½	15½	18½	20½	22½	..	..	..
B 99 ..	F	4	10	12¼	14¾	17¼	18½	19½	..	..	..	..
B 100 ..	F	5¼	8½	10¾	13	16	18½	19½	21	..	..	..
B 101 ..	F	4	8	11½	14	15¾	17½	18	19	21	..	..
B 102 ..	F	8	12¼	15¾	18½	..	..	..	..	..	..	..
B 103 ..	F	4	7¼	11¼	13½	15	..	..	..	..	..	..
B 104 ..	F	4½	14½	19	21½	..	..	..	..	..	..	..
B 105 ..	F	5	8½	14¾	17¼	19¼	21½	..	..	..	..	..
B 106 ..	F	4	6¾	11	14	16¾	18	19½	..	..	..	..
B 107 ..	F	4¼	7¼	14¾	18½	20¼	22½	..	..	..	..	..
B 108 ..	F	4	7¾	11¼	13¾	16½	18½	20½	..	..	..	..
B 109 ..	F	4½	7½	11	15	18¼	19½	21	..	..	..	..
B 110 ..		4½	8¾	14	19½	..	..	..	..	..	..	..
B 111 ..	F	5	8¾	12¾	18	..	..	..	..	..	..	..
B 112 ..	F	4	7¼	9½	12	15¾	18	..	..	..	..	..
B 113 ..	F	5¼	11	18	..	..	..	..	..	..	..	..
B 114 ..	F	5¼	8½	13¼	19½	..	..	..	..	..	..	..
B 115 ..	F	5½	10¾	18	..	..	..	..	..	..	..	..
B 116 ..	F	3½	8	11	14	17½	20	20½	22	..	..	..
B 117 ..	F	6¾	12¾	16	18	..	..	..	..	..	..	..
B 118 ..	F	5½	11½	15¼	17¾	20¼	22	..	..	..	..	..
B 119 ..	F	2½	5	6	8½	11¼	14	15¾	18¾	19½	20¾	22
B 120 ..	F	4	8	15	17	18½	20¼	22½	23¼	24½	..	..
Averages		5·1	9·3	13·8	16·9	18·6	19·8	20·6	21·2	21·5	21·1	22·0

Averages for each Group of Twenty.

1st twenty ..	5·3	9·4	14·0	17·0	18·8	20·0	20·6	20·5	21·5	..	..
2nd twenty ..	5·2	10·3	15·3	18·2	19·6	20·3	20·5	20·7	21·2	..	..
3rd twenty ..	5·8	10·6	14·8	17·6	19·3	20·7	21·7	22·5	..	..	..
4th twenty ..	5·2	9·5	13·7	16·9	18·8	20·0	20·7	22·1	23·0	..	..
5th twenty ..	4·7	8·4	12·5	16·7	18·7	19·2	20·6	20·6	21·2	21·5	..
6th twenty ..	4·5	8·4	12·6	16·1	18·0	19·4	20·6	21·5	20·0	..	..
7th twenty ..	4·7	9·0	13·5	16·2	17·1	19·2	19·7	20·7	21·7	20·7	22·0

Average age .. .. 5·9
Average length.. .. .. 20·4

Table I (C).

Twenty-nine Trout (Males) from Selwyn Stripping, 16th June, 1918.

Log. No.	Length each Winter.						
	1	2	3	4	5	6	7
	In.	In.	In.	In.	In.	In.	In.
B 235	3½	6	13¾	20	..	..	..
B 237	4	7	14½	19½	22½	24½	..
B 239	3½	6	13½	18	20½	22	22½
B 240	5	13	17	19¼	21¾	23	..
B 241	3¼	7	15	..	..	..	..
B 242	4½	8½	13	20¼	21½	..	..
B 243	8¾	14¾	17¾	20	22¾	24	..
B 244	3¼	7	14	20½	22	23	..
B 247	6½	9¾	13½	21	23½	..	..
B 248	3¾	8¼	14¼	20¼	21½	24	..
B 250	6¼	13½	20½	..	..	..	..
B 251	6	14	19½	21¼	22½	..	..
B 252	6¼	15	22	26	..	..	..
B 254	6¾	13½	18½	21½	23½	..	..
B 255	7¾	14¾	20¼	22	..	..	..
B 256	7½	15½	21½	..	..	..	..
B 257	3½	6½	8	9½	17½	24	..
B 259	7	13¼	21	24	..	..	..
B 260	4	8	12½	21	23	..	..
B 261	4½	9	17	..	..	..	..
B 262	6¼	12½	20	23¾	24½	..	..
B 269	5¼	11¼	15	21	23	25	26
B 270	6½	13½	21¼	25	..	..	..
B 271	6¾	12¾	21¼	23¼	26½	..	..
B 276	4¼	9¾	17	21¼	23¼	24	..
C 3	6	15½	..	..	..	..	..
C 5	5¼	8¼	16½	19½	..	..	..
C 8	4¼	7¼	13½	18¼	20¾	22	..
C 13	8¼	15¼	20½	23½	25	..	..
Averages	5·5	10·9	16·8	20·9	22·5	23·5	24·2

Average age	4·8
Average length	22·5
Average length of sixty-six males marked in 1918	22·6

TABLE I (D).

Thirty-six Trout (Females) from Selwyn Stripping, 16th June, 1918.

Log No.	Length each Winter.								
	1	2	3	4	5	6	7	8	9
	In.	In.	In.	In.	In.	In.	In.	In.	In.
B 236	4	6¾	14¾	17¼	19¼	21	21½	..	..
B 238	8	13¾	16½	18½	20	21¾	23	24	25
B 246	4¾	7½	13½	18¼	21	22½	..	..	..
B 249	7	12½	18½	19½	20¾	21½	22¼	24¾	25½
B 253	4¼	7½	10¼	14½	16¾	19	21¼	22½	..
B 263	7¼	13	15½	17½	20	21	..	..	..
B 264	7¼	14	16¾	19¼	21¼	22½	..	..	..
B 265	5¼	14	15¾	17¼	19	20½	21½	..	..
B 266	7¾	13¼	18	..	..	..	..	..	..
B 267	6¼	10¼	14¾	21	24	..	..	..	..
B 268	4	7½	11½	16¼	17¾	19	20	..	..
B 272	4	8¼	15¼	20½	..	..	..	..	..
B 273	5½	10	13½	18½	20¼	23	24	25¼	26
B 274	3½	7¾	14¼	17¼	19¼	21½	22¾	..	..
B 275	4	13½	19½	20½	22	23	..	..	..
B 277	6½	12½	16½	18¾	20½	..	..	..	..
B 278	3¾	7	10	12¾	15¾	18½	19¾	21¾	22½
B 279	5¾	11¾	16	17½	19	20¼	21½	..	..
B 280	5¾	13	19	..	..	..	..	..	..
B 281	3¾	6	11½	17½	20¼	21	22¼	23	..
B 282	8¼	14½	19¼	21	..	..	..	..	..
B 283	6½	11½	16	18½	19½	20½	21	..	..
B 284	4½	7¼	13½	19¼	21	..	..	..	..
B 285	3½	6¼	15¼	17¾	19½	21	22	..	..
B 286	3½	6½	9¼	14¾	18¾	20¼	21½	..	..
B 287	7	12½	15	17½	20½	22	..	..	..
B 288	5¾	9¼	13½	18¾	20	..	..	..	..
C 1	4	5¾	8½	15	17	18½	21	22½	..
C 2	7	11¾	14¾	17	18¾	20½	21½	..	..
C 4	5½	12¾	16	18¼	20	21	..	..	..
C 6	7¼	14¼	21	23	..	..	..	..	..
C 7	4¾	7¾	13¼	16¾	19	20½	..	..	..
C 9	4	13¼	19½	..	..	..	..	..	..
C 10	6¼	13¾	17½	19	..	..	..	..	..
C 11	5	9	13½	17¾	20½	..	..	..	..
C 12	3½	5¾	10½	14¾	18¼	19½	21	22	..
Averages ..	5·4	10·3	14·9	17·9	19·6	20·8	21·6	23·2	24·7

Average age .. .. 6·2
Average length .. .. 21·7
Average length of 156 females marked in 1918 .. .. 21·5

Table I (E).

Thirteen Trout caught with Rod and Line, Lake Ellesmere, 1917–18.

Date.	Log No.	Weight.	Length.	Sex.	Length each Winter. 1	2	3	4	5	6	7
		lb.	In.		In.	In.	In.	In.	In.	In.	In.
20/10/17 ..	B 132	11	28	M	5¾	10¼	13¼	18½	22¾	24½	26¾
21/10/17 ..	B 133	6¾	25	F ?	4½	8½	13¾	16½	19	21½	24¾
27/10/17 ..	B 136	5¼	23	F	4½	8¼	14¼	17	19	21½	..
17/11/17 ..	B 147	8¾	28	M	3¾	10	16¼	22½	27¼	..	..
17/11/17 ..	B 150	4½	22	M	5½	8¼	11½	14¾	16¾	21¼	..
17/11/17 ..	B 151	4½	22	M	6¼	10¼	13	15¼	20	..	..
17/11/17 ..	B 152	2½	17¼	F	4¼	8½	11¾	15	..	..	..
9/12/17 ..	B 159	3¼	21	F	5	7½	13½	15¾	17¾	20	..
8/1/18 ..	B 185	7½	25	..	4¼	9½	16	19¾	21½	24¼	..
6/1/18 ..	B 198	7¾	24	F	6½	12¾	22	..	..	..	..
9/3/18 ..	B 213	7	24	F	4½	9	14¾	19½	22¼	..	..
9/3/18 ..	B 214	7	25¼	F	6¾	15¼	18¾	22¾	..	..	..
9/3/18 ..	B 216	4	19¾	M	5	7¾	11¼	16¾	..	..	..
Averages	..	..	..	..	5·1	9·7	14·6	17·9	20·8	22·2	25·7

Table I (F).

Five Large Trout from Lake Ellesmere.

Date.	Log No.	Weight.	Length.	Sex.	Length each Winter. 1	2	3	4	5	6	7	8	9
		lb.	In.		In.	In.	In.	In.	In.	In.	In.	In.	In.
28/12/16..	A 1	13½	28½	F	6	9¼	21½	25½	27½	..	..	..	..
–/6/15..	A 18	11¼	29	F	5¾	8¾	13	17	21½	23½	25¼	26½	27½
20/10/17..	B 132	11	28	M	5¾	10¼	13¼	18½	22¾	24½	26¾	..	..
17/11/17..	B 147	8¾	28	M	3¾	10	16¼	22½	27¼	..	..	..	..
10/5/18..	B 232	13½	33	M	7¾	13	17	21¼	27½	31	..	..	..
Averages..	..	..	..	..	5·8	10·2	16·2	20·9	25·3	26·5	26·0	26·5	27·5

TABLE II.

Rain Rivers.

Date.	Log No.	Weight.	Length.	Sex.	Length each Winter. 1	2	3	4	5	6
					A. *Cam.*					
		lb.	In.		In.	In.	In.	In.	In.	In.
1/10/17 ..	B 121	2¼	18	..	4½	8¾	13¼	14¾	16½	18
1/10/17 ..	B 122	½	12	..	5	10¾	..	..	..	..
4/10/17 ..	B 123	..	15¾	..	6½	12½	14½	..	..	..
4/10/17 ..	B 124	..	15¼	..	5¼	12¼	14	..	..	..
26/10/17 ..	B 134–5	¾	14¾	..	4	8	12	14¼	..	..
26/11/17 ..	B 153	1½	15¾	..	4	7½	10¾	13½	14½	..
23/12/17 ..	B 160	1¾	16¼	F	5½	9¾	13½	15	..	..
					B. *North Branch, Waimakariri.*					
9/10/17 ..	B 127	..	8½	..	6¼	..	..	..	..	..
9/10/17 ..	B 128	¾	14	..	4½	8	11¼	13½	.	..
9/10/17 ..	B 129	½	11½	..	4½	9½	11¼	..	..	..
8/12/17 ..	B 161	1¼	14¾	F	4	6½	12¼	..	..	..
8/12/17 ..	B 163	1¼	14¾	M	5¼	11¼	13¼	..	..	..
8/12/17 ..	B 165	¾	12	..	4½	10	..	..	..	..
8/12/17 ..	B 169	1½	15½	M	4¾	9¾	13¼	..	..	..
30/12/17 ..	B 173	1¼	15	..	4	7¾	13¼	..	..	..
30/12/17 ..	B 174	½	11¼	..	5¼	10¼	..	..	..	..
8/4/18 ..	B 231	3¼	18¼	M	5½	8¼	12¾	..	..	..
					C. *Styx.*					
24/2/18 ..	B 208	1½	15	..	3¾	9	13¼	14½	..	..
24/2/18 ..	B 209	1	13	..	3½	6	9¾	11¼	12¼	..
24/2/18 ..	B 210	½	10½	..	3½	6½	..	..	..	..
					D. *Selwyn No. 2.*					
7/10/17 ..	B 125	2	18	M	6¼	10½	13¾	16	16¾	17½
7/10/17 ..	B 126	¾	13½	..	5¼	10	12¾	..	..	..
13/10/17 ..	B 130	..	12¾	..	4½	7½	10½	12¼	..	..
14/10/17 ..	B 131	1¼	15½	F	5	9½	13½	14¾	15½	..
28/10/17 ..	B 137	1	14	..	3¼	6½	12½	13¾	..	..
28/10/17 ..	B 138	1¼	15¼	M	4	7¾	13	14	15	..
28/10/17 ..	B 139	..	9½	..	3¾	8	..	..	..	..
28/10/17 ..	B 140	¾	13¼	..	5½	12	..	..	..	..
					E. *Opihi and Tengawai.*					
9/11/17 ..	B 162	..	10½	..	3¾	7½	9½	..	..	..
10/11/17 ..	B 164	..	10	..	3¾	7¼	9½	..	..	..
9/11/17 ..	B 166	..	13½	..	4	7	10¼	11½	12¾	..
10/11/17 ..	B 167	..	10	..	3¼	6	9	..	..	..
9/11/17 ..	B 170	..	11	..	4¾	8¼	10½	..	..	..
9/11/17 ..	B 172	..	13½	..	5¼	9¼	11½	13	..	..
9/11/17 ..	B 168	..	11	..	4½	7¼	10¼	..	..	..
Averages	..	..	..	..	4·6	9·0	12·0	13·7	14·7	17·7

Averages for each River.

A. Cam	..	..	5·0	10·0	13·0	14·4	15·5	18·0
B. North Branch, Waimakariri	..	..	4·8	9·0	12·5	13·5	..	..
C. Styx	..	..	3·6	7·2	11·5	12·9	12·2	..
D. Selwyn No. 2	..	..	4·7	9·0	12·7	14·1	15·7	17·5
E. Opihi and Tengawai	..	..	4·2	7·5	10·0	12·2	12·7	..

Table III.

Snow Rivers.

Date.	Log No.	Weight.	Length.	Sex.	Length each Winter. 1	2	3	4	5	6	7	8	9
					A. *Ashley.*								
		lb.	In.		In.	In.	In.	In.	In.	In.	In.	In.	In.
23/1/18..	B 195	6¼	24½	..	4½	11¾	16½	20¼	22¾	..	..	..	..
23/1/18..	B 197	3¾	20½	F	5¾	11	16¼	..	..	..	..	..	..
7/3/18..	B 212	3	18½	M	6	10	14	16½	..	..	..	..	..
7/3/18..	B 215	4½	20½	..	5	8	14¾	17½	20	..	..	..	..
					B. *Waimakariri.*								
3/12/17..	B 154	2¼	17	M	4	8½	12	13½	14¾	..	..	..	..
3/12/17..	B 155	..	12	..	3½	6	8¼	10½	..	..	..	..	..
30/11/17..	B 156	1¾	16	F	3¾	6¾	10¾	14	..	..	..	..	..
23/1/18..	B 194	4¼	21½	M	5¼	8¾	14½	16½	18¾	20¾	..	..	..
28/1/18..	B 196	2½	18	M	5½	11¼	16	..	..	..	..	..	..
2/2/18..	B 202	2¾	17¾	F	5½	10	13¾	17	..	..	..	..	..
..	B 217	3½	20	..	4¾	10	14½	18	..	..	..	..	..
					C. *Rakaia.*								
10/11/17..	B 144	..	23½	M	3½	5½	8½	11½	13½	15½	19½	21½	22¾
12/1/18..	B 190	6½	25	F	5½	13½	18	22¾	..	..	..	..	..
11/1/18..	B 192	5	24½	M	4¾	9¾	16½	19¾	23¼	..	..	..	..
20/1/18..	B 193	1	14	F	5¼	10¾	..	..	..	..	..	..	..
..	B 199	4½	21	F	5	11¾	14¾	16½	18¾	..	..	..	..
3/2/18..	B 200	7	28	F	7½	11½	18	24	25¾	27½	..	..	..
..	B 203	4½	21	F	5½	10	15	18	19¾	20½	..	..	..
10/2/18..	B 204	3	19	M	4	8¾	16¼	..	..	..	..	..	..
Averages..	..	..	..	..	4·7	9·7	14·3	17·1	19·7	21·1	19·5	21·5	22·7

Averages for each River.

			1	2	3	4	5	6	7	8	9
A. Ashley ..	..	..	5·3	10·2	15·4	18·1	21·4	..	..	..	..
B. Waimakariri	..	..	4·6	8·7	12·8	14·9	16·7	20·7	..	..	..
C. Rakaia ..	..	..	5·1	10·2	15·3	18·8	20·2	21·1	19·5	21·5	22·7

TABLE IV.

Back-country Lakes.

Date.		Log No.	Weight.	Length.	Sex.	Length each Winter. 1	2	3	4	5	6	7	8	9	10
						A. *Marymere.*									
			lb.	In.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
23/12/17	..	B 175	4½	23	M	3½	10	15¼	17½	19½	20¾	21¾	22¼	..	..
24/12/17	..	B 176	6	24	F	6	12	15¾	17¾	20¼	21½	22¼	23	23½	..
24/12/17	..	B 178	3¾	21½	F	6	15¼	19	..	..	..	..	..	..	..
23/12/17	..	B 179	6½	26	M	6	12¼	16	20	22¼	23½	24½	25½	..	..
27/12/17	..	B 180	6	26	M	5¾	13¼	18½	21¾	23¾	24¼	..	..	..	..
27/12/17	..	B 181	7	27	F	4¾	12	16¾	20½	22¼	24	25¼	26¼	..	..
26/12/17	..	B 182	5	22	M	4½	13	19¼	..	..	..	..	..	..	..
26/12/17	..	B 183	4½	20½	F	4½	12	18	..	..	..	..	..	..	..
24/12/17	..	B 188	5½	24	F	6	12½	15½	20	21	22	23¼	..	..	..
25/12/17	..	B 189	7	26	F	6¾	13¾	17¾	20½	21¾	22¾	23½	24¼	25¼	..
						B. *Lake Heron.*									
2/11/17	..	B 142	6	24½	..	2½	7	10½	17	21	23¼	24¼	..	..	..
2/11/17	..	B 143	5	21½	..	3¾	6¾	9¾	11½	17	19	20½	21¼	..	..
1/11/17	..	B 145	8	26	M	4¾	9	18	21½	22¾	23½	24½	25¼	25¾	..
8/11/17	..	B 146	6	24	..	4	7¼	11¾	17¾	20½	21	22	22¾	23¼	23¾
24/11/17	..	B 158	8	26½	M	4½	7½	10½	17½	20¼	23½	24¾	26	..	..
31/3/18	..	B 221	5	21¾	M	4½	8½	16	20¼	..	..	..	..	..	..
31/3/18	..	B 222	5	22¾	M	5½	10½	17½	20	21¼	22¼	..	..	..	..
31/3/18	..	B 223	5½	22¾	M	5¼	12¾	19½	20¾	21¾	..	..	..	..	..
31/3/18	..	B 224	6	23½	F	5	11	19	20½	21¾	22¾	..	..	..	..
31/3/18	..	B 225	6¼	24	M	5	12¼	16	19¼	20½	22	23	..	..	..
31/3/18	..	B 226	4	22¾	F	3½	6¾	8¾	15	18	19½	20¾	21¾	22¼	..
31/3/18	..	B 227	6	22¾	F	5¼	8¼	14	18	21	22¼	..	..	..	..
31/3/18	..	B 228	5	21½	F	4	6½	11½	15¼	18¼	19¾	20¾	21¼	..	..
31/3/18	..	B 229	4½	19¾	F	4	6¼	13½	16¾	18¼	19	..	..	..	..
31/3/18	..	B 230	7	24¾	M	5	14½	19¼	22¼	23¼	..	..	..	..	..
						C. *Lake Alexandrina.*									
10/2/18	..	B 205	5¾	23½	M	6	11½	16½	22¼	..	..	..	..	..	..
10/2/18	..	B 206	10	28¼	F	5¾	11	17	23½	26	27¾	..	..	..	..
						D. *Lake Coleridge.*									
5/11/17	..	B 141*	10½	27½	F	7	15¾	23½	..	..	..	..	..	..	..
10/3/18	..	B 218	17	34½	F	2½	4	8	10½	24	30	32½	34¼	..	..
3/6/18	..	B 234	20	33½	F	3½	7	12¼	19½	26½	29½	31¾	..	..	..

Averages.

		1	2	3	4	5	6	7	8	9	10
A. Lake Marymere ..	..	5·4	12·6	17·2	19·7	21·5	22·7	23·4	24·2	24·4	..
B. Lake Heron	..	4·4	9·0	14·4	18·2	20·4	21·5	22·6	23·0	23·7	23·7
,, "natives"	..	5·1	12·2	18·2	20·5	21·7	22·3	23·0	..	..	..
,, "migrants"	..	4·1	7·4	12·4	17·0	19·7	21·2	22·5	23·0	23·7	23·7

* The length of B 141 (Lake Coleridge) was estimated from the weight.

Marymere—Average age, calculated as at last winter: 6·40 years.
Lake Heron—Average age, calculated as at last winter: 6·93 years.

Art. VII.—*Description of a New Species of the Family Cerithiidae.*

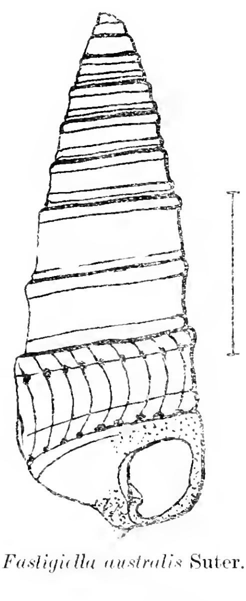
By Henry Suter.

Communicated by R. Speight.

[*Read before the Philosophical Institute of Canterbury, 18th September, 1918; received by Editor, 25th September, 1918; issued separately, 14th May, 1919.*]

Fastigiella australis n. sp.

Shell elongate-conical, gradate, many-whorled, with slightly nodulous cinguli; aperture oval-quadrangular; columella with a distinct fold produced by the entering of the carina of the fasciole. Sculpture: The post-embryonic whorls have a prominent convex and faintly nodulous spiral band below the suture; a similar but narrower band above the lower suture, and below it a fine thread margining the suture. The paratype, which is smaller, shows only the upper band and a distinct thread above the suture below. On the lower whorls the thread margining the suture is lost; strong convex and distant growth-lines turn up which are produced into nodules on the upper and lower cinguli, but the specimens before me, no doubt considerably worn, show only traces of these characters. The body-whorl is distinctly angled and bears two cinguli upon the angle. The base of the paratype shows traces of spiral striation. Spire high, distinctly gradate, angle about 20°. Protoconch lost. Whorls 8 on the imperfect holotype, flat or somewhat concave between the cinguli, the body-whorl angled. Suture deep, canaliculate in the paratype. Aperture ovate, but slightly quadrangular, not channelled above; most likely with a very short and notched canal, but the whole of the mouth is too much damaged in both specimens to be quite certain. Outer lip straight, curved and indistinctly angled towards the base. Columella a little excavated above, bearing on its lower part a fold which evidently extends as a carina upon the fasciole, but the latter is almost completely broken off. Inner lip spreading somewhat over the base, more apparent on the paratype.



Fastigiella australis Suter.

Height, 22 mm.; diameter, 8 mm. (imperfect holotype).

Holotype and one paratype in the Canterbury Museum, Christchurch.

Loc.—Holotype from the upper horizon, Whitewater Creek, and the paratype from the upper horizon, *Struthiolaria* bed, Porter River, Trelissick Basin; both collected by Mr. R. Speight, Curator of the Canterbury Museum.

Remarks.—The genotype is *Fastigiella carinata* Reeve, a living species from the Antilles, and our species differs from it chiefly in the aperture not being channelled above. The umbilicus of the type I take to be simply a deep impression inside the fasciole; Cossmann does not mention an umbilicus in the diagnosis of the genus. Besides the Recent genotype, about half a dozen Tertiary species are known, the genus being evidently of rare occurrence. *F. australis* is, as far as I know, the first species recorded from the Southern Hemisphere.

The Cerithiidae are but scantily represented in the New Zealand Tertiary. At the present time the following six species are on record: *Cerithium hectori* Harris, *Besanconia huttoni* (Cossm.), *Fastigiella australis* Sut., *Cerithidea bicarinata* (Gray), *C. tricarinata* Hutt., and *Batillaria pomahakensis* Harris.

ART. VIII.—*The Structure of* Amphibola crenata *Martyn.**

By WINIFRED CHEYNE FARNIE, M.A., Assistant in the Biology Department, University of Otago.

Communicated by Professor Benham.

[*Read before the Otago Institute, 9th October, 1917; received by Editor, 17th December, 1918; issued separately, 14th May, 1919.*]

INTRODUCTION.

THE shell of *Amphibola* was first brought to the notice of European naturalists by being collected during Cook's voyage to New Zealand in 1769, but the earliest account of the anatomy of *Amphibola* we owe to Quoy and Gaimard in 1832. The only other accounts we have are those of Captain Hutton in 1879 and 1882, and of Bouvier in 1892.†

Quoy and Gaimard (1832) described specimens collected in New Zealand during the expedition of the "Astrolabe." They ascertained that it was a true pulmonate, and that it was hermaphrodite. They give excellent figures of the shell and operculum, but only one of the internal anatomy, and that is lacking considerably in detail; while their account of the anatomy is inaccurate in several points, and not sufficiently detailed.

Captain Hutton (1879) noted the two small triangular tentacles, and described the kidney and alimentary canal in greater detail than Quoy and Gaimard, though his description of the intestine is not quite correct. He also figured and described the nervous system and reproductive organs. In 1882 he published some further notes, wherein he corrects his former account of the radula and traces what he took for the "oviduct" from the hermaphrodite duct. Further mention of Hutton's work will be made throughout my account.

For a systematic diagnosis of the species reference should be made to Suter's *Manual of New Zealand Mollusca* (1913) and *Atlas of Plates* (1915).

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* This paper formed the basis of a thesis for Honours in Zoology at the University of New Zealand, 1916.

† I have been unable to consult this memoir.

Although in the original thesis submitted to the University of New Zealand the histological structure of the various organs was discussed and illustrated, I have thought it advisable to omit these matters in the present paper.

I wish here to express my indebtedness to Professor Benham for his valuable suggestions and great help in preparing this paper for publication.

Habits.

Amphibola crenata is a basommatophorous pulmonate gasteropod found living on mud-flats in sheltered bays, both in brackish and in salt water. It belongs to a series of pulmonates sometimes termed "gehydrophilous" (Cook, 1895, p. 18), in which, while the gill has been replaced by a "lung," the animal has not become truly an inhabitant of fresh water. *Amphibola* and some other genera, such as *Gadinia* and *Siphonaria*, are "intermediate between essentially fresh-water and essentially marine species."

The larger specimens of *Amphibola* are found quite close to the sea, the smaller ones farther up the mud-flat. They occur in enormous numbers on all the flats around the Otago Harbour, and, indeed, all along the coast of New Zealand. They are, of course, covered during high tide, but are exposed to view at low tide, so that the greater part of their life is passed out of water. Nevertheless, sufficient water is retained in the mantle-chamber to keep the tissues moist.

These animals are exceedingly sluggish. When they are in their natural surroundings one has to watch them very closely to see whether they are moving or not; but if they are placed in a little sea-water in a dish their method of locomotion is readily studied. When examined on the shore the only evidences of movement are the slow twirling of the shell as it is being drawn up to cover the slightly extended head and foot, the latter of which is concealed in the mud, and the furrow traced out on its path. The most striking feature of this movement is the very small part of the foot that is exposed at any one time. Its method of locomotion is as follows: A small portion of the anterior part of the foot is protruded, and this acts as a temporary anchor. The shell is then drawn up to cover the exposed part, and as it is twisted from left to right during the process it leaves a small part of the foot exposed on the left side and behind. The animal then glides slowly forward for a space without twisting the shell at all. The above process is repeated, the movement of the shell sometimes being from right to left. The shell is carried at an angle to the surface on which the animal is walking, the right side of the shell being raised a little from the mud, while the left side almost touches it. The animal is very sensitive, retracting into the shell at the slightest touch or at any disturbance of the water.

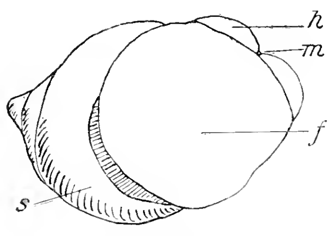

Fig. 1.—*Amphibola crenata* from below (natural size), as seen creeping up the side of a glass vessel of fresh water and thus exposing the whole of the foot. The two lappets of the head project only slightly in front of it. *f*, foot; *h*, head; *m*, mouth; *s*, shell.

Although air-breathing, *Amphibola* is able to live a considerable time immersed in water, either fresh or salt. If kept in a glass of fresh water the cover of which is sealed up it will live for a week; if completely immersed in fresh water but not so sealed up it will live for a fortnight; if completely immersed in sea-water it will live a month; but if left without any water at all it does not live more than a day. Even when the tide is low there is always a certain amount of water left in the mud, so that these animals are not, in their native habitat, left absolutely dry.

EXTERNAL FEATURES.

As Suter gives a good technical description and figure of the shell it is unnecessary to deal with it here.

The *animal* is of small size and of a beautiful rich black colour.

The *head* is but slightly marked off from the foot, and is relatively of great breadth (fig. 2). Its anterior region is rather deeply excavated in the middle line so as to form a pair of lappets, one on each side of the mouth. Some distance from these are situated the pair of small, flat, triangular tentacles, which in the majority are so deeply pigmented that the minute eye is not readily seen, but in paler specimens the eye is recognized as an extremely small black dot of darker pigment close to the tip of the tentacle. Quoy and Gaimard, though mentioning the eyes, failed to note the tentacles. Hutton (1879), however, describes the latter, but states that the eye is at the base. This error is repeated, naturally, in Suter's *Manual*, but any one who examines the creature with sufficient care will be able to confirm my statement.*

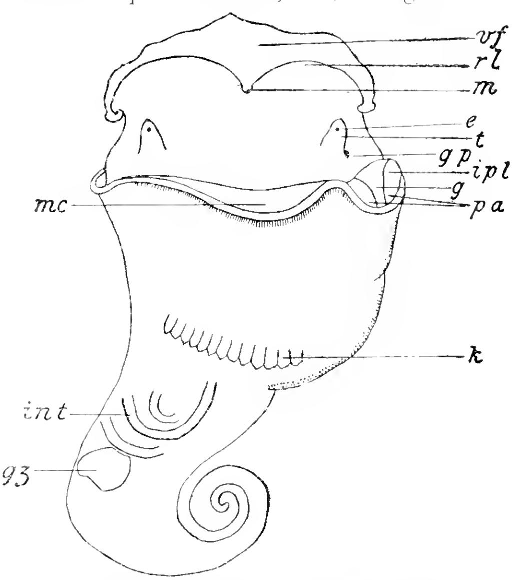

FIG. 2.—Dorsal view of the animal removed from the shell (× 2). The foot is bent upon itself so that the ventral surface of its posterior region is seen in front of the head. Some of the interior organs are seen by transparency. *e*, eye; *g*, groove into which anus opens; *gp*, genital pore; *gz*, gizzard; *int*, intestine; *ipl*, inferior pallial lobe; *k*, kidney; *m*, mouth; *mc*, collar; *pa*, pulmonary aperture; *rl*, right lappet of head; *t*, tentacle; *vf*, ventral surface of foot.

The *foot* is short, and almost circular in outline, as seen from below (fig. 1). In preserved specimens it is very much shrunken, but if examined when the animal is walking it will be seen that the foot is capable of being expanded until a narrow margin is visible beneath the shell all the way round except on the right side. The foot is separated from the head by a slight furrow; there is no distinction into pro-, meso-, and meta-podium, nor have I found any trace of a pedal gland. The anterior part of the creeping-sole is cream-coloured, the posterior part greyish-blue.

* It is not surprising that the tentacles were overlooked by the earlier zoologists, if they had only preserved specimens at their disposal, for when the head is contracted they are difficult to distinguish from wrinklings of the body-wall. As to the eye, in ordinary specimens they, too, are indistinguishable in such material: it is only in fresh specimens and in those in which the pigmentation at the tip of the tentacles is less than usual that they can be seen. [W. B. B.]

Attached to the dorsal surface of the hind end of the foot is the operculum, closely underlying the shell so as to be visible only from the side. When the animal is completely retracted it fits close against the entrance to the spiral portion of the shell, and is firmly held there by muscles.

This characteristic prosobranchiate structure is found in this genus only amongst the Pulmonata.

The thickened edge of the mantle, which, of course, is fused with the neck, and which is usually called the "collar" (fig. 2, *mc*), is light in colour, and is very muscular. It does not project beyond the shell during locomotion, but if the animal is allowed to remain in fresh water the head becomes expanded and the mantle-edge appears under the outer lip of the shell. The upper lip of the pulmonary aperture is then seen fitting into the sinus of the shell.

The margin of the pulmonary aperture is not a simple circular aperture as in *Helix*, but the lower lip is produced outwards into an "inferior pallial lobe" (*ipl*) such as occurs in *Chilina* according to Lang (1900). This lobe is deeply grooved, the groove being triangular in shape, with the apex directed backwards towards the pallial chamber (fig. 2, *g*). The anus is situated at the apex of this groove. Hutton (1879) describes and figures the anus as being to the right of the pulmonary aperture, and both Hutton and Quoy and Gaimard draw the triangular furrow mentioned above as if it were part of the rectum. The anus is really posterior to the pulmonary aperture, although it is capable of being carried beyond it by the extension of the inferior pallial lobe. When the faeces are passed to the exterior the lips of the triangular groove probably close together, so that it is temporarily converted into a tube. This prevents any faeces entering the mantle-cavity. The inferior pallial lobe is also capable of closing against the upper lip of the pulmonary aperture.

Internal Anatomy.

Organs of the Pallial Complex. (Fig. 3.)

The most conspicuous organ on the roof of the mantle-chamber is the *kidney*, which presents several remarkable features. It is pure-white in colour, and occupies the middle region of the mantle, across which it extends obliquely for about two-thirds of its breadth: somewhat flask-shaped in outline, its apex is situated a short distance from the pulmonary aperture, its broader base close to the left side of the roof of the mantle-cavity. Running along its ventral surface is a narrow band of muscle (*mu*) which arises from the middle of the hinder edge of the columella-muscle, which is not shown in the figure. The portions of the kidney on either side of this band are of unequal sizes.

The excretory aperture is a conspicuous longitudinal slit on a papilla at its anterior end (*ex*), which projects freely from the mantle itself. The wall of the kidney is thick, and internally bears numerous filiform papillae which almost fill its cavity. The excretory products can be seen by teasing up a portion and examining it in the fresh state: they appear as clear spherical vesicles of different sizes, each of which has a very thin envelope of a protoplasmic nature, surrounding a drop of hyaline, non-granular fluid. In the centre of this are several round concretions of a brownish colour.

Since the cells of the kidney are not ciliated, they will be unable to aid in the removal of excretory products. Probably the muscle-band which runs along the dorsal surface of the kidney serves this purpose, by compressing the flow and so driving the stuff forwards to the pore.

Lying on the roof of the mantle-cavity, close to the anterior end of the kidney, and extending a short distance underneath it, is an oval mass of white rounded particles covered by a thin pigmented membrane (*hy*). It is situated in a curious depression which extends from the anterior end of

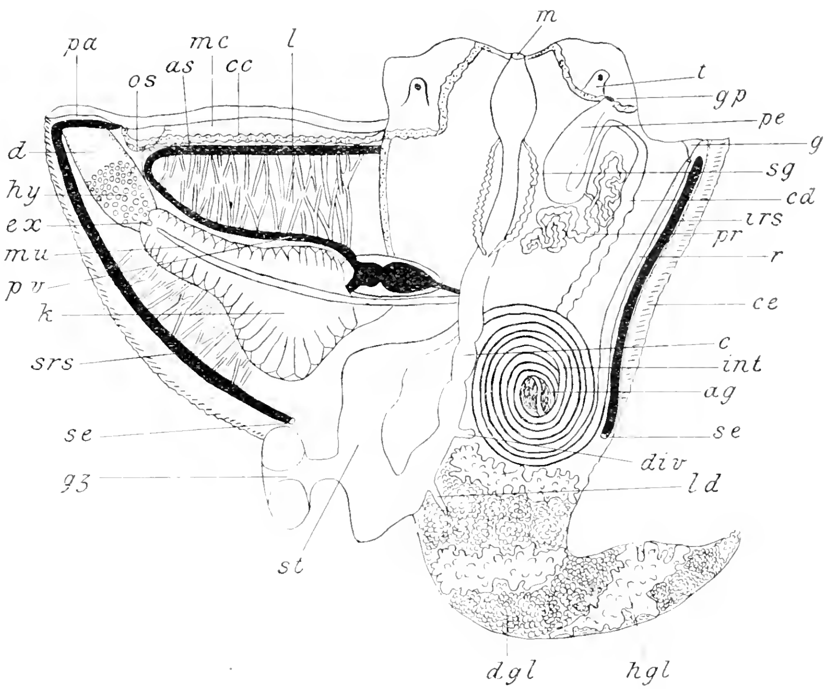

FIG. 3.—General dissection (× 2). The mantle, which has been cut along the collar and along the right side, has been turned to the animal's left, exposing the pallial complex. The head and neck have been opened to disclose the alimentary tract and part of the genital system. The rectal sinus has been severed at the point *se*, where it passes on to the roof of the mantle-chamber. *ag*, albumen-gland; *as*, anterior sinus; *c*, crop; *cc*, cut edge of collar; *cd*, common genital duct; *ce*, cut edge of mantle; *d*, depression in front of renal pore; *dgl*, digestive gland; *div*, diverticulum of oesophagus; *ex*, excretory pore; *g*, groove into which anus opens; *gp*, genital pore; *gz*, gizzard; *hgl*, hermaphrodite gland; *hy*, hypobranchial gland; *irs*, inferior rectal sinus; *int*, intestine; *k*, kidney; *l*, lung; *ld*, duct of digestive gland; *m*, mouth; *mc*, collar; *mu*, muscle-band on kidney; *os*, osphradium; *pa*, pulmonary aperture; *pe*, penis; *pr*, prostate; *pv*, pulmonary vein; *r*, rectum; *se*, cut end of rectal sinus; *sg*, salivary gland; *srs*, superior rectal sinus; *st*, stomach; *t*, tentacle.

the kidney to the edge of the mantle above the pulmonary aperture. When these particles are disturbed with a brush they give off a bluish fluorescent foam, which quickly re-forms as often as it is brushed away. When examined under the microscope the mass is seen to be made up of rounded particles of different sizes, which contain crowds of small granules. Though white by reflected light, the particles are brown by transmitted light, and this colour is due to these granules, which are yellowish-brown in colour. They look like droplets of fat. Possibly this structure represents the hypobranchial gland, which, as Lang mentions, is absent in all pulmonates except *Amphibola*. This peculiar and striking phenomenon was met with in every specimen examined.

The *heart* lies at the base of the left side of the kidney; its wall is formed of a thin, but tough, transparent membrane. The auricle is much smaller than the ventricle, and broader posteriorly than at its anterior end. Its wall is very thin, white, and but feebly muscular. The ventricle is yellow in colour, and its wall is more muscular than that of the auricle.

The *lung* (*l*) is situated between the kidney and the anterior muscular edge of the mantle (fig. 3). The blood-vessels traversing it are not clearly visible, on account of the fact that they have very large cavities and extremely thin walls. Owing to the small size and very delicate walls of the auricle I was unable to inject the lung through the auricle, but I succeeded in injecting it through the pedal sinus, as will be described in the account of the circulatory system.

It is probable that dermal respiration plays as important a part as lung respiration, and the thick layer of pigment covering the mantle in the region of the lung may act as a respiratory pigment, as may also the pigment covering the other parts of the body.

Alimentary System. (Fig. 3.)

The *mouth* (*m*) is placed between the two lappets of the head, and opens into the cavity of the buccal mass. It is dark in colour, somewhat ovoid in shape, the posterior portion being swollen. From the ventral surface of this posterior portion the radula-sac extends backwards for a short distance below the oesophagus. There is no jaw, nor did I find any trace

Fig. 4.—Portion of the radula (× 700). *tc*, central teeth; *tl*, lateral teeth; *tm*, marginal teeth.

of a rudiment of one. Two similar and symmetrical muscular masses project into the cavity of the buccal mass in front of the radula, one on each side of the middle line. They are dark in colour, and each is simply a muscular thickening of the wall of its respective side.

The *radula* is spatulate in shape, the pointed end being anterior. There are forty-four rows of teeth, the rows being set obliquely to the median line. If the radula is mounted whole, only two kinds of teeth are visible, as it is very difficult to spread it out flat, but if separated with needles three distinct kinds can be distinguished (fig. 4)—(1) central, (2) lateral, (3) marginal.

The central tooth (*tc*) has a broad base, bearing a median cusp which is almost square in outline. On either side of this are a number of smaller cusps, six or seven, but the number differs with each central tooth and often on the two sides. The cusps next to the median on either side are smaller than those more remote; but all taper to a sharp point. On either side of the central tooth, and placed slightly above its upper margin, is a small elongated lateral tooth (*tl*) which is somewhat blunt at the tip. Next to this is another lateral tooth, of larger size, which bears two cusps. The division into cusps is not the same in every tooth. Some have a large outer cusp and a very small, narrow inner one; in others the cusps are of equal length and breadth. But this difference is due probably to some being more worn away than others. The remaining teeth on each side of the laterals are the marginals (*tm*). They are all curved, simple, conical teeth, the tips of which are somewhat rounded.

Hutton (1879) describes only two kinds of teeth in the radula of *Amphibola*—median and lateral. He also says the apices of the teeth point forward. He gives a very rough sketch of the radula, but the shape is not correct. In his second paper (1882) he redescribes the teeth. He notes that the median tooth has five or six cusps on either side, not two or three as he formerly thought; that there is a single lateral tooth, which is often divided into two and varies in shape; and that the rest of the teeth are aculeate, and increase in length towards the margin.

The form and great size of the median tooth in *Amphibola* seems unusual among pulmonates, for, judging from figures of radulas of other pulmonates (Bronn's *Thierreich*, pl. xcv)—*e.g.*, *Siphonaria*, *Limnaea*, *Planorbis*, *Auricula*—the median tooth is much smaller and simpler than those on either side.

Perrier (1897) says that the form of the lingual teeth is related to diet: that they are obtuse and generally numerous in herbivorous molluscs, but have the form of a hook and are less numerous in carnivorous genera. The teeth in *Amphibola*, therefore, agree with those of other herbivorous molluscs.

A pair of *salivary glands* open into the buccal cavity (fig. 3, *sg*) near the commencement of the oesophagus. Each gland is a long, linear, yellow, sacculated structure, which passes through the nerve-collar and runs for a short distance backward beside the oesophagus. Posteriorly they taper, and are attached together and to the wall of the oesophagus.

The *oesophagus* extends backwards for about two-thirds the length of the body. The posterior portion lies beneath the intestinal coil, and is visible by transparency on the ventral surface of the uninjured animal. As far as the intestinal coil the oesophagus is a narrow tube, but it then dilates a little, the dilatation being marked off from the portion in front and behind it by constrictions. This specialized portion of the oesophagus is the crop (*c*). Behind the crop the oesophagus becomes broader, and on a level with the posterior end of the intestinal coil it bears a finger-shaped diverticulum on the right side (*div*). Behind this diverticulum the oesophagus becomes broader, and opens into the stomach (*st*), which is U-shaped, the right limb being much smaller and narrower than the left, which extends forwards towards the heart. An outgrowth of the left limb of the stomach forms the gizzard (*gz*), which consists of two globular and symmetrical muscular projections separated by a muscular girdle. If the stomach be opened and its wall examined, two folds of the epithelium in the form of a pad will be seen on its floor, one behind the entrance to the gizzard and the other just in front of it. From each of these two pads a white wavy fold runs along the floor of the stomach towards the intestine. Another wavy fold is present to the right of these two.

The stomach passes into the intestine (*int*), which, after running underneath the aorta on the left side of the body, crosses the median line and then forms the intestinal coil. The intestine is very long, measuring in some specimens 8½ in. when uncoiled. It is coiled round and round the albumen-gland (*ag*) in a double spiral, the total number of complete coils being eight, only five of which are visible on the surface. It coils four times from right to left, the fourth coil crossing the middle of the albumen-gland transversely. After coiling four times in the opposite direction it runs along the right side of the first coil and passes into the rectum. The coils from left to right alternate with those from right to left. The rectum (*r*) runs along the right side of the body, and opens by the anus into the triangular groove already mentioned.

The extremely long coiled intestine is characteristic of herbivorous gasteropods. *Amphibola* has to pass through its alimentary canal enormous quantities of mud in order to obtain the vegetable matter it requires. Examination of the contents of the stomach and the mud itself shows that the food consists principally of diatoms. Several different kinds were found, the most frequent being *Navicula*. The faeces are deposited in long circular strings.

Hutton's drawing (1879) of the gizzard and stomach is not quite correct: and he says there are only five coils in the intestine, all reversed. He draws the triangular groove into which the anus opens as if it formed part of the wall of the rectum itself.

The *digestive gland* (fig. 3, *dgl*) is very large, occupying together with the gonad the hinder end of the body, and extending from the region of the stomach up to the apex of the visceral spire. It occupies the median portion of the spire, and lobes extend to the edge alternating with those of the gonad. It is a much-lobed gland, dark brown in colour, and when examined fresh it is seen to be dotted with numerous brown specks, the so-called entochlorophyll granules.

The duct of the liver, which appears to be single, opens into the right limb of the stomach, near its anterior end (*ld*).

The cells lining the lumen of the liver are long columnar cells, but they are of varying lengths, some extending a considerable distance into the cavity, others being very short. Two kinds of cells are distinguishable. (*a.*) Liver cells: The large cells mentioned above, as well as smaller liver cells, contain small granules, which give the yellowish-green colour to the fresh liver. They stain pink in eosin. (*b.*) Ferment cells: These occur in amongst the liver cells, and each has a large cavity containing a yellowish-brown granule. These entochlorophyll granules can be seen at various stages of formation, some cells containing minute granules, others granules a little larger, others again very large granules. I tried several tests for these granules, with the following results: They turned red when treated with gentian violet, turned pale green when treated with methyl green, remained brown when treated with osmic acid, and turned dark green when treated with eosin. Acetic acid had no effect; but they dissolved in caustic potash.

These entochlorophyll granules are just as numerous in a fasting animal as in one that has been feeding. The only difference I found was that the granules from a fasting animal dissolved in caustic potash at once; those in the other animals took a long time, some of them not dissolving at all.

Schneider (1902) distinguishes three kinds of cells in the liver: (*a*) liver cells, (*b*) excretory cells, (*c*) lime cells.

According to him, two sorts of granules occur in the "liver cells"—small liver-granules, which stain red in eosin, and large excretion granules (entochlorophyll). The "liver cells," he says, perform a nutritive and secretory function. The "excretory cells," he says, stain a deep black in osmic acid. The "lime cells" contain phosphate of lime.

The liver cells, as I have described, are present in the liver of *Amphibola.* I tested for "excretory cells" with osmic acid, but obtained no result; and of "lime cells" I could find no trace.

MacMunn (1900) regards the cells containing entochlorophyll in molluscs as "ferment cells." He also describes "lime cells," but finds no trace of the so-called "excretory cells." He tested for glycogen in the liver, but obtained no results. Nor have I found any trace of glycogen in these cells in *Amphibola.*

The Nervous System. (Fig. 5.)

The nervous system consists of a ring of nerve-tissue surrounding the buccal mass a short distance from its posterior end. The ganglia are bright-orange in colour.

The *cerebral ganglia* are connected by a fairly stout cerebral commissure. From each there passes backwards and downwards a slender connective to the buccal ganglia, which are, as usual, of small size, and are situated slightly behind the entrance of the salivary gland. From the buccal ganglia, which are joined by the commissure, small nerves are given off to the buccal mass.

From each cerebral ganglion the following five nerves are given off to the anterior region of the head: (*a*) A very fine nerve, which runs alongside and close to the buccal mass, innervates the head lappet in the region of the mouth; (*b*) to the outer side of this is a nerve which almost at once bifurcates; (*c*) a very fine nerve, and (*d*) a stouter one which bifurcates (these two run parallel with the posterior branch of nerve *b*): (*e*) the two tentacular nerves run outwards and slightly upwards to enter the base of each tentacle, and one of the two innervates the eye.

From the right ganglion there also arises a stout nerve (*f*) which runs outwards and backwards and then bifurcates, the two branches supplying respectively the anterior and posterior portions of the penis. There is no corresponding nerve on the left side of the animal.

The *pleural ganglia* lie on the body-wall close to the cerebral, to which each is connected by the cerebro-pleural connective. There are apparently no nerves given off by these ganglia, but from the right pleuro-pedal connective, and nearer to the pedal than to the pleural ganglion, a slender nerve is given off which bifurcates almost immediately: the anterior branch (*g*), crossing below the penis, goes to the anterior end of the common genital duct, the posterior supplies the body-wall. On the left side the corresponding nerve, which also bifurcates, is, of course, entirely limited to innervating the body-wall of this side.

The *pedal ganglia* are of about the same size as the cerebral; the pleuro-pedal connectives are very short. From the pedal ganglia several large nerves supply all regions of the foot.

The only really interesting feature about the system relates to the character of the *visceral loop*, which is much longer in *Amphibola* than in ordinary pulmonates. From the right and left pleural ganglia a connective passes back to the visceral ganglion (*gv*), which is situated on the body-wall below the oesophagus, slightly to the right side. It is about the same size as one of the pedal ganglia, and, as we shall see later, probably represents the fused infra-intestinal and abdominal ganglia. From it are given off two strong nerves. The anterior one (*k*) runs out to the right side, ventral to the common genital duct, and bifurcates, one branch running up to supply the inferior pallial lobe, and the other backwards alongside the rectum. The posterior nerve (*l*) is stout, and runs backwards to supply the organs in the visceral spire.

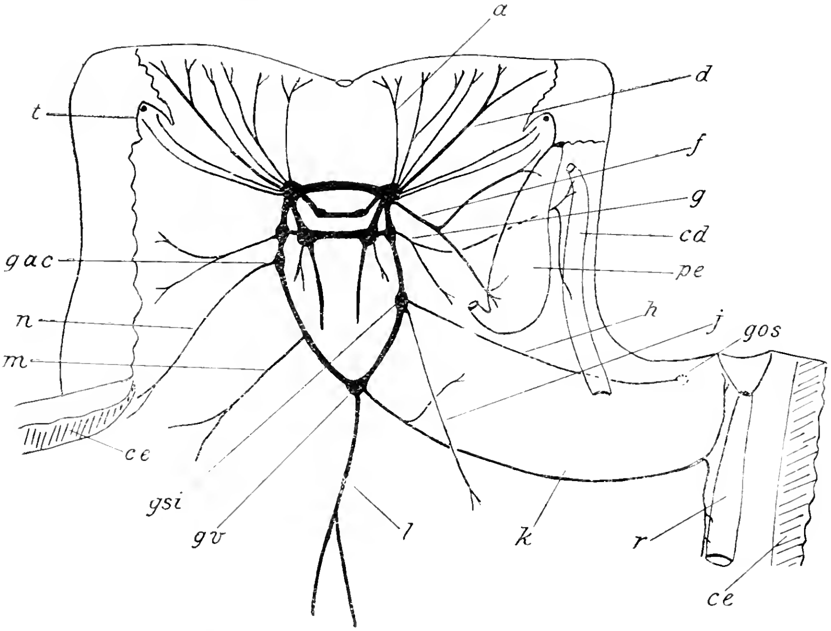

Fig. 5.—The nervous system in situ (× 4). *a*, first cephalic nerve; *d*, fourth cephalic nerve; *f*, penial nerve; *g*, nerve of genital duct and body-wall; *h*, nerve to osphradial ganglion (which is represented in outline as it lies on the roof); *j*, nerve to body-wall; *k*, rectal nerve and its branch to the inferior pallial lobe; *l*, visceral nerves; *m*, *n*, nerves to body-wall; *cd*, common genital duct; *ce*, cut edge of mantle; *gac*, accessory ganglion; *gos*, osphradial ganglion; *gsi*, supra-intestinal ganglion; *gv*, visceral ganglion; *pe*, penis; *r*, rectum; *t*, tentacle.

A short distance from the pleural ganglia the visceral commissure bears two ganglia asymmetrically placed, the one on the right (*gsi*) being larger and farther removed from the pleural ganglion than the one on the left (*gac*). The right one may be termed the supra-intestinal, and from it are given off two nerves.

The *osphradial nerve* (*h*) runs outwards to the osphradial ganglion, which is situated on the mantle on the right side. The osphradial ganglion itself gives off small nerves to the osphradium and the mantle. A slender nerve (*j*) supplies the body-wall.

The ganglion on the left is evidently an accessory ganglion (*gac*) which corresponds to that found on the visceral commissure in *Chilina* (Lang, 1900, p. 220; and Naef, 1911). This accessory ganglion sends off a nerve (*n*) which supplies the body-wall in the region of the collar.

Between this accessory ganglion and the visceral ganglion, but nearer the latter, a nerve (*m*) arises from the visceral commissure and supplies the columellar muscle. There is no ganglion corresponding to this nerve, though perhaps it arises from cells in the accessory ganglion.

According to Pelseneer (1906), "In all Euthyneura except *Actaeon*, *Chilina*, and *Latia* the infra-intestinal ganglion is fused with the abdominal in such a manner that the latter appears to participate in the innervation of the mantle—*i.e.*, inferior pallial lobe." Although we find that the inferior pallial lobe in *Amphibola* is innervated by a nerve from the visceral ganglion, yet serial sections across the latter give no indication of the union of two such ganglia.

In another primitive pulmonate, *Latia*, however, as figured by Pelseneer (1906) the approximation of the ganglionic centres has not gone so far, so that the infra-intestinal ganglion, although very close to the abdominal, has not fused with it. *Latia*, like *Amphibola*, has an accessory ganglion near the left pleural. The nervous system in *Latia* enables one to see how the condition in *Amphibola* may have come about.

The comparison of the nervous system of *Limnaea*, *Chilina*, and *Amphibola* will show more clearly that the visceral ganglion in the last probably represents the fused infra-intestinal and abdominal ganglia.

Hutton's description and figure of the nervous system do not agree with what I have found to be the case. He says that in addition to the cerebral and pedal ganglia there is "a parieto-splanchnic system, which consists of seven ganglia, three on each side, and an azygos infra-oesophageal ganglion connected with the others on either side."

The anterior ganglion of his parieto-splanchnic system corresponds to the pleural ganglion; the posterior one to the accessory and supra-intestinal respectively; but I find no trace of the middle ganglion on either side. He observes no difference in size in these two ganglia, nor their asymmetry; nor does he mention any buccal ganglia. Nothing is said as to the various nerves themselves.

Sense Organs.—Tactile organs are distributed all over the surface of the head and foot. This is evident by the sensitiveness exhibited when the animal is touched, and also by the rich nerve-supply, especially in the anterior margin of the head.

A *statocyst* (or otocyst) is present on each pedal ganglion. It is an oval vesicle, and contains numerous calcareous lenticular statoliths. When examined fresh the statoliths oscillate in the fluid present in the vesicle. These movements cease after a short time. Some of the statoliths lie on the base of the nerve which leaves the statocyst. This nerve is seen running close against the cerebro-pleural connective, so that one may conclude that the nerve of the statocyst comes from the cerebral ganglion.

The *osphradium* is a simple epithelial ridge on the roof of the mantle-cavity close to the collar, near the pulmonary aperture (fig. 3, *os*). A nerve can be seen supplying it from the osphradial ganglion, which is in its turn innervated from the supra-intestinal ganglion. Hutton (1879) figures and describes the statocyst, but makes no mention of the osphradium.

The *eye*, as sections show, presents no peculiarity in structure: it is quite typically constructed. When a tentacle is mounted entire the eye exhibits two distinct portions—a small linear light area, which represents the lens; and a deeply pigmented region, surrounding this but for its anterior end, is the retina (fig. 7). Below the eye, embedded in the substance of the tentacle, may be seen a mass of rounded particles of carbonate of lime such as occur throughout the tissues of the body.

Circulatory System. (Fig. 3.)

The only portion of the circulatory system that needs describing is the venous system. In order to trace out the veins I injected the animal through the foot. The best results were obtained with glycerine carmine, and the kidney was invariably well injected.

The blood is collected into sinuses, as can be proved by thus injecting the animal. From the larger sinuses the blood passes into two main tubular sinuses or veins, the anterior sinus and the rectal sinus (fig. 3).

On the left side the blood from the body enters the anterior sinus (*as*), which lies along the collar. Shortly before reaching the pulmonary aperture it curves round to connect with the pulmonary vein (*pv*), which runs close beside the kidney, to enter the anterior end of the auricle. The anterior sinus gives afferent branches to the lung (*l*) along its whole course, and the blood is collected by efferent branches which enter the pulmonary vein. Thus, though some of the blood enters the pulmonary vein directly from the anterior sinus, most of it reaches the heart only after filtering through the vessels of the mantle-roof, which constitutes the lung.

The rectal sinus consists of two superposed channels, one above the other—the inferior rectal sinus (*irs*) and the superior rectal sinus (*srs*). The inferior rectal sinus commences at the inferior pallial lobe, and runs along the floor of the mantle on the right side of and close to the rectum. It extends back as far as the coils of the intestine, where it leaves the body-wall floor of the mantle-chamber and, bending abruptly on itself, passes forward along the roof of the mantle above its former course as the superior rectal sinus (*srs*) as far as the pulmonary aperture. It then bends at right angles and traverses the mantle as far as the commencement of the collar, where it seems to cease. The blood, which enters both ends of the rectal sinus, is carried through vessels traversing the mantle from the sinus to the afferent renal vein, which runs along the dorsal surface of the kidney, and which is therefore not shown in the drawing. The blood from the afferent renal vein is then distributed through the sinuses in the connective tissue which supports the filiform papillae of the kidney. These trabeculae of connective tissue are traversed by axial sinuses which function as blood-spaces. The blood thus reaches the efferent renal vein, which runs backwards near the ventral surface of the kidney, below the muscle-band, to enter the auricle.

I have had great difficulty in tracing out the circulatory system. The heart and blood-vessels have such extremely thin walls that it is impossible to inject them from the heart. On one occasion the injection went from the auricle along the pulmonary vein and into the anterior sinus directly for a short distance, but I did not observe any injection on the wall of the lung itself. By injecting through the foot the kidney was invariably well injected, and sections across the lung showed that the vessels of the lung had also been injected. As explained above, the afferent and efferent vessels on the wall of the lung are not as clearly visible in *Amphibola* as in *Helix* and in other pulmonates. The same is true of the vessels running from the superior rectal sinus to the renal vein. Sections across the mantle between the kidney and the rectal sinus, however, show the existence of these blood-vessels.

The rectal sinus where it traverses the roof of the mantle is very conspicuous. Quoy and Gaimard (1832) draw it as if it were coming from the ventricle. Hutton (1879) says it does not come from the ventricle, as Quoy and Gaimard figure; but he was unable to trace its connection, nor does he seem to have traced out the circulatory system at all. When the animal is opened by cutting along the right side of the mantle the rectal sinus is necessarily cut across at its hinder end where it bends upwards on to the roof of the mantle. I am not quite certain whether the superior rectal sinus ends, as shown, near the collar (fig. 3), but I can trace it no farther.

Although the rectal sinus in *Amphibola* is a definite blood-vessel, I have called it a "sinus" in order to compare more easily the circulatory system with that of a typical pulmonate—*e.g.*, *Helix*. The superior rectal sinus, then, evidently corresponds to the so-called rectal sinus of *Helix*, the inferior rectal sinus being an additional vessel. The circulation of blood in the lung and in the kidney agrees with that found in *Helix*, except that in *Amphibola*, as in other primitive forms, the blood after being purified in the kidney enters the heart directly.

Reproductive Organs. (Figs. 3, 6.)

Amphibola, like all the Euthyneura, is hermaphrodite. The genital organs lie for the most part on the right side of the body, and comprise the hermaphrodite gland (or ovotestis), albumen-gland, and an undivided genital duct, into which open certain accessory organs.

The genital aperture is situated at the base of the right tentacle (fig. 2), and presumably serves for the exit of both ova and spermatozoa, though I have been unable to trace the course taken by the ova in their passage to the exterior.

The ovotestis (*hgl*), together with the liver, occupies the visceral spire. On the ventral surface it is plainly seen as a light-yellowish-brown organ extending the whole length of the spire and embedded in the dark-brown gastric gland. On the dorsal surface, however, only portions of the gland are visible, separating the darker bands of the liver (fig. 3). It consists of several lobules, each composed of numerous acini, the ends of which are tipped with a dark-brown pigment. These lobules communicate with small ductules which unite to form the hermaphrodite duct (*hd*). Posteriorly it is of a rich brown tint, but anteriorly it becomes paler till it is white. This leaves the ovotestis as a very wavy duct, which passes forward on the ventral surface of the visceral spire to open into the common genital duct (*cd*). Just before the point of entrance it gives off a small finger-shaped diverticulum, the seminal vesicle (*sv*), which underlies the duct and rests close against the albumen-gland.

Pelseneer (1895) in a paper discussing the origin of hermaphroditism in the Mollusca refers to *Amphibola* in these terms: "The wall of the genital gland shows distinct sexual differences upon the two sides of the follicles, in which the female side exhibits projections which are rudiments of the acini of this sex." It will be remembered that Cottrell (1911) shows that in *Siphonaria* the peripheral acini or follicles produce only eggs, whereas the central ones produce spermatozoa. In *Helix* each follicle produces both kinds of germ cell from any part of the epithelium. My own observations tend to show that Pelseneer's statement is correct, except that I do not find any "projections" from the side of the follicles. Sections across the ovotestis of *Amphibola* show that ova and spermatozoa are developed in the same follicle. The spermatozoa, however, are confined to one portion of wall, while from the rest of the epithelium the ova are formed. They develop at a later period of the year. Spermatozoa are fully developed in November, whereas at this date the ova are still small and not ready to be discharged.

The *common genital duct* consists of two distinct regions—(*a*) glandular, (*b*) non-glandular. The glandular region (*gld*), into which the hermaphrodite duct leads, lies in close contact with the posterior ventral portion of the

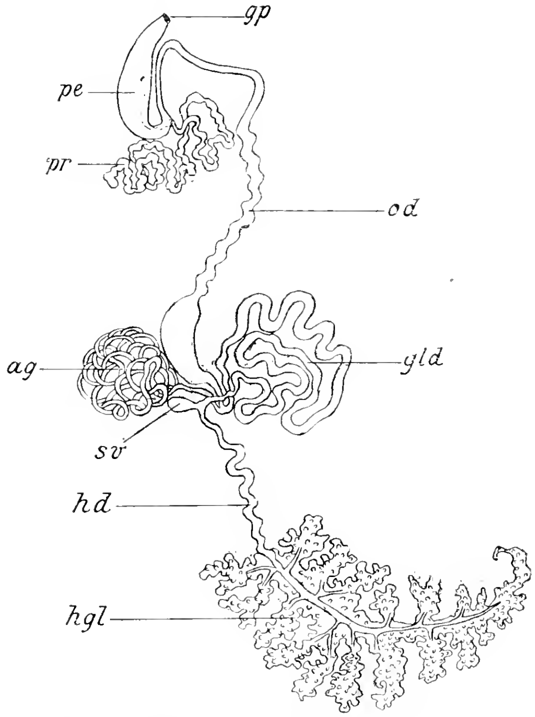

FIG. 6.—The genital system unravelled so as to exhibit as much as possible (× 2). The point of entrance of the prostate into the cavity of the penis is indicated by dotted lines. *ag*, albumen-gland; *cd*, common genital duct; *gld*, glandular portion of common duct; *gp*, genital pore; *hd*, hermaphrodite duct; *hgl*, hermaphrodite gland; *pe*, penis; *pr*, prostate; *sv*, seminal vesicle.

albumen-gland (*ag*). It is a white, mucilaginous, finely coiled tube, all the coils of which I have not attempted to show in the drawing. This tube gradually loses its mucilaginous character and widens to form the commencement of the non-glandular portion (*cd*), which narrows again as it passes forward along the body-wall parallel to, and on the left of, the rectum as a wavy duct of a cream colour. It reaches almost to the base of the right tentacle, narrowing slightly as it does so. It then turns sharply on itself, runs backwards, and after a short distance bends abruptly and becomes much enlarged to form the penis (*pe*), which is a pyriform organ of a light-cream colour with very muscular walls.

Opening into the common duct are two diverticula, the albumen-gland and the prostate. The albumen-gland (*ag*) opens into the distal end of the glandular region opposite the point at which it passes into the non-glandular. It is a brownish or orange-coloured tubule, which is very much convoluted, as Hutton described, and forms a spherical mass, around which are wound the numerous coils of the intestine. It is soft and of a somewhat slimy consistency, and its cells secrete a great quantity of mucilaginous material.

At the commencement of the penis is situated the prostate (*pr*). It is a much-convoluted blindly-ending tube, the distal half pure-white in colour, the proximal half bright-yellow. From this end a slender duct leads away, which, after running in the substances of the muscular wall of the penis, communicates with its cavity near its opening to the exterior.

From the above description it will be seen that the condition of the genital duct in *Amphibola* agrees with the most primitive condition in the Euthyneura—that is, the duct is a sperm-oviduct throughout its length. To this type of duct Lang (1900) and Pelseneer (1906) give the name "monaulic."

As far as I can ascertain, the only other primitive pulmonate closely related to *Amphibola* which exhibits a monaulic type of duct is *Siphonaria*. Cottrell (1911) shows that the reproductive organs of this genus differ from those of *Amphibola* in three chief features: There is no separate albumen-gland, but the common duct is itself glandular, and the much-folded walls of this duct constitute the albumen-gland; the common duct enters the penis close to its external pore and not at its distal extremity; and there is a large spermatheca, the long duct of which opens into the penis close to the common duct. The absence in *Amphibola* of a distinct and definite spermatheca seems a peculiarity.

Limnaea, which has affinities with *Amphibola*, has a "diaulic" type of genital duct which cannot be compared with that of *Amphibola*. In *Chilina*, another primitive pulmonate, the reproductive system of which Lang (1900) figures and describes, the genital duct is "diaulic," the openings of the sperm-duct and oviduct being at some distance from each other. Considering the close relationship of *Amphibola* and *Chilina*, one would have expected a greater similarity in their reproductive systems.

Quoy and Gaimard (1832) described the reproductive system of *Amphibola*. They called the hermaphrodite gland the "ovary," and the hermaphrodite duct the "oviduct." The albumen-gland they named "testicule," and the genital duct which runs up on the right side the "uterus." The opening of the female portion of the duct they figure on the right side of the body, to the left of the anus. The penis they describe as opening near the eye, in the place where the right tentacle would be if it were represented in the figure.

Hutton (1879) correctly describes the hermaphrodite gland and the hermaphrodite duct. The albumen-gland he says consists of two parts—an albumen-gland proper and an accessory gland. The albumen-gland proper opens into the hermaphrodite duct by a duct. According to him, the hermaphrodite duct appeared to divide beyond the albumen-gland into a large sacculated "oviduct," and a narrower but still broad "vas deferens" (which is the "common duct" of my account), but he could not satisfy himself as to how the oviduct left the hermaphrodite duct. He describes it as running along the left of the rectum, to which it is firmly attached. "It appears to open inside the respiratory cavity," but of this he says he was by no means certain. In a later paper (1882) he says he found an animal with the oviduct distended with eggs, and it showed clearly that his supposed "accessory gland" was the commencement of the oviduct.

I can find no opening of a female duct in the position figured by Quoy and Gaimard, nor do I find any oviduct as described by Hutton. What he supposes to be the commencement of the oviduct is the lower end of the genital duct; and serial sections in this region prove this to be so.

Sections across the right side of the body show no trace of a duct between the rectum and the genital duct, whereas sections across the genital duct itself show the existence of a deep fold in its wall, which serves to divide the duct into two portions, presumably, during the passage of the ova and spermatozoa.

Hutton (1879) says the eggs of *Amphibola* are "lodged on the exterior of the mantle in a circular patch near the opening of the renal organ. After fertilization they acquire a thick coat which gives them a bluish-white pearly appearance." These are evidently the fluorescent particles I described in connection with the kidney, where I mentioned that they were products of the hypobranchial gland. They are not eggs, as I have observed them in every animal without exception that I have examined during the year. Moreover, they do not resemble eggs in the slightest degree.

In his second article (1882) Hutton says he found the oviduct so distended with eggs that he was able to trace its connection with the hermaphrodite duct. The "eggs" he found in the oviduct were, I think, the eggs of a parasitic Trematode. I have found them several times, and in some animals they are so numerous on the right side in the muscular region of the body-wall between the rectum and the genital duct that both the rectum and the genital duct are hidden from view—*i.e.*, in the position of Hutton's supposed "oviduct."

At present I am making systematic observations on *Amphibola* so as to ascertain at what time the ova are laid and how they get to the exterior. Every month I collect and preserve the animals in order to cut sections of the reproductive organs and ascertain at what time of the year the eggs are laid. If successful I shall try to follow out the development of the eggs as far as possible.

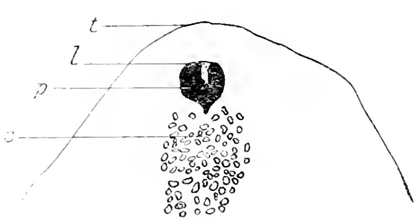

Fig. 7.—The end of a tentacle, with the eye, cleared and mounted entire. *c*, carbonate of lime; *l*, lens; *p*, pigment; *t*, tip of tentacle.

Embedded in the connective tissue and amongst muscles in all parts of the body are numerous bodies composed of carbonate of lime. They are extremely abundant, especially on the mantle-edge. They vary in size, the smallest ones being found embedded in the base of the tentacle below the eye (fig. 7). They vary in shape also, some being spherical, others ovoid, and others again more or less rhomboidal. Examined under the high power some exhibit fine circular striations. When treated with acetic acid they dissolve, giving off large bubbles of carbon dioxide, which can be plainly seen with the naked eye.

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Art. IX.—*Contributions to a Fuller Knowledge of the Flora of New Zealand: No. 6.*

By T. F. Cheeseman, F.L.S., F.Z.S., Hector Memorial Medallist, Curator of the Auckland Museum.

[*Read before the Auckland Institute, 20th December, 1918; received by Editor, 30th December, 1918; issued separately, 14th May, 1919.*]

I. Ranunculaceae.

The Genus Caltha *in the Southern Hemisphere.*

A memoir bearing the above title, written by Captain A. W. Hill, Assistant Director of the Royal Gardens, Kew, has recently appeared in the *Annals of Botany* (No. cxxvii, July, 1918). In this, Captain Hill maintains the subdivision of the genus into the two sections, *Psychrophila* and *Populago*, proposed by de Candolle as far back as 1818, and shows that the peculiar development of the leaf-auricles in *Psychrophila*, which includes the whole of the species found in the Southern Hemisphere, marks off the section much more distinctly than the floral characters proposed by de Candolle. Eleven species are included in the section, three of them being described for the first time. Seven of the eleven are purely American in their distribution, two of them advancing as far north as the Andes of Ecuador or Bolivia; the remaining five extending southwards into southern

Chile or Fuegia, two of them reaching the Falkland Islands. Four species are Australasian, one being found in Victoria, another in Tasmania, and two others (*C. novae-zealandiae* Hook. f. and *C. obtusa* Cheesem.) in New Zealand. Much information is afforded for the first time respecting the degree of development of the leaf-auricles, and woodcuts are given of the chief modifications, the leaves of both the New Zealand species being figured.

It is worth remarking that the section *Psychrophila* is one of those plant-groups proving an alliance between the floras of Australia, New Zealand, and South America.

XVIII. Rhamnaceae.

Pomaderris elliptica Lab.

Kawhia district, growing luxuriantly on the fern-clad spurs and promontories running down into the harbour; *Mr. E. H. Schnaekenberg!* An extension of the southern range of this fine plant, the northern slopes of Mount Pirongia being the previous known limit.

XXII. Leguminosae.

Chordospartium Stevensoni Cheesem.

Avon Valley, Marlborough; *H. F. Hursthouse!* This is a most interesting discovery, the plant being previously known only from the original habitat near the Clarence Bridge, South Marlborough, where it was collected by Mr. George Stevenson in the summer of 1909. Mr. Hursthouse informs me that in the Avon Valley it grows side by side with *Notospartium Carmichaeliae*, and that it is very difficult to distinguish the two in the absence of fruit. He further remarks that when in bloom both are very beautiful and striking plants, certain to attract notice even at a distance of half a mile or more.

Mr. Hursthouse has also favoured me with a large supply of the seeds of *Chordospartium*. It seems to be difficult of germination, for out of great numbers planted, both inside and outside New Zealand, only three plants have been reared.

XXVIII. Myrtaceae.

Metrosideros Parkinsoni Buchanan.

Abundant at the southern end of the Paparoa Range, near Greymouth. Particularly plentiful on the steep slopes south and south-east of Mount Sewell, and also on a spur running to the west of Mount Davy, alt. 2,000 ft.; *P. G. Morgan!* The above are the most southern localities yet recorded for this fine plant.

I have also to record its discovery by *Mr. W. R. B. Oliver* on the summit of Mount Hobson, Great Barrier Island, alt. 2,000 ft. The two specimens kindly given to me by Mr. Oliver have rather narrower leaves than the southern examples, and there are fewer flowers in the cymes, but otherwise they entirely correspond. Its occurrence on the Great Barrier Island, quite 350 miles in a straight line from the nearest of its southern habitats, is a remarkable instance of discontinuous distribution, almost comparable to the case of *Pittosporum obcordatum*, where the only two localities known—that of Kaitaia, in Mongonui County, and Akaroa, in Banks Peninsula—are separated by 550 miles!

XXXIII. UMBELLIFERAE.

Aciphylla similis Cheesem.

Griffin Range, western Southern Alps, alt. 4,500–4,900 ft.; *P. G. Morgan!* The Griffin Range is situated almost immediately to the south of the Otira–Kumara Road, and a little distance below the point of confluence of the Taipo and Taramakau Rivers. It has never been previously visited by a botanist, and I am consequently much indebted to Mr. Morgan for the few specimens he was able to secure during a hasty geological examination of the district.

Aciphylla Kirkii Buchanan.

I am indebted to *Mr. James Speden*, of Gore, for excellent specimens of this curious plant, collected at an altitude of 6,000 ft. on the Remarkables, near the lower end of Lake Wakatipu. Mr. Buchanan's plate and description, given in *Trans. N.Z. Inst.*, vol. 19, p. 214, are far from correct; but they were admittedly founded on very imperfect material. In a memoir on *Aciphylla*, now in course of preparation, I hope to publish an amended description of this and other species of the genus.

Aciphylla simplex Petrie.

I have also to thank *Mr. Speden* for flowering specimens of this, also gathered at an elevation of 6,000 ft. on the Remarkables, near Lake Wakatipu.

XXXVII. RUBIACEAE.

Coprosma tenuicaulis Hook. f.

Tuamarina Swamp, near Blenheim, Marlborough, abundant; *J. H. Macmahon!* So far as I am aware, this is the first record of the occurrence of this in the South Island.

XXXVIII. COMPOSITAE.

Celmisia Walkeri T. Kirk.

Several localities on the Humboldt and Eyre Mountains, Central Otago; *J. Speden!*

Celmisia ramulosa Hook. f.

Eyre Mountains, Central Otago, alt. 5,000–6,000 ft.; *J. Speden!*

Celmisia lateralis Buchanan.

Mount Davy, southern end of the Paparoa Range, near Greymouth, alt. 2,500–3,000 ft.; *P. G. Morgan!* This species has a pre-eminently western distribution, and is seldom seen on the eastern side of the dividing range.

Celmisia prorepens Petrie.

Eyre and Garvie Mountains, Central Otago; *J. Speden!*

Celmisia dubia Cheesem.

Abundant on Mount Davy, southern end of the Paparoa Range, near Greymouth, alt. 2,500–3,000 ft.; *P. G. Morgan!* This locality offers a slight extension of the southern range of this plant.

Helichrysum grandiceps Hook. f.

Griffin Range, western Southern Alps, alt. 4,500–4,900 ft.; *P. G. Morgan!*

Abrotanella linearis Berggren.

Slopes of Mount Davy, southern end of the Paparoa Range, near Greymouth, alt. 2,500–3,000 ft.; *P. G. Morgan!*

XLI. Campanulaceae.

Pratia perpusilla Hook. f.

Marlborough—Wairau River bed, near its mouth; *J. H. Macmahon!* The first specimens I have seen from the South Island; but it is easily overlooked, and probably has a wider range than is generally supposed.

XLIII. Epacridaceae.

Dracophyllum Kirkii Berggren.

Griffin Range, western Southern Alps, alt. 4,500–4,900 ft.; *P. G. Morgan!*

XLIX. Loganiaceae.

Mitrasacme montana Hook. f. var. **Helmsii** T. Kirk.

Abundant from a little over 2,000 ft. to the summit (3,410 ft.) of Mount Davy, at the south end of the Paparoa Range, near Greymouth; *P. G. Morgan!* This is probably the locality where it was originally discovered by Mr. Helms. I have not seen specimens from any locality outside the Paparoa Range.

L. Gentianaceae.

Sebaea ovata R. Br.

Vicinity of Wanganui; *A. Allison!* An entirely fresh locality for this rare and local plant.

Gentiana patula Cheesem.

Griffin Range, western Southern Alps; alt. 4,500–4,900 ft.; *P. G. Morgan!*

Gentiana bellidifolia Hook. f.

Griffin Range, western Southern Alps; alt. 4,500–4,900 ft.; *P. G. Morgan!* (with the preceding species).

LIV. Scrophulariaceae.

Euphrasia Cockayniana Petrie.

Griffin Range, western Southern Alps; alt. 4,500–4,900 ft.; *P. G. Morgan!*

LXI. NYCTAGINACEAE.

Pisonia Brunoniana Endl.

I am informed by *Mr. Robert Hastie* that a small grove of *Pisonia* exists on Cape Bream Tail, a little to the north of Mangawai. This locality, however, is not many miles distant from the Taranga Islands (Hen and Chickens), where the plant is abundant.

LXII. LORANTHACEAE.

Korthalsella salicornioides Van Tiegh.

Queen Charlotte Sound, parasitic on *Leptospermum*: *J. H. Macmahon!* This is the first record, so far as I am aware, for the Marlborough Provincial District. (See my list of the known localities, given in *Trans. N.Z. Inst.*, vol. 43, p. 182.)

LXXIV. BALANOPHORACEAE.

Dactylanthus Taylori Hook. f.

Ranginui Range, near Mangapehi, Main Trunk Railway; *J. Corbitt!*

LXXVI. URTICACEAE.

Urtica ferox Forst.

Bay of Islands County, apparently confined to a *wahi-tapu* known as Ngamahanga, situated about ten miles to the west of Kawakawa; *T. H. Trevor!* This is a marked extension of the range of the species, which has not been previously collected northwards of the Marikopa River, Kawhia, quite two hundred miles away. It is (or, rather, was) abundant between the Awakino and Mokau Rivers and Taumarunui, and is known from several localities between the Main Trunk Railway and the Central Volcanic Plateau. A locality near Te Aroha, reported to me many years ago, has so far not been confirmed.

Mr. Trevor states that the Ngamahanga *wahi-tapu* contains about 29 acres. Up to this year cattle had barely penetrated into it, but they are now working their way steadily towards the centre, and he anticipates that they will soon destroy the major portion of the undergrowth, including the *Urtica*. So far as he can ascertain, it has never occupied an area much exceeding an acre. Its greatest height is about 6 ft. The specimens forwarded to me have leaves from 4 in. to 6 in. in length, and the stinging-hairs are quite copious.

LXXVIII. CONIFERAE.

Dacrydium Bidwillii Hook. f.

Open pumice country at Tiroa, to the east of Mangapehi, Main Trunk Railway; *A. Wilson* and *J. C. Rolleston!* With the exception of the extreme summit of Moehau (Cape Colville), this is the most northerly locality known. Mr. Rolleston informs me that the Maoris call it "Aotea."

Phyllocladus glaucus Carr.

Several specimens in a patch of kauri forest near Birkdale, a few miles from Auckland, on the northern side of the Waitemata Harbour; *H. B. Matthews!* Quite an unexpected discovery. I am acquainted with but two other localities in the Auckland District — one near the Waitakare waterfall, where it was plentiful until the construction of the huge dam for the Auckland water-supply destroyed most of the adjacent forest; the other a little to the north of the mouth of the Waitakare River.

Mr. E. Phillips Turner informs me that a few plants of *P. glaucus* exist in a ravine near the base of Rainbow Mountain, near Waiotapu; and that it is plentiful at Lake Waikare-iti, near Waikaremoana. The latter is the most easterly locality known.

LXXIX. Orchidaceae.

Thelymitra pachyphylla Cheesem.

To this species I refer specimens of a *Thelymitra* collected by Mr. H. B. Matthews between Erua and Makatote, to the west of Ruapehu. It agrees with *T. pachyphylla* in the broad and flat erect staminodia, the margins of which are furnished with simple or branched fimbriae; and the size, mode of growth, and foliage are all very similar. But the flowers are smaller, and the middle lobe of the column shorter and crenulate.

XCI. Cyperaceae.

Kyllinga brevifolia Rottb.

Abundant in swamps on the seaward side of the cliffs to the north of the Manukau Harbour: *T. F. C.* In this locality it is certainly a recent introduction; nor am I aware that it has been previously collected in New Zealand outside the North Cape peninsula. But its nativity in any part of New Zealand must be regarded as exceedingly doubtful.

Carpha alpina R. Br.

Mr. P. G. Morgan sends me a highly depauperated state from the summit of Mount Frederic, north of the Buller Valley; alt. 3,500 ft It forms small dense patches barely more than an inch in height, and the inflorescence is reduced to one or two spikelets.

XCII. Gramineae.

Ehrharta Colensoi Hook. f.

Griffin Range, western Southern Alps; alt. 4,500–4,900 ft.; *P. G. Morgan!*

Microlaena polynoda Hook. f.

In great abundance on the site of the old Maori pa Te Korekore, near Muriwai, about twenty-five miles north of the Manukau Heads: *T. F. C.* This is the only locality I am acquainted with in the Auckland District.

XCIII. Filices.

Asplenium japonicum Thunb.

Banks of the Waiaruhia River, a tributary of the Waitangi, Bay of Islands County *T. H. Trevor!* This locality is some distance to the south of the Okura River, where it was first discovered by Miss Clarke. (See *Trans. N.Z. Inst.*, vol. 22, p. 448.)

NATURALIZED PLANTS.

Aster subulatus Michx.

This plant was first noticed in the vicinity of Auckland about twelve years ago, and soon became plentiful, especially in moist places on harbour reclamations, by roadsides and ditches, &c. It is a native of the United States, where it is principally found in brackish-water marshes, ranging from New Hampshire to Florida.

Erigeron annuus Linn.

Has appeared in some quantity in freshly sown grass at Otukai, Mongonui, January, 1917; *H. Carse!* So far as I am aware, this is the first record of the occurrence of this plant in New Zealand. Native of North America, where it has a wide range; and it has also become naturalized in Europe.

Chlora perfoliata Linn.

Manuka scrub at Parengarenga, North Cape district: *W. R. B. Oliver!* Now recorded for the first time in New Zealand. It is a native of western and central Europe, extending to north Africa and western Asia.

Emex australis Stein.

Near Parkhurst, Kaipara: *H. P. McLeod!* This species appears to be of uncertain occurrence in New Zealand, and never lingers long in any one locality. It has a wide distribution in South and Western Australia and South Africa.

Tradescantia fluminensis Vell.

A garden escape in many localities in the vicinity of Auckland, where it has received the local name of "wandering-jew." Has become specially abundant on portions of the Mount Eden lava-fields: *T. F. C.* Mongonui County: has become plentiful on river-banks near Awanui and Kaitaia, and also covers considerable areas in flat swampy forest: *H. Carse!* *Mr. B. C. Aston* also informs me that it is spreading fast in the vicinity of Wellington. Native of South America, from the south of Brazil to Uruguay and Monte Video.

Elodea canadensis Michx.

Clear running streams near Featherston, not common: *K. W. Allison!* Considering how rapidly this plant increased when first introduced into Britain, it is somewhat remarkable that its spread in New Zealand has been so slow since its first introduction in 1870.

Panicum Lindheimeri Nash.

Vicinity of Kaitaia, Mongonui County; *H. B. Matthews!* Originally found on the summit of a hill by Kerikeri Pa, near Kaitaia; but it has since been observed in several localities in the district. I am indebted to Dr. Stapf, of the Kew Herbarium, for the identification. Native of North America, where it is said to be a common and widely distributed species, found in dry woods and open grounds from Maine to northern Florida, and westwards to southern California.

Cynosurus echinatus Linn.

I am indebted to *Mr. J. P. Kalaugher* for specimens collected by roadsides at Waihi. I believe this is the first record for the Auckland Provincial District.

Selaginella denticulata Link.

Has been known for many years as a garden escape at Pakaraka, Bay of Islands, and has lately appeared in great abundance on the banks of several swampy creeks in the neighbourhood; *T. H. Trevor!* I am also informed by *Mr. B. C. Aston* that it is not uncommon in several localities near Wellington. As it is now firmly established in the Bay of Islands locality, its further increase may be anticipated.

Art. X.—*Some Additions to the New Zealand Flora.*

By T. F. Cheeseman, F.L.S., F.Z.S., Hector Memorial Medallist, Curator of the Auckland Museum.

[*Read before the Auckland Institute, 20th December, 1918; received by Editor, 30th December, 1918; issued separately, 14th May, 1919.*]

1. **Ligusticum petraeum** Cheesem. n. sp.

Species cum *Angelica decipiens* Hook. f. et *Ligusticum aromaticum* Hook. f. confusa, a priore fructu, a posteriore foliis et floribus differt.

Herba aromatica, 5–13 cm. alta. Radix robusta, longe attenuata, ad apicem reliquis foliorum emarcidorum vestita. Folia numerosa, diffusa, 2·5–10 cm. longa, subcoriacea aut herbacea, pinnata; petioli 1–6 cm. longi, basi in vaginam expansi. Pinnae 4–8 jugae, 5–12 mm. longae, ovatae vel ovato-deltoideae, profunde incisae: lobis acutis vel subacutis, nunquam piliferis. Pedunculi multi, graciles, nudi, foliis longiores aut breviores. Umbellae compositae, 2–4 cm. diam., 4–8-radiatae. Involucri bracteae parvae, lineari-subulatae, basi dilatatae. Flores albi. Calycis lobi acuti. Carpella lineari-oblonga; stylis longis, recurvis.

Hab.—South Island: Abundant on the north face of Mount Owen, Nelson, alt. 4,000 ft., usually on the debris from limestone rocks; *T. F. C.* Also plentiful on the southern face of the same mountain; *W. Townson!* Broken River, Canterbury Alps, alt. 3,500 ft.: *T. F. C.* Takitimu Mountains, Southland, alt. 3,500 ft.; *D. Petrie!*

Very aromatic. 2–5 in. high. Root stout, long and tapering, clothed at the top with the bases of the old leaves. Leaves numerous, all radical, spreading, 1–4 in. long, subcoriaceous or herbaceous, pinnate; petiole from $\frac{1}{2}$ to $\frac{1}{3}$ of the length of the whole leaf, broadly sheathing at the base; leaflets 4–8 pairs, rarely more, $\frac{1}{5}$–$\frac{1}{2}$ in. long, ovate or ovate-deltoid or broadly deltoid in outline, deeply and somewhat sharply incised, sometimes almost pinnate at the base; lobes obtuse or subacute, never hair-pointed. Flowering-stems or peduncles many, longer or shorter than the leaves, rather slender, not branched, naked or furnished with a small pinnatifid leaflet about the middle. Umbels compound, $\frac{3}{4}$–$1\frac{1}{2}$ in. diam.; rays 4–8, slender, unequal, $\frac{1}{4}$–$\frac{3}{4}$ in. long.; involucral bracts small, linear: usually with a dilated base. Flowers white; calyx-lobes rather long, acute; styles very long, recurved. Fruit linear-oblong, $\frac{1}{8}$ in. long, not seen quite ripe.

This has much of the habit and appearance of *Angelica decipiens*, and the two are easily confounded in the absence of fruit. There is also a resemblance to some states of *L. aromaticum*; but in reality it differs in habit, in the spreading leaves with their much more remotely placed pinnae, in the unbranched flowering-stems, and particularly in the acute calyx-lobes, and the very long recurved styles. I have been acquainted with it for many years.

2. **Veronica Birleyi** N. E. Brown in *Kew Bulletin* for 1911, p. 345.

"Affinis *V. spathulatae* Benth., sed ramis crassioribus, foliis subsessilibus et pedunculis multo brevioribus differt."

"Suffrutex nanus, 10 cm. altus, ramosus; rami erecti, saepe flexuosi, 1–2 mm. crassi, puberuli demum sublignosi et glabri. Folia conferta vel inferiora ad 4 mm. remota, subsessilia, crassa, 6–9 mm. longa, 4–9 mm. lata, cuneato-obovata vel orbiculata, basi plus minusve cuneata, breviter et obtuse 3–7-loba, utrinque puberula, rubrotincta. Flores pauci, magni, prope apicem ramorum axillares. Pedunculi 2–3 mm. longi, 1–2-flori, bibracteati; bracteae 4 mm. longae, lineari-spathulatae, obtusae, glanduloso-puberulae. Pedicelli 1–1·5 mm. longi, glanduloso-puberuli. Calyx 4-partitus; lobi 5–6 mm. longi, 2·5–2·75 mm. lati, oblongi, obtusi, glanduloso-puberuli. Corolla 'magna, 5-mera, alba' (*Gibbs*). Capsula 5 mm. longa, 4–4·5 mm. lata, glabra, in lobos oblongos obtusos 4 disrupta."

South Island: Between rocks on the top ridge of Mount Bonpland, near Lake Wakatipu, 2435 m., February, 1908; *Miss L. G. Gibbs* (No. 1172).

"Allied to *V. spathulata* Benth., but differs in having much stouter branches, subsessile leaves, a finer and entirely different pubescence, and very much shorter peduncles. The corolla, according to Miss Gibbs, was white, about ¾ in. in diameter, with 5 subequal lobes; several were collected, but unfortunately they were lost. The name is given in honour of Mr. Harry Birley, a well-known guide in the district, who accompanied Miss Gibbs when this plant was collected."

I must express my indebtedness to Miss Gibbs for furnishing me with one of the type specimens. Mr. Brown's description appears to have been overlooked by most New Zealand botanists, for when, a few years later, flowerless specimens were collected on the Copland Pass by Mr. P. Graham, Chief Guide at the Mount Cook Hermitage, they were described as a new species by Mr. D. Petrie, under the name of *Veronica Grahami*. (*Trans. N.Z. Inst.*, vol. 45, p. 273, 1913.)

In March, 1917, it was again collected by Mr. W. A. Thomson and Mr. J. Speden in considerable quantity at an elevation of 5,000 ft. on Mount Tennyson, near Garston, Lake Wakatipu. An excellent series of specimens was obtained, showing that the plant attains a somewhat greater size than had been supposed, a single plant sometimes covering an area 6 in. to 9 in. across. Late in autumn the old leaves become almost glabrous, but the younger shoots are always densely puberulous. The flowers vary in size from ½ in. to ¾ in. in diameter.

As it seems important that the first description of this plant, and a knowledge of the original locality, should be readily accessible in the Dominion, I have placed the particulars on record herewith.

3. **Earina aestivalis** Cheesem. n. sp.

Affinis *E. mucronatae* a qua differt caulibus robustioribus firmioribusque, foliis latioribus et brevioribus, floribus majoribus, labello longiore, lobis lateralibus majoribus et acutioribus.

Hab.—North Island: Near Ahipara, *R. H. Matthews!* and at Kaiaka, *H. Carse!* both localities in Mongonui County. In forest at Muriwai, and near the mouth of the Waitakare River; *T. F. C.* Forest by the Waikanae River, Wellington: *B. H. Morison!*

Rhizome creeping, much as in *E. mucronata*. Stems numerous, 9–18 in. long, suberect or drooping, smooth, compressed, rather broader and stouter than in *E. mucronata*, and firmer. Leaves 3–6 in. long, $\frac{1}{5}$–$\frac{1}{3}$ in. broad, flat, stiff, erect, narrow-linear, acute or acuminate; midrib and veins conspicuous on the under-surface, not so evident above. Panicle terminal, 2–5 in. long; branches or racemes 3–7, rarely more, 1–1½ in. long, 4–7-flowered; bracts short and broad, clasping, many-striate. Flowers larger than in *E. mucronata*, $\frac{1}{3}$ in. diam. or more. Sepals and petals similar in size and shape, linear-oblong, subacute. Lip longer than in *E. mucronata*, and brighter in colour; lateral lobes wider and more acute. Column short, stouter.

I have been acquainted with this plant for several years, having gathered specimens at the mouth of the Waitakare River as far back as 1895. But the differences between it and *E. mucronata* are mainly comparative, and before describing it I was anxious to satisfy myself as to how far they were constant. Since then I have seen specimens gathered in several localities between the North Cape peninsula and Wellington; and as I find that the distinguishing characters—viz., stouter and stiffer habit, broader and more rigid leaves, larger flowers, longer lip with broader lateral lobes, and stouter column—are constant throughout, I cannot any longer refuse it distinction as a separate species. In addition to the above, there is the important fact that it flowers from the beginning of January to the first week in February, whereas the flowering period of *E. mucronata* is two months earlier at least, stretching from the first week in October to the middle or end of November. At Muriwai, a few miles to the north of the mouth of the Waitakare River, I observed it in full bloom on the 16th January, 1916; while typical *E. mucronata* growing in the vicinity had practically matured its capsules.

4. **Thelymitra aemula** Cheesem. n. sp.

Species ad *T. ixioides* proxime accedit, sed differt columnae lobis lateralibus multo elongatis, et lobo mediano non cristato.

Caules robusti vel graciles, 18–60 cm. longi. Folium auguste lineare, crassum, canaliculatum. Folia caulina vel bracteae vacuae 2. Flores 3–8, caerulei, in racemum 4–10 cm. longum dispositi. Sepala et petala oblonga vel ovato-oblonga, obtusa vel subacuta. Columna brevis, crassa, superne attenuata, 5-loba; lobis lateralibus elongatis, complanatis, penicillatis; lobo mediano breve, dorso non cristato.

Hab.—North Island: *Leptospermum* scrub at Birkdale, near Auckland: *H. B. Matthews!*

Stems stout or slender, 6–16 in. high. Leaf shorter than the stem, narrow-linear, thick, channelled in front. Cauline leaves or empty bracts 2, short. Flowers 3–8, about ½ in. in diameter, blue, rather closely placed in a raceme 1½–4 in. long. Sepals and petals oblong or ovate-oblong, obtuse or subacute. Column short, stout, broad at the base, narrowed above, winged; the wing extending behind the anther and free from it except at the base, 5-lobed; the two lateral lobes twice the length of the others, flattened, fringed with cilia for the greater part of their length; middle lobe short and broad, thickened and denticulated at the tip, but smooth at the back; the two intermediate lobes distinct from the central one, reaching half the height of the lateral lobes, broad, thick, and fleshy, jagged at the top. Anther broad, produced into a pointed tip that just overtops the level of the median lobe of the column-wing.

This interesting discovery is due to the activity of Mr. H. B. Matthews, so well known from the many additions made by him to the orchid flora of the North Cape peninsula. It is doubtless very closely allied to *T. ixioides* and the Australian *T. canaliculata*, but appears to constantly differ in the lateral lobes of the column being much longer, flattened, and more copiously penicillate; and the middle lobe, although denticulate at the top, is not at all warted or crested at the back. The flowers appear to be invariably blue; but the column is surrounded by a narrow band of violet just below the lobes, above which the colour is bright yellow.

ART. XI.—*A New Variety of* Pteris macilenta.

By H. CARSE.

[*Read before the Auckland Institute, 20th December, 1918; received by Editor, 30th December, 1918; issued separately, 14th May, 1919.*]

Pteris macilenta A. Rich. var. **saxatilis** Carse var. nov.

Planta decumbens vel suberecta: quam typo in partibus omnibus minor tenuiorque Stipes 8–24 cm. longus, tenuis, canaliculatus, flavus, suffuscus vel purpureus, glaber, infra squamosus. Frondes 10–36 cm. longae, 8–15 cm. latae, ovatae vel lanceolatae, valde membranaceae, haud lucidae ut in typo, 3–4-pinnatae Rhachis fere filiformis. Pinnae primariae distantes, inferiores 8–18 cm. longae, adscendentes; pinna terminalis 25 mm. longa; segmenta ultima alte et acute dentata, apex saepe laciniatus. Sori in segmentorum sinubus brevissimi.

This variety of *Pteris macilenta* has for years appeared to me worthy of a distinctive name. It differs from the type in many important characters, and, while occasionally forms connecting it with the type on the one hand and with var *pendula* on the other are seen, the usual form of this variety could not be mistaken. It is most plentiful in rather dry situations in forests, usually where detached rocks crop up.

The following are some of its main characters: The plant is decumbent or suberect, with a very short usually erect rhizome. Stipes 8–24 cm. long, slender, grooved, pale yellow, reddish-brown, or almost purple (as are the rhachises), darker at the base, quite smooth except for a few scales below. Fronds 10–36 cm. long, 8–15 cm. wide, ovate or lanceolate, very membranous, pale dull green, glabrous, 3- rarely 4-pinnate below; rachis almost filiform; primary pinnae distant, usually 6 pairs, lower opposite, 8–15 cm. long, obliquely placed on the stipes; terminal pinnae 25 mm. long. Secondary pinnae stalked, on the lower branches again pinnate, on the upper pinnatifid, terminal ones adnate and decurrent. Pinnules 12–20 mm. long. Ultimate segments deeply and sharply toothed, the apex often laciniate. Veins free, or very slightly anastomosing along the costa. Sori in notches between the segments, very short.

Hab.—Among detached rocks in hilly forests. Mongonui County, Bay of Islands, Whangarei, Manukau County; *H. C.* Coromandel Peninsula; *H. B. Matthews!* Thames; *D. Petrie!*

Art. XII.—*New Fossil Mollusca.*

By J. A. Bartrum, Auckland University College.

[*Read before the Auckland Institute, 20th December, 1918; received by Editor, 30th December, 1918; issued separately, 14th May, 1919.*]

Plate VII.

The following Mollusca have mainly been collected from fossiliferous sands near the mouth of Kawa Creek, about fourteen miles south of the mouth of the Waikato River, which are described by the author in another paper in this volume (pp. 101–6). One—*Chione auriculata* n. sp.—was collected by the author when in company with Dr. Marshall at Pakaurangi Point, near Batley, Kaipara Harbour, in 1916; another—*Bittium oamaruticum* n. sp.—was within a large gasteropod collected by Dr. Marshall from the Hutchinson's Quarry beds at Oamaru and given to the author; whilst there is one—*Raëta tenuiplicata* n. sp.—which was collected by Mr. R. P. Worley from the Okahukura Tunnel. All were submitted to the late Mr. H. Suter for identification, and pronounced by him to be new species.

In addition to *Chione auriculata* n. sp. there was identified also by Mr. Suter, from the Pakaurangi Point beds, along with other fossils collected by the writer, a specimen of *Mesalia striolata* (Hutt.), a species not listed by Dr. Marshall in his recent paper.*

Bittium oamaruticum n. sp. (Plate VII, fig. 1.)

Very small elongate tapering shell of 11 very slightly convex whorls increasing gradually in size. Protoconch $2\frac{1}{2}$ whorls, smooth: the other whorls with strong subvertical rounded axial ribs subequal in width to the interspaces, and made slightly nodular by 6 or 7 prominent rounded spiral threads with linear interspaces. The radial costae are 13 in number on later whorls, dying out on flattened base of body-whorl. Only one or two spiral threads on base below the angle of the body-whorl. Sinuous growth-lines distinct on base. Suture fairly deep, margined. Columella smooth, oblique, imperfect. Aperture imperfect, one-third of body-whorl being absent; would appear to have been narrowly ovate and notched posteriorly. Inner lip very narrow, a mere film on body-whorl.

Length, approximately 5 mm.; diameter, 1·7 mm.

Holotype in Auckland University College collection.

Locality: Hutchinson's Quarry beds. Collected by Dr. P. Marshall, 1917.

Remarks.—Classed as a new species of the genus by the late Mr. H. Suter, though the lack of knowledge of the aperture appears to render the generic position somewhat uncertain. If correctly placed, this genus is now for the first time described fossil from New Zealand rocks.

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* P. Marshall, The Tertiary Molluscan Fauna of Pakaurangi Point, Kaipara Harbour, *Trans. N.Z. Inst.*, vol. 50, pp. 263–78, 1918.

Chione auriculata n. sp. (Plate VII, fig. 2.)

Rounded-quadrate, small, rather compressed shell, almost equilateral; posterior end squarely truncated. Lunule large, lanceolate, very sharply raised at dorsal margin into a prominent triangular ear-like portion; margins sharply incised. Beaks rather small, little raised, approximate; a distinct ridge from beak to lower angle of truncated posterior end of shell.

Anterior dorsal margin forming triangular projection at lunule, the anterior side of triangle shortly forming an angle with the rounded anterior end. Posterior dorsal margin descends gently in convex curve to prominent angle with straightly truncated posterior end. Broadly rounded basal margin forms distinct angle at posterior end, and merges gradually into rounded anterior end.

Concentric ornamentation prominent; growth-lines are densely crowded and crossed by innumerable microscopic radiate lines. On lower half of shell are strong, broad, rounded lamellae, distant and somewhat irregular, 6 almost complete lamellae visible. They broaden out at posterior ridge of shell, and on dorsal portion beyond this are others nearer to the beak not developed anteriorly beyond this ridge. The lamellae crowd on the lunule, making it platy.

Hinge and other internal characters could not be observed.

Length, 10·6 mm.; height, 9 mm.; diameter, 4·6 mm.

Holotype in author's collection; complete but for anterior half of left valve.

Locality: Pakaurangi Point, Kaipara Harbour. Collected by Bartrum, 1916.

Circulus cingulatus n. sp. (Plate VII, figs. 3 and 4.)

Very small, umbilicate, almost discoidal shell, coiled in a very flat spiral. Whorls 3½ or 4, very rapidly increasing, the protoconch smooth, the rest sculptured by prominent spiral, angular, sharply elevated raised bands: 5 of these are visible between the sutures on penultimate whorl, 15 on body-whorl, regularly distributed, about 8 on basal portion, but absent from umbilicus. Interspaces approximately equal in width to the ridges, striated strongly by closely spaced transverse growth-lines, which alone ornament umbilicus.

Aperture somewhat incomplete, apparently circular, with a minute posterior sinus. Outer lip partially incomplete in holotype, moderately sharp, slightly crenate externally owing to spiral sculpture. Inner lip fairly solid, forming partial margin to the umbilicus; this latter not widely open and showing no coiling of whorls.

Diameter, 4 mm.; height, 1·9 mm.

Holotype and two imperfect paratypes in author's collection.

Locality: Kawa Creek, south of Port Waikato. Collected by Bartrum, 1917.

Remarks.—The late Mr. Suter remarked that this species comes nearest to *C. politus* Sut., from which, however, it is quite distinct.

Raëta tenuiplicata n. sp. (Plate VII, figs. 5 and 6.)

Shell of moderate size, very thin, obovate in outline, anterior end rounded, posterior produced and angled. Apparently agape anteriorly. Beaks directed forwards, sharp, fairly swollen, on posterior half of shell, approximate. From just below the beak a distinct wide shallow sinus passes vertically to basal margin, giving shell a folded aspect. Anterior dorsal margin descends gradually, straight at first and then according with broadly convex anterior end. Posterior dorsal margin incomplete; descends steeply, apparently slightly concave, to narrowly produced posterior end. Anterior end rather imperfect, but evidently angled with gently sinuous basal margin, which rises obliquely towards narrowing posterior end.

Lunule not marked off, raised centrally, oval. Ornamentation shown only on isolated remnants of original surface; narrow, shallow concentric grooves somewhat irregularly excavated, closely spaced, about 2 per millimetre. Radiate close lines visible on surface of cast but not on shell itself. Hinge and other internal characters unknown.

Length, actual 37 mm., restored approximately 42 mm.; height, 32 mm.; diameter, 18 mm.

Holotype and one paratype (both imperfect) in Auckland University College collection.

Locality: Okahukura Tunnel. Collected by R. P. Worley, 1916.

Siphonalia propenodosa n. sp. (Plate VII, figs. 7 and 8.)

Oval turreted shell, solid, fairly large, closely approaching *S. nodosa* (Mart.) but distinct in sculpture. Whorls 8½, protoconch apparently 2½ whorls, the first smooth, the others axially costate. Spire short, angle 55°, whorls gradually increasing. Suture not impressed, slightly sinuous. Whorls somewhat angled, and lightly excavated above the angle. Aperture imperfect on the holotype, but well shown in a paratype; high, oval; outer lip fairly thin, slightly callous, and finely notched or crenulate within; faintly angled at both keels of body-whorl. Posterior notch very distinct; anterior canal oblique, strongly recurved, broad, short, and truncated at base. Columella slightly excavated above and inflected to the left at canal. Inner lip spread broadly on body-whorl; siphonal fasciole distinct, crossed by coarse lamellae. Height of aperture and canal about twice height of spire.

Ornamentation of spiral threads especially strong on base of body-whorl and with finer interspaced threads particularly prominent there. On later spire-whorls and on body-whorl close below suture is a spiral row of minute elevated tubercles on a somewhat indistinct keel. On the whorls, at the prominent carina at the angle, is a conspicuous spiral band of about 11 sharp nodules merging in earlier spire-whorls into distinct costae which run to the anterior suture.

Besides these two rows of tubercles on the body-whorl are two others—one prominent one on the lower of the carinae of the body-whorl, and a faint one on the base a little below this last. Growth-lines strongly shown and numerous on the body-whorl.

Height, 32 mm.; diameter, 18 mm.

Holotype and two paratypes in author's collection.

Locality: Coast near Kawa Creek, south of Waikato River, Auckland. Collected by Bartrum, 1917.

Remarks. The late Mr. Suter remarked: "Near *S. nodosa* (Mart.), but distinguished from it by the row of tubercles below the suture, and a fourth row upon the base. The former character brings it near *S. conoidea* (Zitt.), from which, however, it is quite distinct."*

* Personal communication.

Siphonalia kawaensis n. sp. (Plate VII, figs. 9 and 10.)

Three specimens in a moderately good state of preservation; that chosen as holotype is incomplete at the apex of the spire, but shows the aperture and ornamentation well.

Shell oval, of medium size. Spire about half height of shell, angle 55°. Whorls about 8, gradually increasing. Protoconch (shown by a paratype), 2½ smooth whorls.

In ornamentation identical with the preceding species, *S. propenodosa*, except that the spiral band of nodules on the base of the body-whorl is less distinct. Aperture oval, distinctly notched above, and passing below into a broad short greatly reflected oblique anterior canal, truncated at the base. Columella arcuate above, oblique below. Outer lip thin, sharply angled at upper carina of body-whorl, less so at lower one, somewhat crenulate within. Inner lip very broadly spread over body-whorl as a thick callosity, which is produced into a most conspicuous strong tooth-like process at about the middle height of aperture, just below the band of nodules on the base.

Height, 43 mm.; diameter, 25 mm.

Holotype and two paratypes in author's collection.

Locality: Coast near Kawa Creek, south of Waikato River, Auckland. Collected by Bartrum, 1917.

Spisula aequilateralis gilberti n. var. (Plate VII, fig. 11.)

A very plentiful pelecypod in the Kawa bed, but difficult to collect perfect on account of friability both of fossils and containing beds. Unfortunately the author's specimens were crushed in transit by post from the late Mr. Suter, who examined them, and are not therefore as desirable types as might be obtained.

Shell moderately large, solid, with very heavy hinge with normal dentition and characters. In ornamentation the variety agrees with the normal species, the radial sculpture being perhaps closer and more distinct. In outline and contour there are constant differences. The variety is laterally more compressed, being less globose, and is flattened anteriorly on lower half of valve. The posterior dorsal margin descends rapidly from near the umbo and is straight, the dorsal region much flattened. The anterior dorsal area also is somewhat flatter than in the normal species.

Length, 74 mm.; height, 59 mm.; half diameter, 17·5 mm.

Holotype and imperfect paratype in author's collection.

Locality: West coast, near Kawa Creek, south of Waikato River, Auckland. Collected by Bartrum, 1917.

Terebra benesulcata n. sp. (Plate VII, fig. 12.)

Small, cylindrico-conical shell, with sharp elongate spire. Whorls 7 in the incomplete holotype, rather flattish, gradually increasing; suture rather deep. Spire about 4 times height of aperture. Protoconch absent.

Growth-lines crowded, rather sinuous, specially distinct on penultimate and body whorls. Two spiral rows of strong rounded tubercles, the lower slightly the stronger, with a moderately deep broad sulcus between them, characterize the whorls. Ten tubercles on the penultimate whorl; those of the lower row are continued as low costae to the anterior suture, but on the body-whorl die out before reaching the basal portion. No other spiral sculpture.

Aperture oval, lightly notched posteriorly, and produced anteriorly into a very short widely-open canal sharply bent to the left. Basal margin straight, not notched. Columella fairly short, straight, subvertical. Inner lip thinly and narrowly callous, ending in a point below. Outer lip incomplete. Siphonal fasciole distinct.

Length of imperfect holotype, 9 mm.; diameter, 2·3 mm.

Holotype and two fragmentary paratypes in author's collection.

Locality: West coast, near Kawa Creek, south of Waikato River, Auckland. Collected by Bartrum, 1917.

Tugalia kawaensis n. sp. (Plate VII, fig. 13.)

Small, conical, rounded shell, somewhat produced anteriorly: subcentral, blunt apex, directed back. Posterior slope gentle, straight or only slightly concave, anterior gently convex. Posterior and lateral margins rounded, lateral margins converging towards broadly truncated anterior end.

Slit-fasciole distinctly raised as sharp fold of shell, but not sculpturally differentiated except that it is stronger than adjacent radial riblets. These latter are well developed, about 50 in number, well raised, rounded. Some at intervals better developed than intervening ones; interspaces subequal to ribs. Broad, concentric, rounded ribs, about 8 or 9 in number, are prominent in interspaces, and make the radial ribs themselves slightly nodular; specially prominent in the fragmentary paratype. Towards apex concentric and radial ribs alike diminish.

The interior muscle-scar hooked back anteriorly towards apex.

Length, 6·2 mm.; breadth, 5·3 mm.; height, 2·3 mm.

Holotype and a fragmentary paratype in author's collection.

Locality: West coast, near Kawa Creek, south of Waikato River, Auckland. Collected by Bartrum, 1917.

Turbo postulatus n. sp. (Plate VII, fig. 14.)

Unfortunately only a fragment, comprising little more than the basal portion of the body-whorl, is available for description. It appeared to the writer to represent a species of *Turbo* previously unknown in the New Zealand fauna, a fact verified by the late Mr. Suter, who declared it to be a new species of that genus.

In spite of the fragmentary nature of the holotype it seems advisable for convenience of reference to give this shell a specific name and to append its description.

Shell fairly large, diameter approximately 27 mm., imperforate; columella mainly straight, highly oblique, but bent to the right near produced basal margin of aperture. Outer lip imperfect, thin; inner lip a widespread thin callosity on body-whorl and the somewhat excavated umbilical region, tapering rapidly to a point below.

Sculpture of body-whorl distinctive: growth-lines very numerous and prominent, crossing several convex, broad, well-raised spiral keels, these latter separated by subequal interspaces. On the indefinitely delimited basal portion of the body-whorl are approximately 4 such keels. The fourth of these is much stronger and broader than the others; it surrounds the relatively depressed umbilical tract and causes a distinct sinuosity of the basal margin of the aperture.

Holotype in author's collection.

Locality: West coast, near Kawa Creek, south of Waikato River, Auckland. Collected by Bartrum, 1917.

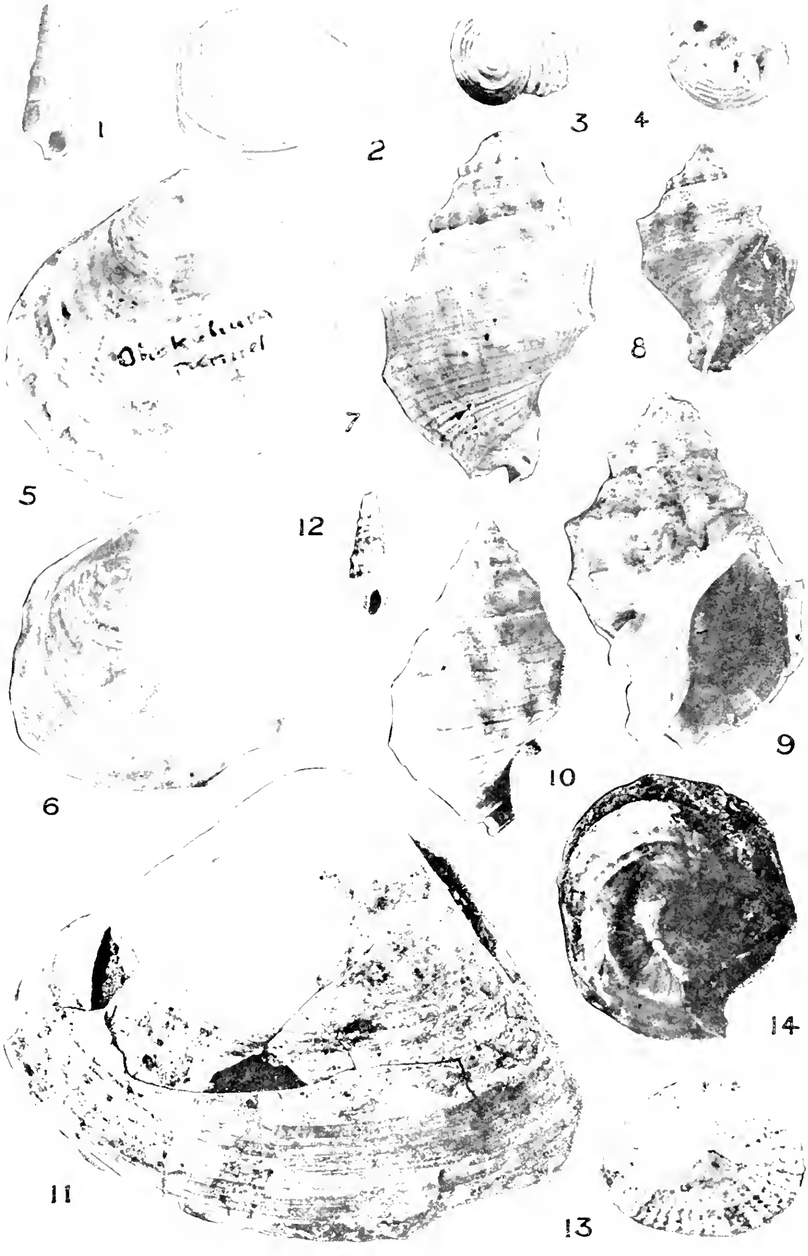

FIG. 1.—*Bittium oamaruticum* n. sp., 5 mm. × 1·7 mm.
FIG. 2.—*Chione auriculata* n. sp., 10·6 mm. × 9 mm.
FIGS. 3, 4.—*Circulus cingulatus* n. sp., holotype, diam. 4 mm.
FIG. 5.—*Raëta tenuiplicata* n. sp., holotype, 37 mm. × 32 mm.
FIG. 6.—*Raëta tenuiplicata* n. sp., paratype.
FIG. 7.—*Siphonalia propenodosa* n. sp., paratype.
FIG. 8.—*Siphonalia propenodosa* n. sp., holotype, 32 mm. × 18 mm.
FIG. 9.—*Siphonalia kawaensis* n. sp., holotype, 43 mm × 25 mm.
FIG. 10.—*Siphonalia kawaensis* n. sp., paratype.
FIG. 11.—*Spisula aequilateralis gilberti* n. var., holotype, 74 mm. × 59 mm.
FIG. 12.—*Terebra benesulcata* n. sp., 9 mm. × 2·3 mm.
FIG. 13.—*Tugalia kawaensis* n. sp., 6·2 mm. × 5·3 mm.
FIG. 14.—*Turbo postulatus* n. sp., diam. approx. 27 mm.

Face p. 100.]

ART. XIII.—*A Fossiliferous Bed at Kawa Creek, West Coast, South of Waikato River, New Zealand.*

By J. A. BARTRUM, Auckland University College.

[*Read before the Auckland Institute, 20th December, 1918; received by Editor, 30th December, 1918; issued separately, 26th May, 1919.*]

WHILST on a hurried trip from Port Waikato to Raglan early in 1917 the writer observed at the coast near Kawa Creek, about fourteen miles south of the Waikato River, a very interesting section in the Tertiary succession, and discovered a fossiliferous bed that had escaped the notice of earlier geologists examining the coast section. He was able later to spend about a day and a half collecting from this bed, in which he found molluscan fossils in great numbers, but very fragile and without great variety. No doubt, however, further collecting will add greatly to the present list of fauna. Even though incomplete, this list shows many points of interest, and the object of this note is to illustrate these, and to publish some facts in connection with the more recent geological history of the Kawa Creek district that may have more than local interest, and help to throw light upon the mutual relationships of the later Notocene beds of a wide diastrophic district.*

RÉSUMÉ OF THE GEOLOGY OF KAWA CREEK – PORT WAIKATO DISTRICT.

The oldest rocks exposed in the area studied are Mesozoic shales, sandstones, and local conglomerates, best exposed in the vicinity of Port Waikato. They are disposed in a somewhat irregular asymmetrical anticline of which the axis is situated about half a mile east of the coast-line, to which its strike approximates. The western limb is the steeper, the dips there varying from 20° to 50°, whilst the strikes, unless where local complications occur, range approximately from north-west to N. 5° E. In the core of the anticline appear dark-grey to black marine shales with locally abundant belemnites, moderately frequent pelecypods and brachiopods, and occasional gasteropods. Above these are well-bedded alternating sandstones and shales, with minor conglomerate, in which plant-remains are ubiquitous, and which furnish one of the best collecting-grounds for Mesozoic plants in New Zealand. The late Dr. E. A. Newell Arber has recently described the flora as Neocomian in age.†

Resting discordantly upon the eroded edges of the Neocomian are limestones of the Notocene, usually fairly pure, but sometimes very marly. Near their base they are strongly algal, and contain abundant fragments of the Mesozoic shales, a fact well shown near the mouth of the Huruwai Stream on the coast section. What fossils have been collected from these limestones have their analogues in the Oamaruian of other parts of New Zealand.‡ Warping, minor folding, and some faulting have caused the

* J. A. THOMSON, Diastrophic and other Considerations in Classification and Correlation, and the Existence of Minor Diastrophic Districts in the Notocene, *Trans. N.Z. Inst.*, vol. 49, pp. 397–417, 1917.

† E. A. NEWELL ARBER, The Earlier Mesozoic Floras of New Zealand, *Palaeontological Bulletin No. 6*, N.Z. Geological Survey, 1917.

‡ Dr. J. A. Thomson very kindly examined the brachiopods for the writer.

corresponding basal portions of these Oamaruian limestones to appear at very unequal heights above sea-level, whilst from many areas they have been removed by erosion, leaving the Mesozoic rocks exposed. The pre-Oamaruian surface of these last can only be surmised, for the evidence obtained is inconclusive, but it certainly appears to have possessed the broadness and simplicity so noticeable in the pre-Notocene surfaces of other parts of New Zealand.*

Whatever may have been this surface, upon it was deposited the basal limestone, and then a sequence of marls, blue sandstones, and impure fine-grained limestones. Then came the gentle folding, or warping, with the accompanying minor faulting that has already been noted — movements that probably accompanied a period of relative land-elevation, evidenced near the Kawa Creek by the sharp planation of the edges of the upper beds of the Notocene sequence either by marine or subaerial erosion. The reverse swing of the oscillation now caused this surface of planation to be covered up by the fossiliferous marine sands that furnish one of the main objects of this article. Their fossils show that they are practically the uppermost Notocene, and it is probable that they are comparable with certain massive sandstones, discovered recently by Dr. Henderson in the Te Kuiti district, which unconformably overlie the upper beds of the Tertiary sequence in that area.†

The closing members of the succession at the Kawa are not without interest, and may now be given. Unconformably above the fossiliferous sands is a local basaltic accumulation (both lava and agglomerate), followed by about 30 ft. of fresh-water silts, in which are intercalated a few thin, impure lignite-seams. Above these is a similar thickness of sands which appear to be wind-bedded: then a bed of pumice silt — itself a most interesting discovery — which is followed by ancient dune sands rising to a height of nearly 400 ft. above sea-level, and more or less continuous north-west to Port Waikato.

Details of the Coastal Section near Kawa Creek.

Without entering upon a discussion of the relative merits of different lines of evidence in the correlation of the New Zealand Notocene beds, or of the vexed question of the substantial conformity or otherwise of these strata, the writer considers that in the instance he is describing the mutual stratigraphic relations of the beds have a very real importance. The physical unconformity is very marked, and if it is coeval with that described by Dr. Henderson in the Te Kuiti district‡ it will no doubt serve a useful purpose in the classification of the latest Notocene strata of a wide district, if not of New Zealand. It seems desirable, therefore, to set forth in greater detail the observed section near the mouth of the Kawa Creek in which this unconformity is evident.

It may be remarked, further, that there is a very definite disconformity evident in the sea-cliffs immediately south of the Waikawau Stream, which is several miles north of the Kawa Creek, but this is in beds much below those at the latter locality.

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* See, for example, C. A. Cotton, The Structure and Later Geological History of New Zealand, *Geol. Mag.*, dec. 6, vol. 3, pp. 243–49, 314–20, 1916.

† J. Henderson, The Geology of the Te Kuiti District, with Special Reference to Coal Prospects, *N.Z. Journ. Sci. & Tech.*, vol. 1, p. 114, 1918.

‡ J. Henderson, *loc. cit.*

Amongst the lower beds of the observed section at the Kawa Creek locality are a series of thin greensand bands alternating with strong flaggy glauconitic limestone layers up to 1 ft. in thickness, the whole comprising a stratum about 15 ft. in depth, which strikes north and south and dips westward at approximately 15°. A normal strike fault traverses the section, accompanied by two lesser faults, and somewhat complicates its interpretation. This fault has a throw varying up to about 40 ft., and dips steeply eastward.

Above the flaggy bands are bluish-white calcareous mudstones exposed for approximately 50 ft. of height in the sea-cliffs: they strike nearly north and south, and dip gently (at approximately 8°) westward. They are poorly fossiliferous, showing macroscopically merely a few sporadic Foraminifera and molluscs: *Crepidula monoxyla* (Less.) was the only specifically determinate mollusc collected. The greensand and flaggy calcareous bands just beneath contain very abundant Foraminifera and occasional distorted brachiopods. The former have been forwarded to Mr. F. Chapman, of Melbourne Museum, but his report upon them is not yet available.

If one may judge from a rather limited number of fossils, mainly pelecypods, brachiopods, and echinoids, in beds of the same sequence but at a lower horizon, both sets of beds so far described—the flaggy bands and overlying mudstone—are probably Middle or Upper Oamaruian in age.*

The gently upturned edges of these beds are now most regularly truncated by an erosion-plane, rising from approximately 50 ft. above sea-level at the coastal section south of the Kawa Creek to about 80 ft. just north of the mouth of the Kawa, about half a mile distant. From its extreme regularity it would appear to be a result of marine planation, and it is clearly to be noted that this followed the gentle folding or warping and faulting which have just been described as apparent in the coast section.

On the erosion surface rest yellow to bluish sands crowded with casts or actual shells of molluscs, a few bryozoans, corals, and other organisms. Near the base the remains are moderately well preserved, and have furnished the collection made by the author and listed in this paper. In depth these sands reach about 40 ft. They cannot be followed northward from the section now described, but what appears to be the same bed can be seen near where the coastal route regains the coast a mile or so southwards after deviating inland to avoid some impassable basalt sea-cliffs, and again still farther south.†

Here they have been disrupted by this basalt and overlain by columnar lava. At the more northerly locality, similarly, other lava or agglomerate rests on a locally irregular erosion surface of the fossiliferous sands, the agglomerate showing considerable variation in thickness, in places thinning to 1 ft. or so, in others thickening to as much as 20 ft. Close by is exposed part of the somewhat complex vent of the volcano, whence came this material, and whence poured forth a flood of basaltic lava reaching probably several miles westward, for a small islet more than a mile from the shore appears to be basaltic. The columnar jointing of the flow renders it an easy prey to the great waves characteristic of this exposed coast.

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* Dr. J. A. Thomson, who examined the brachiopods, reports that they are certainly Oamaruian.

† Hutton observed these beds and noted their unconformable relations to the underlying beds, but failed to obtain any marine fossils in them. He tentatively correlated them with the Waitemata sandstones, but suspected that they might be much younger. (F. W. HUTTON, On the Relative Ages of the Waitemata Series and the Brown Coal Series of Drury and Waikato, *Trans. N.Z. Inst.*, vol. 3, pp. 244–49, 1871.)

Above the volcanic material come grey and white silts with impure lignite bands, all apparently of fluviatile origin, for they show good current-bedding in places. There is a depth of 30 ft. of these silts, which are then succeeded by an equal thickness of consolidated iron-stained sands, probably of dune origin; and again above these there is a most interesting bed, 10 ft. to 20 ft. in depth, of pumice silts, also evidently of fluviatile origin.

A succession of dune-sands, rising to approximately 350 ft. above sea-level, and deeply stained and cemented by concretionary limonite, completes the section.

All these beds above the fossiliferous sands are undoubtedly Notopleistocene† in age, and, though of considerable interest, are beyond the scope of this paper, which is chiefly concerned with the fossiliferous sands.‡

List of Mollusca from the Fossiliferous Sands.

The Mollusca listed below come from near the base of the fossiliferous sands, and within a few feet, therefore, of the unconformity duly noted in the Kawa section. The identifications in nearly all cases were made or checked by the late Mr. H. Suter. For convenience of reference the genera are arranged in alphabetical order in the list. Recent species are preceded by an asterisk.

Ancilla hebera (Hutt.).
*—— *novae-zelandiae* (Sow.).
**Anomia* cf. *huttoni* Sut.
**Arca novae-zelandiae* Smith.
—— *subvelata* Sut.
**Barnea similis* (Gray).
**Calyptraea maculata* (Q. & G.).
**Cardita calyculata* (L.).
**Chione mesodesma* (Q. & G.).
—— *meridionalis* (Sow.).
*—— *spissa* (Desh.).
Circulus cingulatus Bartrum.§
Crepidula gregaria Sow.
*—— *monoxyla* (Less.).
—— *striata* (Hutt.).
**Dentalium ? huttoni* T. W. Kirk.‖
—— *pareorense* Pilsbry and Sharp.
—— *solidum* Hutt.
**Diplodonta zelandica* (Gray).
**Divaricella cumingi* (Ad. & Ang.).
**Dosinia anus* (Phil.).
*—— *caerulea* (Reeve).
*—— *magna* Hutt.
Drillia aequistriata Hutt.
*—— *laevis* (Hutt.).
**Emarginula striatula* Q. & G.
Fulgoraria sp.
Glycymeris globosa (Hutt.).
*—— *striatularis* (Lamk.).
**Gomphina maorum* Smith.¶
Hipponix antiquatus* (L.).
**Leda bellula* A. Ad.
Lima colorata Hutt.
**Loripes concinna* Hutt.
**Mactra discors* Gray.
*—— *scalpellum* Reeve.
Marginella ? harrisi Cossm.
*—— *pygmaea* Sow.
**Murex zelandicus* Q. & G.
**Myodora antipodum* Smith.
**Natica australis* (Hutt.).
*—— *zelandica* Q. & G.
**Nucula hartvigiana* Pfr.
*—— *nitidula* A. Ad.
Olivella neozelanica (Hutt.).
Ostrea, several sp.

† J. A. Thomson, *loc. cit.*

‡ It is perhaps permissible to point out that the pumice silts offer strong evidence that the Waikato or some such river flowed westward to this portion of the coast in early Notopleistocene times, bringing the pumice from the central rhyolitic country. Pumice terraces of corresponding height above sea-level are described by Henderson on the banks of the Waikato River near Cambridge (J. Henderson, *N.Z. Journ. Sci. & Tech.*, vol. 1, pp. 112–15, 1918).

§ Described in this volume (p. 97).

‖ Two specimens, small, incomplete at anterior end, come near *D. huttoni*, but ornamentation shows more numerous longitudinal ribs than in the type

¶ Not before recorded fossil.

** New to fauna.

Paphia curta (Hutt.).
Pecten williamsoni Zittel.
Pinna sp.
Polinices ambiguus Sut.
* — *amphialus* (Watson).
— *ovatus* (Hutt.).
— *sagenus* Sut.
**Protocardia pulchella* (Gray).
**Psammobia lineolata* Gray.
* — *stangeri* Gray.
Siphonalia costata (Hutt.).
— *kawaensis* Bartrum.†
— *propenodosa* Bartrum.†
**Spisula aequilateralis* (Desh.).
— *aequilateralis gilberti* Bartrum.†
*— *ordinaria* (Smith).
Struthiolaria sp.
**Tellina alba* Q. & G.
* — *glabrella* Desh.
* — *huttoni sterrha* Sut.‡
* — *spenceri* Sut.§
* — *urinatoria* Sut.‡
Terebra benesulcata Bartrum.†
**Tugalia bascauda* Hedley.
*— *intermedia* (Reeve).
— *kawaensis* Bartrum.†
Turbo postulatus Bartrum.†
Turris duplex Sut.
Turritella huttoni Cossm.
* — *symmetrica* Hutt.
**Venericardia difficilis* (Desh.).
*— *lutea* (Hutt.).
*— *purpurata* (Desh.).

A critical examination of this list shows the following facts: Including new ones, seventy-four species have been identified, four of them doubtfully so, and in addition three genera represented, one of which has no living representatives. Forty-six of the species are still living—a percentage of 62: one of these—*Hipponix antiquatus* (L.)—is new to the New Zealand fauna, whilst three are recorded fossil for the first time. There are six new species and one new variety.

A considerable amount of information about the upper Notocene fossils probably awaits publication by the New Zealand Geological Survey, but, depending upon literature now available, the writer finds that as many as sixteen of the twenty-nine extinct species have not previously been described from beds higher than the Awamoan stage. Eleven species are found fossil only in the Wanganui and Petane beds,|| or are Recent species now first recorded fossil, and one more—*Dosinia anus* (Phil.)—is known only from Pliocene beds elsewhere in New Zealand.¶

Dr. J. A. Thomson, Director of the Dominion Museum, who has available for comparison many unpublished identifications of fossils from North Otago and South Canterbury made by the late Mr. H. Suter, very kindly compared the Kawa faunal lists with those of the various typical Canterbury, North Otago, and other localities, and reported as follows: "I find that forty-seven of your species are known from the Awamoan or lower beds, while twenty-three are not.** These twenty-three include, of course, all the new species, and the remaining seventeen are all Recent species with the exception of *Drillia aequistriata* Hutt., *Olivella neozelanica* (Hutt.), and *Polinices ambiguus* Sut. The last species I cannot trace; the two former are certainly Wanganuian."††

† Described in this volume (pp. 96–100).
‡ Not before recorded fossil.
§ The late Mr. Suter informed the writer that he obtained a specimen of this shell in a collection from Poverty Bay made prior to 1874 (locality No. 60 of the New Zealand Geological Survey). Otherwise it was formerly unknown fossil.
|| Wanganui system (Pliocene) of Marshall (New Zealand and Adjacent Islands, *Handbuch der regionalen Geologie*, 1911).
¶ H. SUTER, *Manual of the New Zealand Mollusca*, 1913.
** Species doubtfully identified are omitted.
†† Personal communication.

It appears evident from these considerations that the fauna is intermediate between the Awamoan and Wanganuian. It is unfortunate that the beds immediately below the unconformity at the base of the fossiliferous sandstones at the Kawa locality are so poorly fossiliferous, since their exact correlation is a matter of great importance, and in addition a good idea could then be gained of the relative importance of the above-mentioned unconformity.

In conclusion, it is necessary only to point out once more the probability of the wider occurrence of beds of the same age as the above in the district. An example probably even now is furnished by certain sandstones overlying unconformably the upper beds of the Tertiary sequence near Te Kuiti.*

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

By D. Petrie, M.A., Ph.D.

[*Read before the Auckland Institute, 20th December, 1918; received by Editor, 30th December, 1918; issued separately, 26th May, 1919.*]

1. **Lagenophora cuneata** sp. nov.

L. foliis parvis coriaceis cuneato-obovatis, ± 1·5 cm. longis ± 0·6 cm. latis, supra parce tomentosis sub apice rotundato-dentatis, a marginibus incrassatis; culmis 12 cm. longis vel brevioribus erectis valde gracilibus, sub apice ± pubescentibus; capitulis parvis ± 6 mm. latis; acheniis parvulis vix curvatis anguste lineari-ovatis a marginibus incrassatis in rostrum obliquum angustatis.

Stems loosely tufted, short, slender, spreading by short stolons. Culms erect, stiff, very slender, brownish-green, 12 cm. high or less, with one or two minute bracteoles, glabrous below, usually more or less pubescent towards the top. Leaves radical, few, coriaceous, cuneately obovate, ± 1·5 cm. long, ± 0·6 cm. broad near the top, variable in outline, rarely entire, usually with two bluntly rounded teeth near the apex, sometimes with two pairs of teeth in the upper half of the blade, margins thickened and when dry more or less recurved, glabrous below, more or less clothed above and along the edges of the petioles with long whitish hairs consisting of a single row of cells, narrowed into a flattened petiole about as long as the blades, veins obscure. Heads small, ± 6 mm. across; involucral scales oblong, thin and scarious at the edges, obtuse, purplish at the more or less ciliately jagged tips; ligules short, narrow, white, revolute. Achenes small, linear-obovate, scarcely curved, thickened at the margins, narrowed into a short oblique beak.

Hab. Eweburn and Sowburn Creeks, Maniototo County; Cromwell; Flagstaff Hill, Dunedin; Macrae's, Waihemo County; Tasman Valley; Takitimu Mountains; D. P.

2. **Brachycome linearis** comb. nov.

When the late Mr. T. Kirk transferred my *Lagenophora linearis* to the genus *Brachycome* he substituted the specific name *lineata* for *linearis*. The name *B. linearis* seems, however, not to be preoccupied, and by the present rules of botanical nomenclature it is the proper name of the species in question.

* J. Henderson, The Geology of the Te Kuiti District, with Special Reference to Coal Prospects, *N.Z. Journ. Sci. & Tech.*, vol. 1, p. 114, 1918.

3. **Urtica aspera** sp. nov.

Planta *U. incisae* Poir. affinis; differt floribus dioeciis; foliis subcoriaceis obtuse nec alte serratis; culmis ramis ac petiolis pilis pungentibus dense vestitis; foliorum nervis parce similiter vestitis.

A rather rigid much-branched dioecious herb, 30–40 cm. high. Stems moderately stout, densely clothed with rather stiff white stinging hairs, as are the branches, petioles, and inflorescence. Leaves opposite; petioles rather stout, as long as the blades or somewhat longer; blades coarsely and bluntly but not deeply serrate, ovate or ovate-deltoid, more rarely cuneate at the base, ± 5 cm. long, ± 3 cm. broad, acute, subcoriaceous, with scattered stinging hairs on the nerves both above and below. Male inflorescence single or geminate from the axils of the upper leaves of the stem and the branches, rather long spicate, bearing short rather distant small clusters of flowers; perianth glabrous; female inflorescence simple or branched, with more numerous crowded flowers; nuts broadly ovoid, enclosed in the not enlarged perianth.

Hab.—Among tussock-grass in the more open parts of Firewood Creek, Cromwell, at about 2,300 ft.: Sowburn, Maniototo County, among patches of *Discaria toumatou* Raoul: D. P. Head of Awatere Valley, Marlborough: L. Cockayne. An indifferent specimen collected by B. C. Aston in the Dee Valley, Clarence basin, is probably of this species.

4. **Thelymitra caesia** sp. nov.

T. pulchellae Hk. f. affinis; differt floribus subcoeruleis, sepalis petalisque acutis, columnae lobo posteriore bifido ac apice subcrenulate incrassato, lobis lateralibus latis valde complanatis brevioribus insuper a marginibus subpectinate fimbriatis.

Stems moderately slender, 65 cm. high or less. Leaves shorter than the stem, variable in length, long-sheathing at the base, linear, fleshy, concave above, shining light green, midrib obscure. Cauline bracts usually two, thin, short, sheathing for most of their length, rather abruptly acuminate; floral thin, lanceolate-acuminate, slightly exceeding the peduncles. Flowers about five, laxly racemose, shortly pedunculate, large (± $2\frac{1}{2}$ cm. across); sepals and petals ovate or ovate-lanceolate, acute (sepals slightly the longer), lavender-coloured but closely streaked with deep blue; lip broader, paler, sharply narrowed above and less acute. Column stout, broadly winged, much shorter than the perianth, 3-lobed; posterior lobe bifid, shorter than the anther, its divisions truncately obtuse, thickened and slightly incurved along their somewhat wavy brownish-yellow tops; lateral lobes short but equalling the anther, forming broad thin flattened plates, subpectinately fimbriate along the upper margins, the fimbriate processes more or less cut into very short hair-like subdivisions; anther broad, connective produced into a short slightly grooved tip.

Hab.—Birkdale-Glenfield Reserve, Waitemata County. Flowers late November and early December.

This species was collected recently by Mr. H. B. Matthews, who has for several years devoted much time and attention to hunting up the native orchids, with quite remarkable enthusiasm, acuteness, and success. To him I am indebted for the specimens examined and for a note of the tint of the leaves and the colour of the perianth. When the species is better known the range in stem-height and in the number of flowers may be greater than the present description discloses. The species is clearly a fairly close ally of *T. pulchella* Hk. f.

Art. XV.—*Further Notes on the Horowhenua Coastal Plain and the Associated Physiographic Features.*

By G. Leslie Adkin.

[*Read before the Wellington Philosophical Society, 18th September, 1918; received by Editor, 18th September, 1918; issued separately, 26th May, 1919.*]

In this paper I present further data bearing on the history of the Horowhenua coastal plain and the associated Quaternary deposits, and also discuss some of the main points raised by the dissension of opinion between Dr. Cotton* and myself.†

Dimensions and Eastern Limits of the Horowhenua Coastal Plain.

As shown by the following table, the Horowhenua coastal plain attained its maximum breadth of twenty-six miles in the vicinity of Palmerston North,‡ and gradually narrowed in a south-westerly direction.

Localities.	Two Miles South of Paekakariki.	Te Horo.	Otaki.	Muhunoa.	Levin.	Buckley Road, Shannon.	On Palmerston–Pahiatua Road.
Width in miles ..	0	3½	4	8	8½	12	26
Altitudes above sea-level, in feet§	..	320	330	360	530	540	770
Distances between, in miles	17	4½	9	4	4½	26	

The thickness of the coastal-plain formation‖ depends upon the relief of the early Pleistocene land-surface upon which it lies, attaining its maxima and minima along the margin of the old land according to its remoteness from or proximity to the apexes of the Ohau, Otaki, and other fans. Two miles south of Shannon the formation lies on the lower part of the northern slope of the Ohau fan, and there its original thickness was about 500 ft. On the lower edge of the southern slope of the fan of the Manawatu River, near the margin of the old land due east of where Linton now stands, its former thickness probably exceeded 600 ft. These figures are only approximate, and require to be verified or corrected by calculations based on careful surveys.

* C. A. Cotton, The Geomorphology of the Coastal District of South-western Wellington, *Trans. N.Z. Inst.*, vol. 50, pp. 212–22, 1918.

† G. L. Adkin, The Post-Tertiary Geological History of the Ohau River and of the Adjacent Coastal Plain, Horowhenua County, North Island, *Trans. N.Z. Inst.*, vol. 43, pp. 496–520, 1911.

‡ The writer has at present no data as to the extent of the Horowhenua coastal plain north of this point, beyond which, however, it is known to extend.

§ These are the altitudes of the highest traceable sandstone in the localities specified.

‖ The term "raised-beach formation" has been abandoned as being misleading, substituting "coastal-plain formation," "coastal-plain sandstone," or, more briefly, "sandstone formation."

South of the Manawatu Gorge the former shore-line (*i.e.*, the eastern or inner margin of the coastal plain) lay along the western border of the old land, and was very irregular and indented, the sea winding in and out round the projecting spurs. Sea-cliffs were cut along the old-land margin, and these in places are in a good state of preservation, notably near Paekakariki, Otaki, and Ohau, and between Shannon and Tokomaru.

As shown by the altitude of the upper edge of the coastal plain on the Palmerston–Pahiatua Road (see above table), it is evident that prior to its initial emergence an arm of the sea ran through the Manawatu Gorge and spread out in the Woodville–Pahiatua–Dannevirke district to form a shallow harbour or estuary, into which the Manawatu River flowed. "Lacustrine deposits" are reported to exist in the district defined, the supposed former lake being due to the ponding of the Manawatu River by an unusually rapid uplift of the mountain axis.* This theory is now shown to be erroneous; the supposed lake was in reality an estuary, and the so-called "lacustrine deposits" are doubtless estuarine deposits.

Dissection and Topographic Development of the Horowhenua Coastal Plain.

Since its uplift above sea-level the coastal plain has been very thoroughly dissected by the rivers and streams that extended their courses across it, assisted by others that take their rise within its borders. Extensive stretches of plain unbroken by the marks of stream erosion, which at first must have been the predominant feature, no longer exist. Instead, irregular strips and areas of flat open plain are intersected by a network of water-courses. These flat areas, however, are not the original surface of the coastal plain, but denuded surfaces corresponding to the original one. The erosion by rain, for instance, uniformly lowered the surface of large areas, the resultant silt being washed into the channels of the then less-developed stream-systems.

The rivers, the larger of the minor streams, and the lesser ones have all left their distinctive marks upon the plain, producing a diversity of surface forms. The present topography therefore varies from youthful to mature.

The rivers, the former fan-builders, in their passage from the hills to the sea rapidly cut into the soft marine beds (or sandstone, as they may briefly be designated), and swept them clear away, exposing their fans, without exception, to a greater or less extent.

The usual work of the larger of the minor streams was to carve wide shallow channels in the sandstone, and later to aggrade their bottoms with fine alluvium, forming flood-plains often of considerable fertility. Bordering the courses of these streams the topography of the sandstone has often reached a mature stage — of low relief and smooth curved contours.

The lesser minor streams are for the most part tributaries of the larger ones. Many take their rise in the plain, and occupy narrow youthful channels divided by broad flat-topped sandstone ridges. Others of brisker flow, with their sources in the hills, have cut in the sandstone formation a descending succession of wide-flaring, flat floors, usually free from even a veneer of alluvium, and opening out at different levels into the valley

* D. Petrie, Account of a Visit to Mount Hector, &c., *Trans. N.Z. Inst.*, vol. 40, p. 290, 1907.

of the trunk stream. These correspond to successive levels in the valley of the trunk stream—namely, benches cut in the sandstone side of the valley as it was deepened; the surface of the built flood-plain; and subsequent levels cut in the flood-plain alluvium. Along the margin of the ranges the lesser streams have deposited cones and steep slopes of alluvium; these attain their maximum development between Waikanae and Te Horo, and north of Tokomaru.

Sufficient has been said to show that the topography of much of the coastal plain is quite youthful, and that only small tracts here and there have reached a mature or submature stage. On the other hand, two portions exist in which, by reason of their position and the vagaries of the drainage-lines, modification by stream erosion has been even less pronounced than elsewhere and their topography is strikingly youthful. These portions, both situated at the foot of the ranges—one at Palmerston North, the other near Shannon—have been somewhat isolated by the larger adjacent streams, and, as their present surface has been but slightly lowered from the original level, they stand out plateau-like above the surrounding country. The comparatively few gullies intersecting them are as a rule deep, steep-sided, and narrow, the wide flat-topped divides terminating abruptly at the top of the gully-walls. A peculiar feature is that the streams draining these gullies seem to have reached a more mature stage than the topography. The topography is undoubtedly youthful, as shown by the wide, flat-topped uplands, but the streams themselves are sluggish, and often meander on flat, graded bottoms, frequently swampy. The explanation is probably the porous character of the formation, which retards the development of the gullies and consequently of the topography, while the streams have meanwhile attained a temporary base-level.

The Deformation of the Southern End of the Horowhenua Coastal Plain.

Until recently the writer entertained the belief that the Horowhenua coastal plain terminated, and that its inner margin descended to sea-level, in a south-westerly direction, coincidently with the present complex lowland, at a point about two miles south of Paekakariki. Doubt was cast on this supposition by the compilation of the above table, which shows, *inter alia*, the altitudes of the inner margin of the coastal plain southwards from the vicinity of the Manawatu Gorge. As tabulated, these altitudes form a descending series (marked by a certain step-like irregularity), proving the differential character of the uplift that raised the coastal plain. The method adopted to determine the height of the inner margin of the coastal plain was to select suitable localities along its length and ascertain the altitude of the highest traceable beds in those localities. The irregularity of the altitudes obtained is explained by the denudation of the beds even in the selected localities

On the Palmerston-Pahiatua Road, eight miles south of the Manawatu Gorge, the coastal plain appears to have attained its maximum uplift, and here the beds of its inner margin are found 770 ft. above the present sea-level. Proceeding southwards, the beds on the inner margin are found at decreasing altitudes until Te Horo is reached near which place the sandstone beds are found at a height of 320 ft. If, as previously supposed, the inner margin of the coastal plain descended to sea-level at Paekakariki, the average slope of that margin would have been about 13 ft. per mile, and the greatest altitude it attained at Te Horo would have been 200 ft. At

Te Horo the sandstone beds are, however, traceable at the foot of the hills up to a height of 320 ft., leaving a discrepancy of 120 ft.

Plotted diagrammatically to scale (fig. 1), the available data show that the inner margin of the coastal plain had a southward slope of only 10 ft. per mile, so that the southern end of the plain originally extended beyond Paekakariki some miles south of the present entrance of Porirua Harbour. This being so, it is evident that some great change has taken place, a change involving the destruction, or at any rate the disappearance, of the former southern portion of the coastal plain, since south of Paekakariki a bold steep coast, and not a lowland fringe, borders the sea. I shall now endeavour to demonstrate the cause and features of this change, and shall also present certain corroborative phenomena.

The south-western portion of the Wellington Province may be regarded as consisting of a series of earth-blocks, both large and small. The largest block, comprising the Tararua and Rimutaka Ranges, is bounded on the east by the Wairarapa fault, and is rising, as evidenced by its relation to the Wairarapa depression, situated at the base of its steep eastward-facing scarp, and by the emergence of the Horowhenua coastal plain, which lies

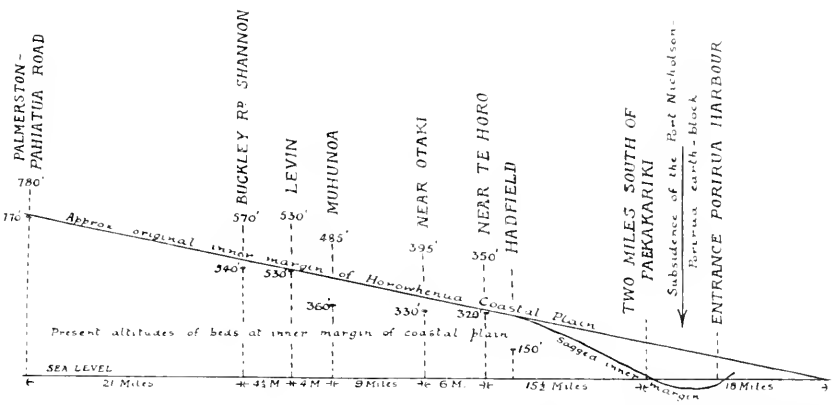

FIG. 1.—Longitudinal section of the Horowhenua coastal plain, showing the sagging (warping) of its southern end due to the subsidence that drowned the Porirua–Horokiwi valley-system to form Porirua Harbour.

on its tilted back slope. Another large block, comprising what is known as the Wellington Peninsula, is also rising, seemingly rather uniformly, as shown by the platforms and benches of the Kaukau and Tongue Point cycles of Cotton.* Between these two lies the subsiding Port Nicholson - Porirua Harbour block, now cut in two by the Wellington fault. On the south-east, or downthrow, side of the fault the subsiding tendency became a pronounced fact, and this part of the block has been depressed below the present sea-level to form the harbour of Wellington: on the other hand, the portion north-west of the fault was differentially tilted northward, drowning the stream-valleys incised upon its seaward border to form the branching Porirua Harbour.

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* C. A. COTTON, Notes on Wellington Physiography, *Trans. N.Z. Inst.*, vol. 44, pp. 246–65 (ref. to pp. 248–51), 1912.

The subsidence or downward tilting of the northern part of the Port Nicholson – Porirua block involved the southern end of the Horowhenua coastal plain, which lay athwart its axis, gradually bending and depressing it below sea-level somewhat in the fashion depicted in fig. 1.* North-westward of the main axis of subsidence the surface of the subsiding portion of the coastal plain sloped up to the normal slowly rising surface of that part lying beyond the influence of the Port Nicholson – Porirua block.†

It is a well-established physiographic principle that sea erosion is seldom, if ever, extensively developed on a rising coast, but that subsidence not only causes sea-advance but also facilitates sea erosion. On the rising and emerging major portion of the Horowhenua coastal plain there is no evidence of its seaward edge having been cut back by the action of the sea; on the other hand, the down-warping of the narrow southern end of the coastal plain permitted not only a local inroad of the sea, but also simultaneous marine erosion. This erosion advanced, in the immediate vicinity of the intersecting axis of subsidence, to the cliffed margin of the old land: this took place a couple of miles north-east of Paekakariki, as pointed out by Cotton.‡ Farther away, as at Hadfield,§ the newer line of cliffs lies half a mile to seaward of the old-land cliffs, and more remote still they die out and do not reappear.

The Significance of the River-cut Rock Floors in the Ohau Valley.

The evidence I wish to bring forward in support of my contention‖ that the Horowhenua piedmont alluvial plain, formed by the lateral coalition of the larger river-fans, was built up on a stationary surface at the foot of an inland mountain range, and not, like the Canterbury Plain, as conclusively demonstrated by Speight,¶ laid down on a subsiding maritime area, is furnished by the old river-cut rock floors in the intermont portion of the Ohau valley. Unlike the Canterbury rivers, those of Horowhenua—*e.g.*, the Ohau—as the result of a fixed base-level, reached a state of perfect adjustment of load to volume and grade. If the Ohau fan and valley-plain had not reached completion, and if the deposition of detritus by the river had not ceased, the rock floors, by which the area of the valley-plain was considerably extended, could not have been formed. The capping of the shingle beds of the valley-plain with a thick layer of clay alluvium was in itself evidence of the termination of the task of fan-building; and the cutting of the rock floors by the powerful lateral corrasion which immediately followed conclusively proves the fact.

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* This assumes the very recent advent of the Wellington fault. (See also Cotton *loc. cit.*, p. 258.)

† The southern end of the Horowhenua coastal plain was intersected *obliquely* by the axial line of the Port Nicholson – Porirua block, the northern extension of which is regarded as running through the gap at Pukerua railway-station, and thence, inside the island of Kapiti, seawards, its general trend being slightly east of north. The entrance to Porirua Harbour seems to be a submerged water-gap.

‡ *Loc. cit.* (1918), p. 218.

§ The coastal-plain formation has been truncated for a distance of a mile and a half along the line of railway northward from the Hadfield flag station, and cliffs from 60 ft. to 90 ft. high have been developed.

‖ G. L. Adkin, *loc. cit.*, p. 504.

¶ R. Speight, A Preliminary Account of the Geological Features of the Christchurch Artesian Area. *Trans. N.Z. Inst.*, vol. 43, pp. 421–24, 1911.

Lateral corrasion was a negligible factor during the building of the fan and valley-plain; but with the cessation of deposition it became predominant, and the hill-spurs and ridges bounding the built part of the valley-plain were cut back on a level with its surface. The large amount of material derived from this lateral corrasion was transported across and deposited beyond, and not upon, the surface of the fan, the spoil being delivered to the trunk Cook Strait River, of which at that time the Ohau was but a branch.

In several places the old rock floors still exist up to their original level, and form small flat-topped rocky hills. Elsewhere they have been incised by the Ohau and its tributaries rejuvenated in the present cycle of erosion, and their former extent is marked by rock terraces capped by gravel veneers of varying thicknesses. Little, if any, gravel or shingle was deposited on the *original* surface of the rock floors, showing how complete was the transportation of coarse detritus by the river during the time of lateral corrasion. Similar rock floors will doubtless be found in the intermont portions of the valleys of the other Horowhenua rivers.

DR. COTTON'S INTERPRETATION OF THE PHYSIOGRAPHY OF THE COASTAL LOWLAND.*

Cotton's views regarding the history and sequence of deposits of the coastal lowland which extends from Paekakariki to Palmerston North and beyond appear to be the result of a misconception arising from observations based for the most part on the extreme southern part of the coastal belt. As shown above, that part of the coastal belt is not typical of the whole, the important incidents of deformation and sea erosion being peculiar to that locality. I hasten to say that Cotton's observations on the area a few miles north-east of Paekakariki† are undoubtedly substantially correct: it is the application of inferences drawn from that locality to the coastal lowland in general to which exception must be taken.

The Sequence of the River-fans and the Sandstone Formation.

In the paper referred to, Cotton dissents from my view that the coalescing fans of the rivers along this coast form the basal member of the Quaternary formations, and that it (the basal member) is directly overlain by the sandstone formation (my Horowhenua coastal plain). Cotton puts the sandstone formation at the base of the series, and regards the river-fans, with which he classes all the gravel deposits of the lowland, as being "among the youngest elements of the lowland physiography."

One of the chief causes of Cotton's divergent opinion as to the sequence of these formations would seem to be the greater complexity of the lowland than he at present recognizes. In addition to the coalescing fans (piedmont alluvial plain) of the larger rivers, and the sandstone formation (Horowhenua coastal plain), the deposits and activities of the minor streams, large and small, have been the cause of innumerable complications. As these minor streams drain the same terrains as the rivers, the gravels and other deposits of both are in many respects similar, and frequently indistinguishable; hence great confusion and false deductions may result from any but the most careful study. The classing-together of the great river-fans and

* *Loc. cit.* (1918.). † *Ibid.*, p. 218.

the small fans, alluvial slopes, and flood-plains of the minor streams seems inadvisable, since, according to the present writer's interpretation of the physiographic history, a great space of time and two diastrophic movements separated the building of the two groups of deposits. The superposition of the coastal plain on the river-fans is, however, a conclusion founded on facts, which are as follows:—

The exposed surface of the upper part of the Ohau fan surmounts the right bank of the trench in which the river now flows, and extends to the line of Queen Street, which runs east from the town of Levin. Northward of this line a continuous sandstone landscape stretches away in the direction of Shannon, and is traversed by the flood-plain of the Koputaroa Stream, a tributary of the Manawatu River. Two miles and three-quarters north-west of Queen Street an artesian well was sunk in the Koputaroa flood-plain to a depth of 90 ft., and the beds pierced were approximately as follows:—

Yellow clay	9 ft.	Alluvium of Koputaroa Stream (flood-plain).
Gravel	10 ft.	
Blue clay	3 ft.	
Sand	56 ft.	Sandstone formation.
Blue swamp-clay with wood ..	4 ft.	Ohau fan.
Shingle with seam of clay ..	8 ft.	

As the site of this well is 58 ft. above sea-level, the surface of the Ohau fan at this point is 24 ft. below sea-level, a level which corresponds very exactly with the produced slope of the exposed surface of the fan between the line of Queen Street and the fan-apex. The interfingering of fan gravels and sandstone formation over a zone nearly three miles in width is in the highest degree improbable, so the superposition of the sandstone on the fan, and not the reverse, is thus established.

Similar relationships are revealed in the present valley of the Ohau River at a point two miles and a half up-stream from the Wellington–Manawatu Railway bridge. A river-cliff section shows the surface of the Ohau fan surmounted by a thick undisturbed layer of sandstone, which has been preserved in this site by overlying gravels derived from the initial incision of the Ohau valley-plain when the cutting of the present trench-like Ohau Valley commenced. This interesting stratigraphic occurrence is shown and explained in the diagrams (fig. 2), and no further comment is necessary here other than to emphasize its bearing on the question raised.

The Origin and Nature of the Sandstone Formation.

The evidence outlined above, by proving that the sandstone formation lies upon the river-fans, and not *vice versa*, places serious difficulties in the way of an acceptance of Cotton's theories of a prograded strand-plain composed of gravel fans and peneplaned sand-dunes. The theory is forced to demand a gradual secular subsidence of the area of deposition in order to account for old land-surfaces contained within the gravel fans and now depressed, in some cases hundreds of feet, below the present sea-level; it relies on the supply of an immense amount of waste with which to maintain its *existence* in the face of prolonged subsidence; and it postulates occasional small movements in a reverse direction to enable retrogradations of the coast-line under wave-attack to advance not more than about half its former prograded width. The last precludes all possibility of a movement of uplift on a fairly large scale, certainly not more than 100 ft.

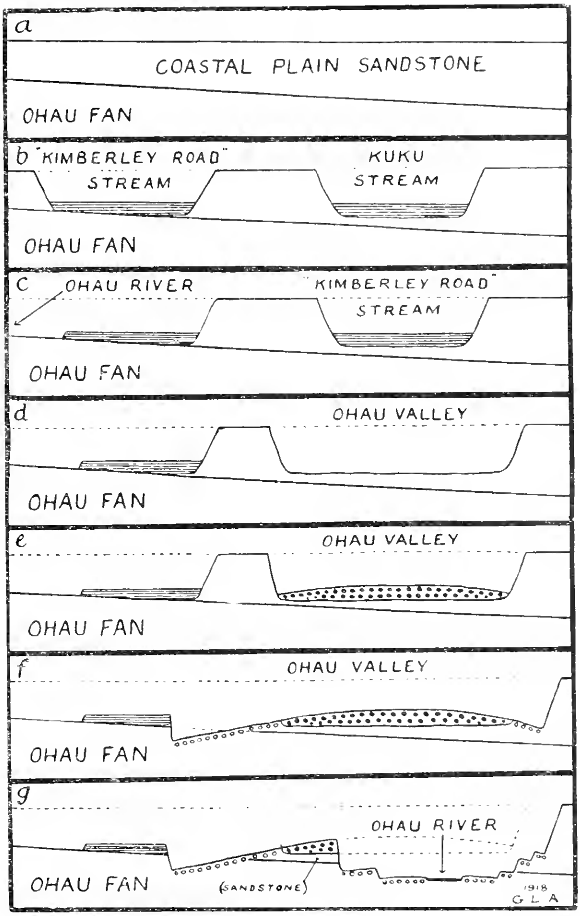

FIG. 2.—Diagrammatic sections showing the evolution of the Ohau Valley in its fan about a mile below the fan's apex.

a. Coastal-plain sandstone resting on the south-west slope of the Ohau fan.
b. The cutting of the shallow valleys of the "Kimberley Road" Stream and the former Kuku Stream; and the building of flood-plains (horizontal shading).
c. The invasion of the Kuku Valley by the "Kimberley Road" Stream, and the removal of the right bank of the latter's former valley by the Ohau River flowing in its "north-west" course.
d. Diversion of the Ohau River (at a point up-stream) into the original Kuku Valley, and its enlargement by the river.
e. The alluviation (black dots) of the valley of the Ohau (at this point) by gravels, &c., derived from the incision of the "valley plain."
f. The effect of lateral corrasion by the Ohau River after the alluviation. (Terrace or flood-plain gravels shown as open dots.)
g. Final deepening and terracing of Ohau Valley, resulting in its present form. In the high terrace-face on the left a layer of sandstone lies between the upper gravels (black dots) and the surface of the Ohau fan.

How, then, can Cotton's alternative explanation of a coastal plain followed by "the remaining events . . . . the same as those outlined in the previous explanation" be possible? Obviously it could not. The secular subsidence would carry the "coastal plain of subaqueous sands," along with the old land-surfaces mentioned above, far below the present surface, and it would be hidden either by continuous river-gravels or by blown sand, and the lowland would approximate to that suggested by Cotton in his first explanation. This, I think, disposes of the alternative explanation.

Since the gravel fans of the larger rivers are below and not upon the sandstone formation, the prograding of Cotton's strand-plain had to rely, in face of subsidence, on the supply of sand and the detritus of minor streams. But proof has been given above that the river-fans were built not on a subsiding maritime area, but on a stationary inland surface. Cotton's principal explanation is thus as untenable as the alternative one. If, however, these difficulties can be explained away, further evidence is furnished by the texture and structure of the sandstone formation.

The variation in the composition of the sandstone formation in a north-east and south-west direction—viz., from friable pumiceous sand north of Tokomaru to relatively compact greywacke-derived quartzose sand south of that locality—cannot be explained by the aeolian hypothesis; but if the variable material is regarded as shallow-water deposits laid down along a shelving coast to form a potential coastal plain no difficulty presents itself. Similarly, by the aeolian theory, the sand carried farthest inland would be the finest, or at least as fine as that at the source of supply—*i.e.*, along the prograding shore-line. But this is an inversion of the actual facts. All along the coastal lowland, and in the quartzose areas more especially, the sandstone is coarsest along the inner margin, grading to a finer texture towards the present coast-line—facts strongly supporting the marine-deposition theory and quite adverse to the aeolian.

Perhaps the most striking features of the sandstone formation are the cross-bedding and delicate lamination. The dunes of blown sand that lie nearer the present coast-line do not exhibit a similar structure, and it is in this respect that the two formations are in such strong contrast, though the compact texture of the one and the looseness of the other is equally striking. This diversity of structure under similar, if not identical, climatic and geographical conditions points to dissimilar origins for the sandstone and the blown sand: the former must thus be a subaqueous deposit.

I agree with Cotton that pseudo-stratification is sometimes present in the sandstone; but there is also quite frequently a well-defined true stratification. Alternations of thin beds of loam or clay interstratified with thicker ones of sandstone are quite common. Occasionally a sandstone stratum is intersected by two sets of joints, and breaks up into cubical blocks while *in situ*, while the layers above and below are compact. In these and other ways the presence of true stratification is revealed, and I contend that the structure of the sandstone formation adds to the weight of evidence of its having originated as a marginal marine deposit uplifted to form a young coastal plain.

I have but little hesitation in affirming that the peneplanation of dunes of blown sand* is a physical impossibility; such, in any case, is the verdict

* C. A. Cotton, *loc. cit.* (1918), p. 216.

in this district. Bordering the present Horowhenua coast-line, a belt of dunes, the aeolian origin of which has never been questioned, covers a strip of country from three to six miles in width. The dunes along the inner margin of the belt are the oldest, and these have reached a state of very considerable stability. These old dunes are generally covered with a thick layer of humus derived from the growth and decay of manuka and other vegetation, and are also fixed by a turf of natives grasses. In spite of these characteristics no trace of a drainage-system is being or has been incised upon them. Rain descending upon the dunes sinks immediately into their substance, to the complete exclusion of any run-off whatever. The great difference between the dunes and the sandstone is that in the one a cementing medium is entirely lacking—hence their great porosity and immunity from dissection by surface waters; whereas in the other the hydration of certain ferrous constituents, together with the presence of colloidal matter,* has cemented the sand-grains into a fairly compact and somewhat impervious mass—sufficient, indeed, to permit of dissection by stream-action.

The River-terraces.

In support of his theory of occasional phases of retrogradation of the shore-line of a strand-plain, Cotton claims that, in addition to the line of cliffs cut by the sea in the toe of the plain, terraces or valley-in-valley forms resulted, and furnish evidence of the retrogradation. The only true terraces

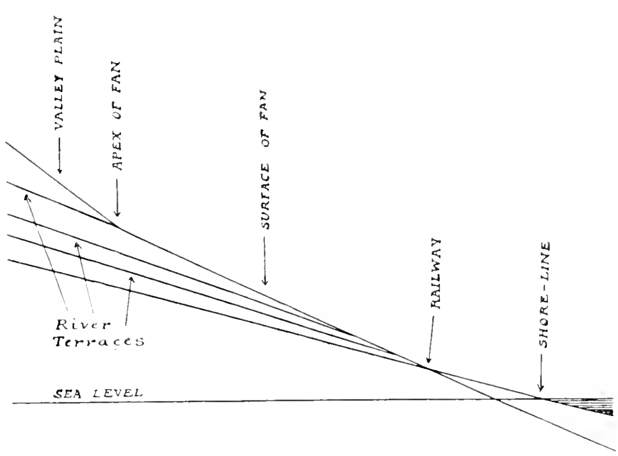

FIG. 3.—Generalized diagrammatic section of the Ohau fan, showing actual form of terraces.

of the Horowhenua lowland are those that fringe the sides of the trench-like valleys cut in the large gravel fans. It can be shown by two lines of evidence that the existing terraces do not furnish evidence of coastal retrogradation: (1.) If, as Cotton himself points out, the rivers rebuilt their fans during a second (or some later) period of progradation, they must have filled and obliterated the terraces of the trenches incised during the preceding

* E. C. BARTON, The Work of Colloids in Sandbank and Delta Formation, *Geog. Journ.*, vol. 51, pp. 100–15, 1918.

period of retrogradation. Thus the present terraced trenches of the fan-building rivers cannot be relics of the retrogradational phase, and must therefore be due to some other cause and of a later date. (2.) The profile of the existing terraces is not such as would have resulted from shore-recession.

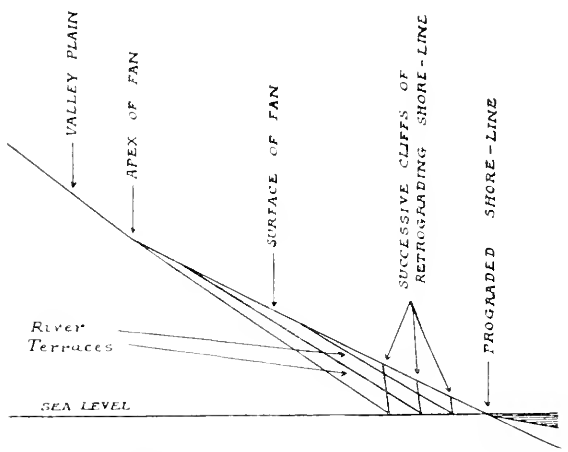

FIG. 4.—Diagrammatic section of a river-fan, showing form of terraces developed during a period of retrogradation following the normal progradation of the shore-line by a copious supply of waste.

This is clearly shown by a comparison of fig. 3 and fig. 4; the former shows the form and arrangement of the terraces of the Ohau Valley, and the latter, terraces developed in a fan truncated and trenched as a result of retrogradation of the shore-line by sea erosion.

ART. XVI.—Ceina, *an Aberrant Genus of the Amphipodan Family Talitridae.*

By CHARLES CHILTON, M.A., D.Sc., LL.D., F.L.S., Hector Memorial Medallist, Hon. Member Roy. Soc. N.S.W., Professor of Biology, Canterbury College, N.Z.

[*Read before the Philosophical Institute of Canterbury, 18th December, 1918; received by Editor, 30th December, 1918; issued separately, 26th May, 1919.*]

THE genus *Ceina* was established in 1893 by Della Valle for the single species *C. egregia* (Chilton), which had been described in 1883 under the genus *Nicea* Nicolet, a genus now considered to be identical with *Hyale* H. Rathke. The species was placed under *Nicea* because it appeared in many respects to come near to *Nicea rubra* G. M. Thomson, *N. fimbriata* G. M. Thomson, and other species then referred to *Nicea*; but it was pointed out at the time that it differed in several important characters, and some points in the original description were left more or less doubtful. Stebbing in 1888 (p. 1712) mentioned the species, stating that its generic position was not quite free from doubt. In establishing the new genus *Ceina*, Della Valle gave a brief description which may be translated as follows: "Upper antennae a little longer than the peduncle of the lower. Second gnathopods of male chelate. Third uropods represented by peduncle without rami. Telson divided." He pointed out that the species was deserving of further investigation, particularly with regard to both pairs of maxillae and to the terminal uropods. In this paper I endeavour to supply the information that Della Valle considered was necessary, and I regret that various circumstances have prevented its being supplied earlier.

In 1906 (p. 554), in his revision of the Amphipoda for *Das Tierreich*, Stebbing described the genus as follows: "Antenna 1 longer than peduncle of antenna 2. Maxillipeds, finger of palp broad, subtriangular. Gnathopod 1 in male and female and gnathopod 2 in female subchelate, small. Gnathopod 2 in male much larger, subchelate or (in maturity) chelate. Uropod 3 tubercular, without rami. Telson partially cleft."

There are also one or two points not mentioned in this description owing to their having been previously undescribed which are worthy of being included in the generic description. Thus, in the mandibles the usual molar tubercle is quite absent, and appears to be represented or replaced by a peculiar lappet on the inner surface directed backwards towards the base of the appendage. In the first maxilla the palp is absent or very minute, as in most of the species of *Orchestia*; the outer lobe is of normal structure, but the inner lobe is very small, barely half as long as the outer, and without the usual two plumose setae. It thus differs from the character of this maxilla as laid down by Stebbing for the family Talitridae, where he says "maxilla 1, inner plate slender, tipped with 2 plumose setae"; Sars (1895, p. 21) also gives this as one of the characters of the family, and the diagnosis of the family will therefore need to be slightly modified to include the genus *Ceina*. The second maxilla and the maxillipeds are fairly normal; but the large chelate second gnathopod of the male is a distinctive feature, and the terminal uropods are peculiar, being represented only by a short tubercle, which probably is the modified peduncle without rami. In this last character *Ceina* differs markedly from *Hyale* and approaches the allied genus *Chiltonia*, where the terminal uropods are represented by a single joint.

The generic diagnosis and the synonymy of the species may be given as follows:

Ceina Della Valle.

Ceina Della Valle, 1893, p. 530; Stebbing, 1899, p. 397, and 1906, p. 554.

The genus may perhaps be defined as follows: Mandible without definite molar tubercle. First maxilla with palp absent or vestigial, inner lobe small and without plumose setae. First gnathopoda small and subchelate in both sexes; second gnathopoda large and chelate in the male, subchelate in the female. Third uropoda represented by a small rounded lobe. Telson formed of a thick plate, partially cleft.

It is not easy to assign a definite position to this genus among the allied genera of the family. In many of the characters it more or less resembles *Hyale*, but it distinctly differs from this genus in the mandibles, first maxillae, the vestigial third uropoda, and the telson. In the last points it shows some approach to the genus *Chiltonia*, but the special character of the mandibles and of the inner lobe of the first maxillae are different from anything known to me among other Talitridae; the vestigial nature of the palp of the first maxilla is, of course, a character possessed by many of the species of *Orchestia*, *Talorchestia*, &c. The large chelate second gnathopod in the male is strikingly different from that of any of the species of *Hyale* or allied genera, but is found only in the male, the second gnathopod of the female being of the usual subchelate character.

Ceina egregia (Chilton). (Figs 1 to 25.)

Nicea egregia Chilton, 1883, p. 77, pl. 2, fig. 2 *a–l*. *Ceina egregia* Della Valle, 1893, p. 530, pl. 58, figs. 14–21. *Ceina egregia* Stebbing, 1906, p. 554.

As there is only one species of the genus at present known, it is impossible to give a separate specific diagnosis. A detailed description of the animal and of the different appendages is given below.

Colour usually dark red, sometimes greenish or bluish; appendages and extremity of body often white, or partly white and partly red.

Length of either sex about 6 mm. or 7 mm.

Localities: Cape Maria van Diemen (T. B. Smith); Tauranga (W. R. B. Oliver); Lyttelton (C. Chilton); Shag Point, Otago (W. R. B. Oliver).

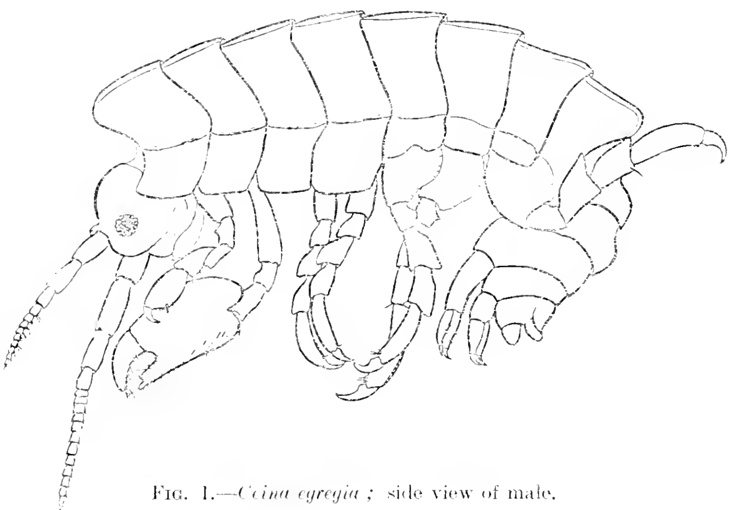

Fig. 1.—*Ceina egregia*; side view of male.

Remarks.—The animal is found at the roots of kelp and on various seaweeds, generally about low-tide mark, and when disturbed remains still or moves only slightly. By its shape and colour it is often difficult to detect as it lies partially coiled up on the seaweed. The dark colour does not usually cover the whole body, and its outline being different from that of the body itself the concealment of the animal is thus made more perfect.

The colour of different specimens varies considerably, and shows many irregularities, all tending, however, to conceal the animal. Of one female specimen from Lyttelton, collected 16th January, 1906, I have the following note as to its colour: "Colour greenish, shading into pink, patchy, with darker dots on legs, &c.; antennae with bases white, and then with alternate bands of purplish pink and white."* This specimen was found among corallines, and the general appearance of the animal caused by its dorsal crest, the way in which it coiled itself up, and by its colour, was very suggestive of a piece of coralline.

The peraeon and pleon are strongly compressed dorsally and carinate, the first segment of the peraeon forming a rounded crest projecting forwards over the posterior part of the head. Comparison of a number of specimens shows that the amount of carination is approximately the same in both sexes, though in the original description it was stated that the female was more strongly carinated than the male. The carination is naturally less marked in immature specimens.

The upper surface of the head is turned slightly upwards at the base of the upper antenna.

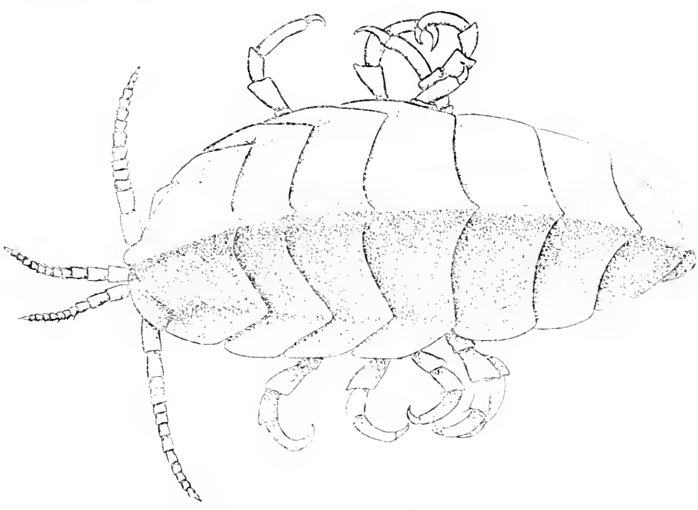

FIG. 2.—*Ceina egregia*; dorsal view of female.

The eyes are round and of moderate size, containing numerous ocelli; they are red in colour, and project a little beyond the surface of the head as a small convex lobe on each side.

The various appendages may be described as follows:—

The upper antenna (fig. 3) is rather longer than the peduncle of the lower; the first joint of the peduncle is longer than the second, and is produced at the lower distal angle into a subacute tooth; the third joint is slightly shorter than the second. The flagellum is as long as the peduncle, and consists of about 9 joints, all of which bear numerous simple "olfactory" setae in addition to a few ordinary acute setules. In one ovigerous female examined the flagellum contained only 7 joints.

The second antenna (fig. 4) has the last joint of the peduncle rather longer than the penultimate; the flagellum is rather stout, longer than the peduncle, and containing about 13 segments, each with tufts of short

* This banding of the antennae with different colours is very common in the Amphipoda, and its effect is to disguise the length of the antennae as the animal lies against seaweed, rock, &c., and thus render it less conspicuous.

setules at the distal end. The relative lengths of the joints of the peduncle are not constant: the last two joints are sometimes more nearly equal, especially in the male, than is shown in fig. 4, which is taken from a female specimen.

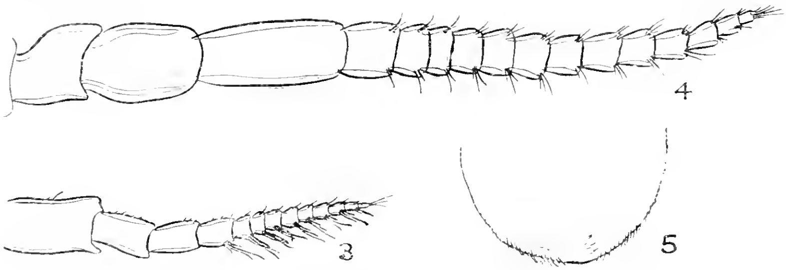

FIG. 3.—*Ceina egregia*; first antenna.
FIG. 4.—*Ceina egregia*; second antenna, from a female specimen.
FIG. 5.—*Ceina egregia*; upper lip.

The upper lip (fig. 5) is broader than long, its margin evenly rounded and fringed with the usual short setae.

The mandibles present several characters of importance. They are somewhat slender, curved in the usual way so as to be strongly convex on the outer side, and on this surface they bear a small rounded tubercle about half-way between the base and the apex (see figs. 7 and 9). At the base a strong process projects inwards on the inner or concave surface.

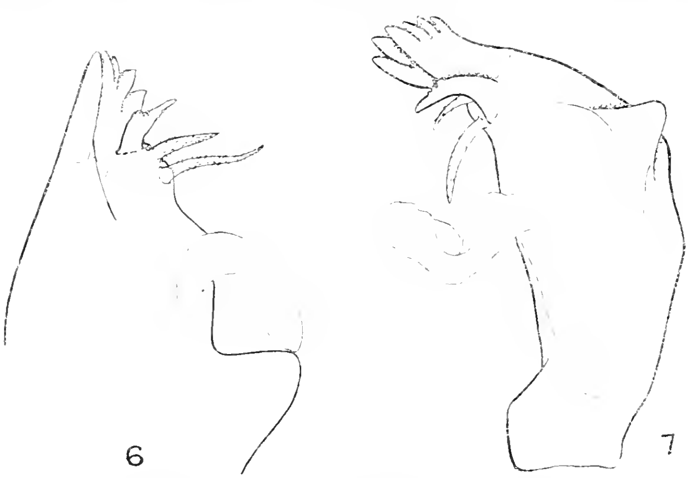

FIG. 6.—*Ceina egregia*; right mandible, seen from inner side.
FIG. 7.—*Ceina egregia*; right mandible, seen partly from outer side: molar lappet shrivelled.

There is no trace of a molar tubercle of the usual type, the animal thus differing from the description laid down by Sars for the Orchestidae (1895, p. 21), in which he says "molar expansion large and thick." In place of the molar tubercle there is a slender lobe or lappet which arises about the middle of the inner concave surface of the mandible, and is bent back towards the base, reaching to the basal process already referred to: the surface of the lappet is finely striated, as if covered with very minute setae, but these are extremely small and delicate, and the whole surface of the lappets seems to be only thinly chitinous and delicate: in one specimen it has shrivelled into an irregular shape in the process of mounting. The remainder of the mandible is strongly chitinous and firm. The cutting-edge of the mandible, as usual, differs on the two sides. On the left side (figs. 8 and 9) the outer cutting-edge is convex on the outer side, concave within, and formed of about 6 or 7 strong sharp teeth. The accessory masticatory lobe is somewhat similar in general appearance, and bears 4 or 5 sharp teeth. From the base of this arises a very stout spine or process with 4 teeth on its concave side. The spine row consists of 3 stout spines with their distal portions scabrous. In the right mandible (figs. 6 and 7) the outer cutting-edge is similar to that on the

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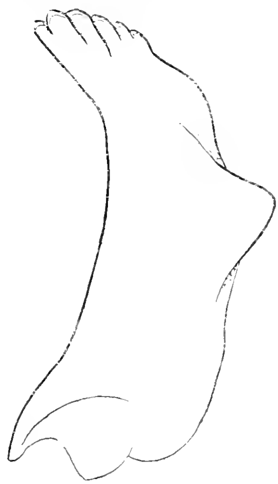

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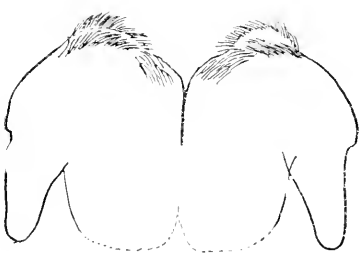
FIG. 8.—*Ceina egregia*: left mandible, from inner side.
FIG. 9.—*Ceina egregia*: left mandible, from outer side.

left, and is composed of 5 or 6 teeth, but the accessory masticatory lobe appears to be absent or represented only by a stout bent spine or process which has a tooth on its outer margin about half-way between the base and apex. The spine row in this mandible contains only 2 scabrous spines.

The lower lip (fig. 10) agrees in shape with that of species of *Hyale* and allied genera, the two lobes bearing numerous setae on the central part of their convex extremity, and a few minute setae on the surface.

The first maxilla (fig. 11) has the outer lobe extremely strong and highly chitinized, especially on the outer side and towards the distal end. At its extremity it bears a number of stout spines of the usual character, the inner ones of which are more denticulated on their inner margins than the outer spines are. These all lie closely crowded together, so that it is difficult to count them accurately, but there appear to be 8 or 9: Stebbing gives the possession of 9 apical spines as one of the characters of the family Talitridae. The inner lobe differs markedly from the normal character found in this family. It is small, slender, and delicate, reaching only about half-way along the inner margin of the outer lobe, and there is no sign of the usual two plumose setae, the rounded extremity bearing only a few very fine minute setae. The palp is either absent altogether or is represented only by a small mark on the outer convex margin; but though this corresponds in position and shape with the minute palp found in many species of *Orchestia*, it does not project beyond the margin of the outer lobe, and is apparently fused with it.

The second maxilla (fig. 12) is of normal shape, being formed of 2 subequal delicate lobes, each with the usual terminal fringe of long setae; a few finer setae are found on the inner margin of the inner lobe and the outer margin of the outer lobe: there is no sign of the special plumose seta bounding the apical fringe of spines of the inner margin which is mentioned by Stebbing in his definition of the family Talitridae.



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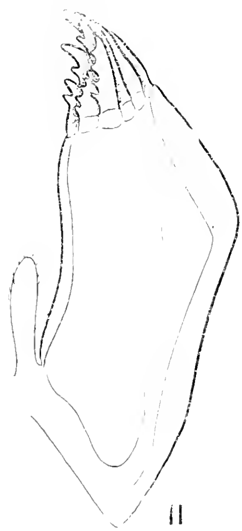

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Fig. 10.—*Ceina egregia*: lower lip.
Fig. 11.—*Ceina egregia*; first maxilla.
Fig. 12.—*Ceina egregia*; second maxilla.

The maxillipeds (fig. 13) present one or two special characters, but on the whole are similar to those of species of *Hyale*. The outer and inner lobes are of nearly the same length, the inner lobe bearing at its truncate extremity 2 or 3 short blunt teeth with 1 or 2 longer dentate spines; the inner margin of the lobe is free from setae except near the distal end. The outer lobe is slightly broader than the inner, the outer margin being convex, and its inner margin supplied with numerous spinules. The merus, or first joint of the palp, has its outer angle much produced so as to reach fully as far as the end of the carpus; its inner distal margin is much hollowed for the reception of the carpus, which extends farther towards its base on the inner than on the outer side. The carpus and propod are subequal and somewhat oval in shape, with the inner margins strongly convex and bearing a fringe of long spines; the propod in addition has a distinct transverse row of long spines near its distal end. The dactyl is large and well developed, somewhat triangular in shape, strongly curved, and slightly twisted so that its outer or lower surface is convex. It is comparatively free from setae, but its surface shows numerous rows of very minute striations, possibly caused by rows of very minute setules.

I have not noticed any differences between the mouth-parts of male and female specimens such as occur in *Hyale camptonyx* (Heller), *H. grenfelli* Chilton, and possibly in some other species. The differences between the male and the female appear to be confined to the second gnathopoda.

The first gnathopod of the male (fig. 14) is of normal shape, its side plate rectangular with the longer angles rounded, the carpus slightly shorter than the propod, triangular, its hind-margin fringed with stout

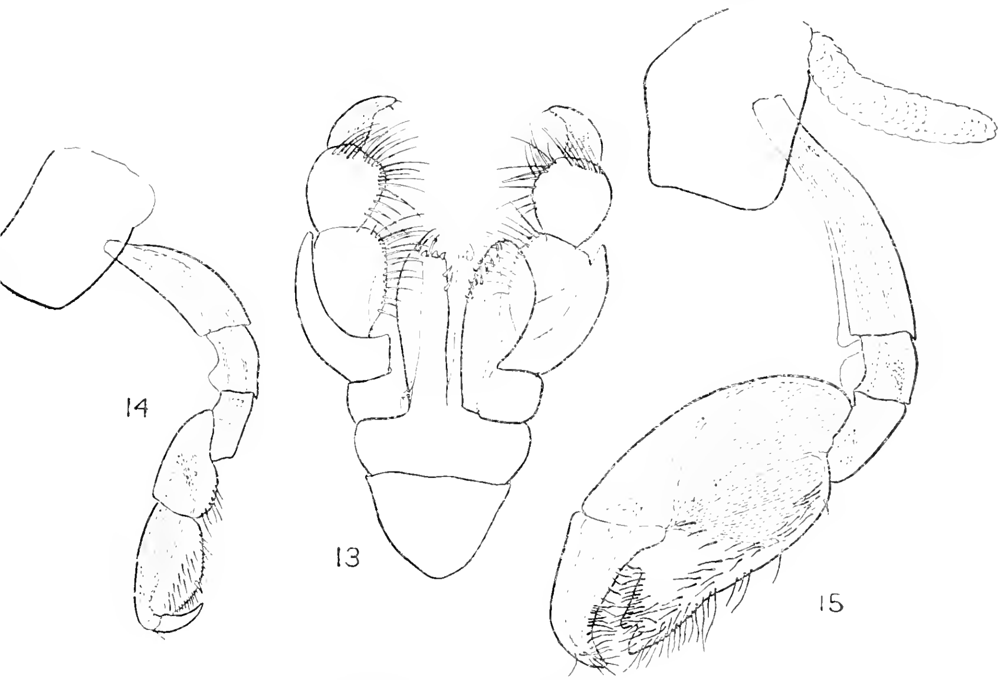

FIG. 13.—*Ceina egregia*; maxillipeds.
FIG. 14.—*Ceina egregia*; first gnathopod of male.
FIG. 15.—*Ceina egregia*; second gnathopod of male.

setae; the propod oval, palm rather oblique, straight or slightly curved, defined by a stout spinule with subapical cilium. The palm is fringed with a row of simple setae, and the hind-margin and surface of the joint near the hind-margin bear numerous fairly stout setae, all serrate or pectinate.

The second gnathopod in the male (fig. 15) is very large and very different from that of any of the species of *Hyale* known to me. The side plate is rectangular, rather deeper than broad, with margins entire and free from setae; the branchia is long and narrow. The basis is long and slender, broadening only slightly distally; its anterior margin is grooved and produced into a small lobe at the distal end; the ischium is short, with the anterior outer margin produced into a rounded lobe; the merus about as long as the ischium, and, like the two preceding joints, free from setae; the propod, with which the carpus is coalesced, is very large, fully as long as the rest of the limb, and has the posterior distal angle produced so as to form with the very strong finger a powerful chelate appendage; the anterior margin is strongly convex, the posterior is straight or slightly sinuous and bears a number of setae, especially towards the distal end, these setae being less numerous in older specimens; the palm projects strongly and has a blunt tooth towards the end; the finger bears along its inner margin a regular row of long setae, and near the extremity a tuft containing a considerable number of setae. The shape of the propod and finger will be best seen from the figure, which is taken from a fairly well developed male. In one specimen examined, apparently older, the palm is deeply concave, the fixed finger is longer and more produced, the tooth on the inner margin is blunter and nearer the apex, the setae both on the fixed finger and the dactyl are less conspicuous.

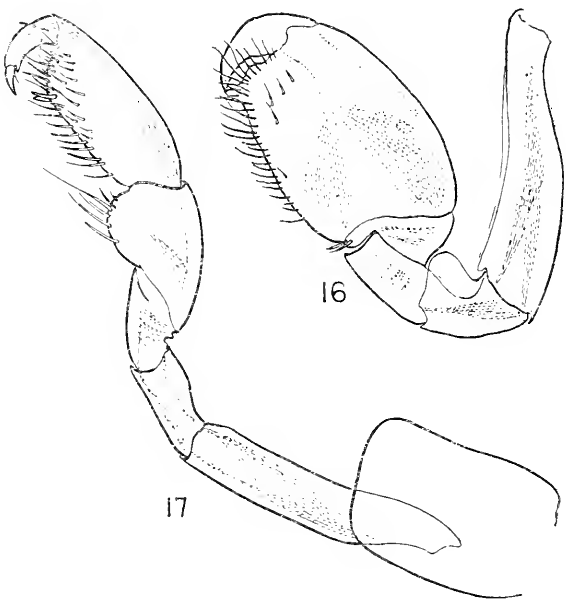

Fig. 16.—*Ceina egregia*; second gnathopod of immature male.
Fig. 17.—*Ceina egregia*; first gnathopod of female.

In the immature males the second gnathopod (fig. 16) is of much more normal shape, and in quite young forms is probably the same as in the female. The figure shows one in which the carpus can still be distinguished as a separate joint; it is short and triangular, fairly well marked off from the propod on the anterior side, and produced posteriorly into a small lobe lying between the merus and propod, and appears to be more or less fused with the latter; its presence, however, is indicated even on the posterior margin by a small number of setae on the posterior margin. The propod is broader than in the fully developed specimens, and is subchelate, having the palm transverse, slightly convex, defined by a fairly stout acute tooth or spinule. The hind-margin and the palm bear numerous long setae.

and there are a few scattered on the surface of the joint; the concave margin of the dactyl bears a row of small setae, but the tuft near the apex has not yet been developed.

The first gnathopod of the female (fig. 17) shows the same general shape as that of the male, but appears to be somewhat longer and more slender: the basal joint is long, slender, somewhat curved; ischium and merus of about equal length, these three joints practically free from setae; carpus is shorter than the propod, triangular, and with 5 or 6 spines on its posterior margin; the propod oblong rather than oval, palm slightly oblique, fringed with fine spinules and bounded by a stout spine; numerous other spinules fringe the hind-margin, and others are situated on the surface near the margin; the finger is strong and much curved.

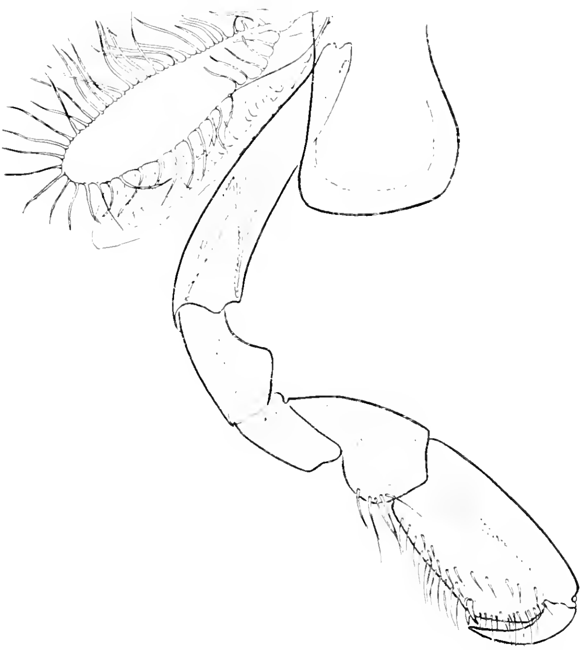

FIG. 18.—*Ceina egregia*; second gnathopod of female.

The second gnathopod of the female (fig. 18) is similar in general appearance to the first, but is somewhat larger and has the carpus slightly shorter in proportion to the propod: the branchia is oval in shape, somewhat narrow and nearly as long as the basal joint; the brood plate is oval, as long as the basal joint, and has its margin fringed in the usual way with long slender setae.

The peraeopoda are very nearly subequal in length, the first (fig. 19) and second being only slightly shorter than the following; all are strongly chitinous and comparatively free from setae. They are all fairly normal in shape, and only one or two points require special notice. The basal joint of the third (fig. 20) is moderately produced posteriorly but narrows a little below; its margin is free from setae or serrations, but shows short transverse lines, giving it a crinkled appearance. In the fourth peraeopod (fig. 21) the expansion of the basal joint is rather greater proximally

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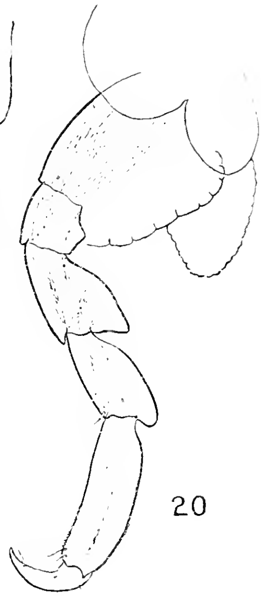

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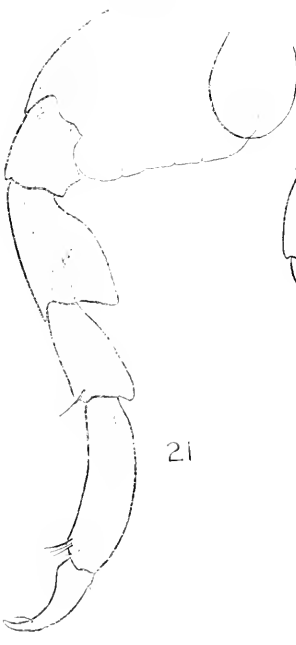

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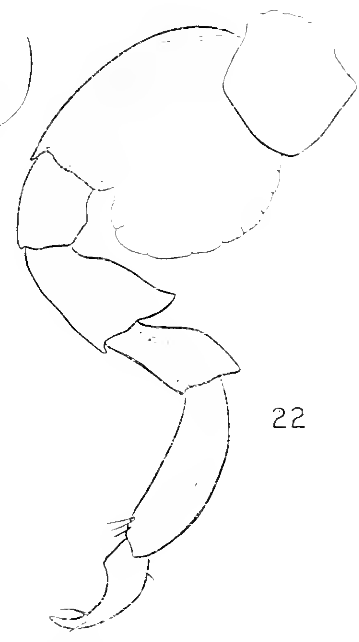

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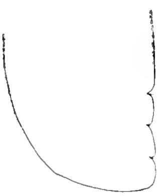
Fig. 19.—*Ceina egregia* ; first peraeopod.
Fig. 20.—*Ceina egregia* ; third peraeopod.
Fig. 21.—*Ceina egregia* ; fourth peraeopod.
Fig. 22.—*Ceina egregia* ; fifth peraeopod.

but distally it narrows a little more than in the third; in the fifth (fig. 22) the expansion is considerably broader than in the fourth, and the posterior margin is regularly and strongly convex. In all the peraeopoda the propod is considerably longer than the carpus, and bears a few small setae on the inner margin at the base of the finger. The finger is stout, strongly curved, and the spinule on its inner margin is of moderate thickness.

The segments of the pleon (fig. 23) have the downward expansions rather narrow, the anterior angle much rounded off, the posterior nearly rectangular but rounded; the posterior margin with a few shallow crenations and a very minute setule in each depression.

The uropoda are all short and somewhat stout (fig. 24). In the first the peduncle is longer than the rami and bears a spinule on its upper margin at the end; the rami are subequal, and both bear lateral as well as apical setules. The second uropod is similar in shape but has the peduncle only as long as the rami; these reach as far back as those of the first uropod.



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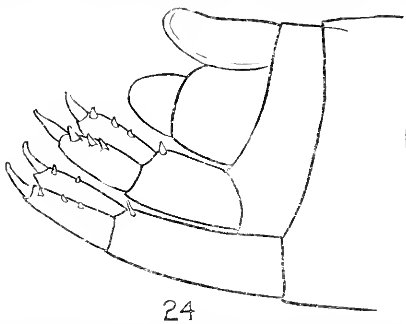

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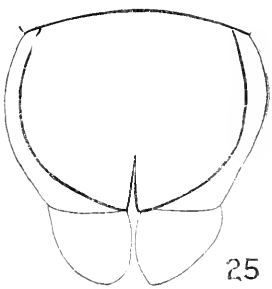

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FIG. 23.—*Ceina egregia*; pleon segment 3, lower portion.
FIG. 24.—*Ceina egregia*; urus and uropoda, side view.
FIG. 25.—*Ceina egregia*; telson from above, with terminal segment and third uropoda.

The third uropod (figs. 24 and 25) is represented only by a small semicircular lobe with entire margins attached to the sixth segment of the pleon and representing either the peduncle or the peduncle and rami fused.

The telson (fig. 25) is convex dorsally, and when viewed from above shows as a semicircular plate with entire margins without setae and cleft for about one-third of its length. Viewed laterally the plate appears to be fairly thick and strongly curved so as to be concave below.

The figures, which add so much to the value of this paper, have been prepared by Miss E. M. Herriott, M.A., Assistant in the Biological Laboratory of Canterbury College. They all refer to *Ceina egregia*, and unless otherwise stated are drawn from a male specimen.

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ART. XVII.—*New Species of Mollusca, from various Dredgings taken off the Coast of New Zealand, the Snares Islands, and the Bounty Islands.*

By Miss M. K. MESTAYER.

Communicated by R. L. Mestayer.

[*Read before the Wellington Philosophical Society, 24th July, 1918; received by Editors, 30th August, 1918; issued separately, 26th May, 1919.*]

Plate VIII.

THE species described or referred to in the following paper were, with one exception, obtained from dredgings taken by Captain Bollons, of the s.s. "Hinemoa," in various parts of the Hauraki Gulf, off the North Cape, and off the Bounty and Snares Islands. *Scissurella regia* and *Discohelix hedleyi*, of which the dimensions are for the first time given, are from dredgings off the Three Kings Islands and the North Cape.

I wish to acknowledge my great indebtedness to Mr. C. Hedley, Dr. J. A. Thomson, and the late Mr. H. Suter for their unfailing kindness and help; and to Miss J. K. Allan for the trouble she has taken over the drawings from which the figures are prepared.

Family SCISSURELLIDAE.

Scissurella regia Mestayer.

I take this opportunity of correcting an oversight in connection with my paper in vol. 48 of the *Transactions.** In the description of *Scissurella regia* on page 124 the measurements of the holotype were accidentally omitted. They are as follows: Height, 2 mm.; major diameter, 2·5 mm.; minor diameter, 2 mm.

At the same time I record the finding of two imperfect specimens—one in a dredging taken by the "Nora Niven," sixty miles east of Lyttelton, in 100 fathoms, and the other in a dredging in Pickersgill Harbour, Dusky Sound. A wider range is indicated for this species than at first supposed.

Schismope subantarctica Hedley.

This species occurs at Lyall Bay, Wellington, N.Z. It was described by Hedley† from the Macquarie Islands. I found it also in a dredging off the Snares Islands in 50 fathoms.

Family LIOTIIDAE Gray.

Genus LIOTIA Gray, 1847.

Liotia suteri n. sp. (Plate VIII, figs. 1–3.)

Bounty Islands; 70 fathoms.

Shell small, somewhat discoidal. *Whorls* 3, compressed, with a rather broad peripheral keel, which gives a serrated appearance to the edge of the upper surface. *Spire* flat. *Protoconch* of one minute flat whorl. *Suture*

* M. K. MESTAYER, Preliminary List of Mollusca from Dredgings taken off the Northern Coast of New Zealand, *Trans. N.Z. Inst.*, vol. 48, pp. 122–28, pl. xii, 1916.

† C. HEDLEY, *Australasian Antarctic Expedition,* vol. 4, pt 1, p. 36, pl. v, figs. 54, 55, 1916.

distinct, serrated, bordered below by a narrow groove and a nodulous rib. *Body-whorl* apparently smooth, but in a good light and under a strong pocket-lens very fine hair-like radial lines are to be seen. *Upper* and *under surfaces* convex. *Aperture* circular, with a heavy double varix, bearing four deep pits. In the holotype the aperture is closed by a dark-brown raised spiral disc, covered with fine radial threads, which may perhaps be the operculum, though it has somewhat the appearance of a small polyzoan. *Umbilicus* deep, moderately open, revealing all the whorls; margined by a rather broad radially ribbed groove. *Colour* light-cream; the paratype is slightly browner.

Measurements.—Major diameter, 3 mm.; minor diameter, 2 mm.; thickness, 1·5 mm.

Material.—The holotype and one paratype (juvenile).

Remarks.—Mr. Suter's comment on it was, "*Liotia* n. sp. distinct from *Liotia serrata* Suter," the type of which is in his collection. *Liotia suteri* slightly resembles two species from the Philippines—(1) *Liotia discoidea* (Reeve),* in its depressed form and peripheral keels, and (2) *Liotia crenata* (Kiener),† in its heavily variced aperture and smooth base. It differs from *Liotia crenata* (Kiener) in that the whorls only show one peripheral keel above the suture, and from *Liotia discoidea* (Reeve) in having a smooth base and much more heavily variced aperture. It seems to be a rather rare species, as I have had a considerable amount of material dredged at various stations off the Bounty Islands, and these are the only specimens obtained. Both holotype and paratype are a good deal water-worn, especially the latter, which is not quite perfect. Both specimens are in my collection.

Family ORBITESTELLIDAE Iredale.

Orbitestella hinemoa n. sp. (Plate VIII, figs. 7–9.)

Snares Islands; 50 fathoms.

Shell minute, translucent, thin yet strong, discoidal. *Whorls* 3, sharply angled: periphery vertical with a strong central keel nearly one-third its width. *Protoconch* minute, one whorl. *Spire* only very slightly raised on the convex surface. *Base* concave. *Sculpture*, one strong peripheral keel, and faint traces of a raised spiral thread near the suture; many fine raised radials extend from the suture into the widely open umbilicus. *Aperture* quadrate. *Outer lip* thin, sharp, wavy. *Colour* white.

Measurements.—Holotype: Diameter, 1 mm.; thickness, $\frac{1}{3}$ mm.

Material.—The holotype and forty-one paratypes from the type locality. The holotype is in the Dominion Museum.

Remarks.—There is a good deal of variation in the distinctness of the sculpture; on the holotype the radial threads are indistinct, but they are very distinct on a paratype, which is placed with it on that account. The species owes its specific name to the ship from which the dredging was taken. Mr. Hedley says it is allied to *Orbitestella bastowi* (Gatliff), the type of this genus; unfortunately, I have been unable to see either the figures or description of Gatliff's species, so am unable to say how it differs from *O. hinemoa*. The sculpture is so fine that though the figures (7–9) show it quite correctly, yet a moderately high power on the microscope is required to bring it out.

* *Man. Conch.* (1) x, p. 109, pl. 36, fig. 3.
† *Man. Conch.* (1) x, p. 111, pl. 36, figs. 12, 13.

As the *Proceedings of the Malacological Society of London* are not always readily accessible in New Zealand, I append Iredale's definition of this genus:—

"*Orbitestella* gen. nov.

"I propose this name, and designate as type *Cyclostrema bastowi* Gatliff (*Proc. Roy. Soc. Vic.* (n.s.), vol. xix, 1906, p. 3, pl. ii, figs. 8–10). I also indicate it as representative of a new family Orbitestellidae, which is composed of a series of minute marine molluscs with the following characters: Shell thin, pellucid, discoidal, dextral, of few whorls and of peculiar sculpture; widely umbilicate, columella vertical, aperture never variced, irregular in shape, edges thin.

"I had hoped to describe the group, giving figures, but at present this is impossible. I have species from various parts of New Zealand, the Kermadecs, Lord Howe Island, Norfolk Island, New Caledonia, Sydney Harbour (New South Wales), north coast of Tasmania, and Port Lincoln (South Australia)—in fact, every austral locality from which I have received a parcel of fine shell sand or fine dredgings. Commonly live shells have been secured when live sand was received. All the species are very minute, and I have about a dozen distinct species, divisible into two groups, and I hope later to thoroughly elaborate the family with good figures."*

Family ARCHITECTONICIDAE.

Discohelix hedleyi Mestayer.

With regard to this species I regret that, as in the case of *Scissurella regia*, in my paper previously referred to the measurements of the holotype were accidentally omitted. They are: Height, 0·5 mm.; diameter, 1 mm.

Family EPITONIIDAE.

Crossea cuvieriana n. sp. (Plate VIII, fig. 10.)

Off Cuvier Island, Hauraki Gulf, N.Z.; 38–40 fathoms.

Shell small, turbinate, rather thin. *Whorls* 3, the last rather large, convex. *Protoconch* small, smooth, glossy, about two whorls. *Sculpture*, five spiral ribs, of which the upper two are stronger than the others; all are characterized by very fine close threads crossing them. Even under a strong pocket-lens the tops of the spirals appear quite smooth, but a 3 in. objective on the microscope shows that the spirals are crossed by the threads. The axial sculpture is formed by strong lamellae, somewhat unevenly spaced, which become rather crowded on the base; between the suture and the two upper spirals the interstices are about four times the width of the lamellae. The basal sculpture resembles *Crossea cancellata* Ten.-Woods, but in that species the spirals are smooth. *Umbilicus* very small. The umbilical rim is very strong and finely crenulated like the spirals. *Aperture* vertical, circular, decidedly canaliculated at the base. The outer lip is slightly channelled by the five spirals, inner lip thin, sharp, only slightly reflexed towards the umbilical rim. *Colour* white or very light brown; dull surface. Individual specimens vary somewhat in the density of the shell, the white specimens being more translucent than the brown ones.

* T. Iredale, More Molluscan Name-changes, *Proc. Malac. Soc.*, vol. 12, part vi, p. 327, 1917.

Measurements.—Height, 3 mm.; diameter, 3 mm.

Material.—Holotype and six paratypes from the type locality; one from off the Bounty Islands, 70 fathoms; and two from off the Hen and Chickens Islands, Hauraki Gulf, 25–26 fathoms.

Remarks.—This species is allied to *Crossea cancellata* Ten.-Woods,* from which it is readily distinguished by the five crenulated spirals. The strength of the sculpture varies slightly in different individuals, and the foregoing description is based on the white holotype and on a well-sculptured paratype, which is placed with it in the Dominion Museum. Mr. C. Hedley saw a juvenile specimen and informed me that he considered it a new species, so I examined my various dredgings and obtained some much larger specimens.

Family TURRITIDAE.

Leucosyrinx thomsoni n. sp. (Plate VIII, fig. 5.)

Off Hen and Chicken Islands, Hauraki Gulf, N.Z.; 25–26 fathoms.

Shell small, fusiform, thin. *Spire* a little higher than the aperture. *Protoconch*, two whorls, globular, white, smooth, dull. *Whorls* 5 (holotype 4), sharply shouldered, convex, contracting rapidly to the *canal*, which is very short, open, and slightly reflexed to the left. *Anal notch* very slight, near the rather deeply impressed *suture*. *Sculpture*, three sharp spiral ribs on the periphery, and many fine spiral threads on the base and canal. On the sloping shoulder between the suture and the first spiral are two or three very fine spiral threads, which are, however, almost obscured by the fine sharp axial threads which run slightly obliquely from spire to base, and are somewhat irregularly spaced. *Columella* short and smooth. *Outer lip* thin, channelled by the spiral ribs; *inner lip* merely a thin glaze on the columella and body-whorl. *Colour* white or creamy. *Operculum* unknown. *Animal* unknown.

Measurements.—Holotype: Height, 3 mm.; diameter, 1·5 mm.

Material.—The holotype and fifteen paratypes from type locality; and from the Bounty Islands, Cuvier Island, Auckland Islands, and Dusky Sound, only one specimen from each. Thus it has a fairly wide range.

Remarks.—This species is rather variable in sculpture, but the three strong spirals on the body-whorl, and the very short canal, are distinctive characters. Some of the young paratypes from the type locality have much stronger spirals: and there is also slight variation in the axial sculpture, some showing it more than others. The holotype is a young specimen of only four whorls; a paratype of five whorls which has been used with it in the above description also shows a fine spiral thread between the first and second ribs. Both these specimens are in the Dominion Museum. The nearest ally of this species is the following one, *Leucosyrinx cuvierensis*, which also occurs in the Hauraki Gulf.

The species is named in honour of Dr. J. A. Thomson, Director of the Dominion Museum.

Leucosyrinx cuvierensis n. sp. (Plate VIII, fig. 4.)

Off Cuvier Island, Hauraki Gulf, N.Z.; 38–40 fathoms.

Shell small, fusiform, fragile. *Spire* slightly shorter than the aperture and canal. *Protoconch*, two whorls, rounded, smooth, dull. *Whorls* 3,

* H. SUTER, *Manual of the New Zealand Mollusca*, p. 324, 1914.

regularly increasing, shouldered, convex, contracting sharply to the canal. *Sculpture,* on the body-whorl four spiral ribs; only the upper two show on the spire-whorls. Some specimens have an extra small spiral thread between the main ribs: on the holotype it is between the second and third ribs. The axial sculpture consists of fine sharp nearly equidistant threads from the apex to the basal rib, rendering the spirals nodulous. From the basal rib only fine growth-lines show along the canal. The *anal notch* is merely a curve on the sloping shoulder near the suture, and is easily overlooked. *Suture* rather deeply impressed. *Canal* fairly long, widely open, inclined to the left, with a very slight backward curve. *Outer lip* sharp, convex; *inner lip* merely a thin glaze on the columella. *Columella* short, vertical. *Colour* a dirty white. *Operculum* unknown. *Animal* unknown.

Measurements.—Height, 4·5 mm.; diameter, 2 mm.

Material.—The holotype and three paratypes from type locality; fifteen from off Hen and Chickens Islands, Hauraki Gulf; and seven from five miles W. ½ N. from Cuvier Island, Hauraki Gulf, 38 fathoms.

Remarks.—The sculpture is rather variable; sometimes the spirals are more prominent than on the holotype, and in some specimens the axials are coarser and wider apart. In either case the four spirals are a constant character, as even if the extra spirals are present they are only fine threads. One or two of the paratypes at first sight resemble *L. thomsoni,* from which they are easily distinguished by the fewer spirals and absence of spiral sculpture on the base.

Mr. C. Hedley, who saw specimens of both species, said they were new species of the genus *Leucosyrinx.* They do not seem to be very closely allied to any other New Zealand species, either Recent or fossil.

Veprecula cooperi n. sp. (Plate VIII, fig. 6.)

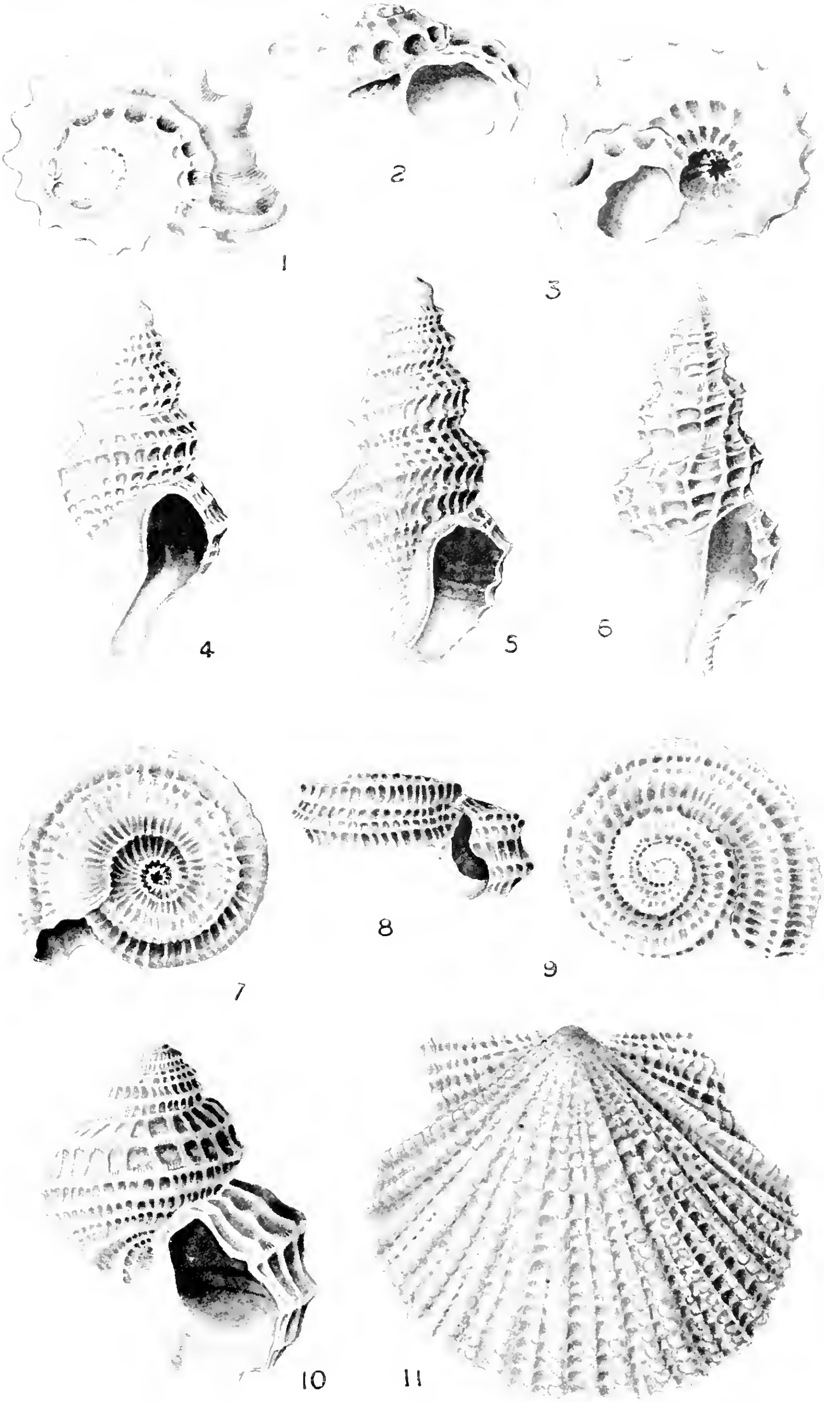
Off the Hen and Chickens Islands, Hauraki Gulf, N.Z.; 25–30 fathoms.

Shell small, fragile, fusiform, slender, prickly. *Spire* pagodiform. *Whorls* 5, plus a three-whorled embryonic apex, which is finely longitudinally ribbed; whorls convex, contracting rapidly. *Sculpture,* four sharp raised spiral ribs, crossed by about twelve equally sharp raised axial ribs, which disappear below the fourth spiral, and are interrupted above by the broad anal fasciole. The intersection of the ribs is marked by a sharp prickle; between the raised ribs are deep oblong pits, the surface of which is smooth and dull. The *anal fasciole* is crossed by fine crescentic growth-lines, and bordered on its outer edge by a narrow double thread. *Anal slit* nearly 1 mm. in length. *Suture* distinct, serrated by the lowest spiral. Coming from inside the vertical columella and covering the base and canal are about twelve fine equidistant spiral threads. *Canal* short, open, very slightly recurved. *Outer lip* thin, sharp; in the holotype it is slightly thickened by the last axial rib; the inner surface is deeply grooved by the spirals, and less so by the axials. *Colour* uniform light biscuit-brown. *Operculum* unknown. *Animal* unknown.

Measurements.—Holotype: Height, 5 mm.; diameter, 2 mm.

Material.—Eighty-six from type locality, and forty-nine others from the Hauraki Gulf and North Cape, at depths ranging from 26 to 73 fathoms.

Remarks.—So far as I can see at present, this species has no near ally in the New Zealand molluscan fauna. Its nearest ally seems to be



[J. K. Allan del.

FIGS. 1–3.—*Liotia suteri* n. sp.
FIG. 4.—*Leucosyrinx cuvierensis* n. sp.
FIG. 5.—*Leucosyrinx thomsoni* n. sp.
FIG. 6.—*Vepreculа cooperi* n. sp.
FIGS. 7–9.—*Orbitestella hinemoa* n. sp.
FIG. 10.—*Crossea cuvieriana* n. sp.
FIG. 11.—*Pecten* aff. *transenna* Suter.

Face p. 134.]

Vepreculu vepratica (Hedley), of Australia.* Mr. Hedley, who kindly compared the species, says, "It seems to differ from the New South Wales *Vepreculu vepratica* by more radial riblets and by the protoconch being more delicately sculptured." *V. hedleyi* (Melvill),† which has a longer canal, is also allied to this species.

It is named in honour of the late Mr. C. Cooper, of Auckland, who directed my attention to it. Though I have a fairly large number of specimens, yet owing to their fragility very few are perfect.

Melvill in his paper† proposed the name *Veprecula*, as a subgenus of his *Clathurina*; but Hedley in *A Check-list of the Marine Fauna of New South Wales, Part I*, page 83, 1918, treats it as a full genus; and it is on his advice it is so treated here.

Family PECTINIDAE.

Pecten aff. transenna Suter. (Plate VIII, fig. 11.)

Six and a half miles E. 5° N. from the North Cape, N.Z.; 75 fathoms.

In the *Manual of the New Zealand Mollusca*, 1914, Suter describes a minute *Pecten* he obtained in a dredging taken off the Snares Islands (p. 881, pl. 52, fig. 3). While examining a dredging taken by Captain Bollons off the North Cape I found a single valve of a *Pecten* totally unlike any I had so far seen. Some time ago I sent it to Mr. Suter for his opinion, and his note on it is: "*Pecten* aff. *transenna* Suter. My specimens from the Snares are evidently not adult, only 3·4 mm. by 3 mm., and much worn. Your specimen, a left valve, is perfect, and I am much inclined to take it as representing my species." He also suggested publishing a photograph of it. It is on Dr. J. A. Thomson's recommendation that the following description of my specimen is published, with the accompanying figure.

Left valve small, roundly ovate, with straight dorsum and small subequal ears. *Colour* light-cream, opaque. *Valve* moderately convex, with twelve primary radial ribs, running almost to the umbo; increased by secondary riblets to twenty-four at the margin, with traces of two or three more rudimentary riblets; these are crossed by about thirty raised concentric threads, which form small rounded tubercles on the radials. *Beak* slightly anterior, a little raised, round, smooth. *Ears* small, not distinctly marked off from the disc; their sculpture similar to the disc. *Anterior end* a little shorter, convex, receding below, slightly sinuated below the ear: *posterior end* nearly straight to the fourth riblet on the ear; thence rapidly descending, convex. *Ventral margin* broadly convex. *Hinge-line* straight, with a minute resilium beneath the umbo. *Interior* creamy, shining, grooved by the radials, with the concentric threads clearly visible. *Margin* slightly denticulated by the ribs.

At about 0·5 mm. from the edge there is a well-marked groove (possibly a rest period), and the growth has been continued on a slightly different plane, the last three or four concentric threads being at a slight angle to the rest of the shell, so that it almost looks as if it had a tiny frill along its front edge.

Measurements.—5 mm. by 4 mm.

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* *Mem. Austral. Mus.*, No. 4, p. 384, fig. 97.

† *Proc. Malac. Soc. London*, vol. 12, pts. iv–v, pp. 189–90, 1917.

Art. XVIII.—*Notes on the Autecology of certain Plants of the Peridotite Belt, Nelson: Part I—Structure of some of the Plants (No. 2).**

By M. Winifred Betts, M.Sc.

Communicated by Professor Benham, F.R.S.

[*Read before the Otago Institute, 10th December, 1918; received by Editor, 30th December, 1918; issued separately, 26th May, 1919.*]

10. Rubus australis Forst.

Growth-form.—"A tall climber, reaching the tops of the highest trees: stems stout, woody at the base; branches slender, drooping, armed with scattered recurved prickles. Leaves 3–5-foliolate or rarely pinnate, with 2 pairs of leaflets and a terminal one: leaflets coriaceous, glabrous, very variable in size and shape, 2–5 in. long, ovate-oblong or ovate-lanceolate to linear-oblong or almost linear, acute or acuminate, truncate or cordate at the base, sharply serrate; petioles and midribs armed with recurved prickles."†

Anatomy.

Leaf.—The upper epidermis consists of small cells, which are oval or rectangular in transverse section. These cells have their walls somewhat thickened, and there is a thick smooth cuticle. There are no stomates on the upper surface.

The lower epidermis is formed of small more or less squarish cells. These cells have their walls slightly thickened, and there is a cuticle, which is not, however, as thick as on the upper face of the leaf. Stomates are frequent on the lower surface. The guard-cells are small, and are at the same level as the epidermal cells; the stomates are protected by guard-cell ridges.

Beneath the upper epidermis there is a hypoderma consisting of large rectangular cells with thickened walls.

The chlorenchyma is differentiated. The palisade tissue is composed of 3 layers of thin-walled cells containing fairly large chloroplasts. The 2 outer layers are very compact, but there are air-spaces between the cells of the inner layer. The spongy tissue consists of rather small, irregular, thin-walled cells, which are loosely arranged.

The midrib is prominent. Above the xylem there is a group of large cells with thickened lignified walls. The xylem contains vessels of large diameter. Beneath the phloem there is a zone of sclerenchyma, in which the cells are small and have thick walls and small cell-cavities. Below this zone there are some large cells with thickened lignified walls. Above the midrib the epidermal cells are much smaller, and a few of them are produced into unicellular hairs, with thick walls which are not cutinized. Above and below the midrib there is collenchyma.

Stem.—The epidermis consists of very small dome-shaped cells with their lateral and their external walls cutinized. The cuticle is uneven, and is very thick.

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* For No. 1 see *Trans. N.Z. Inst.*, vol. 50, pp. 230–43, 1918.

† T. F. Cheeseman, *Manual of the New Zealand Flora*, 1906. (See No. 1 of these Notes, *loc. cit.*, p. 231.)

The cortex consists of 6–9 layers of cells with thick walls. This tissue is very compact. The endodermis is well marked; it is composed of two distinct zones: adjoining the cortical cells there is a single layer of fairly large cells containing starch. Then comes a ring, 1–2 cells wide, of large rectangular cells with suberized walls.

The pericycle fibres form a wide band. The fibres are of small diameter, and are closely packed. The walls are thick, and the lumen small.

The phloem forms a wide band of small-celled elements. The xylem consists for the most part of vessels of large diameter, but there are also wood-fibres. The medullary rays are 2–3 cells wide, and the cells have lignified walls.

The pith is solid, and consists of round and polygonal cells, which vary considerably in size. The walls are thickened, lignified, and pitted.

11. Viola Cunninghamii Hook. f.

Growth-form.—A small tufted herb. It has a somewhat woody rootstock, creeping below and tufted above. The leaves are glabrous, and are tufted on the top of the rootstock, or on short branches springing from it; they are about ½ in. long, triangular-ovate, truncate at the base, obtuse and obscurely crenate: the petioles are ½–1¼ in. long, and are occasionally pubescent. The stipules are adnate to the base of the petiole.

Anatomy.

Leaf.—The upper epidermis consists of large oval cells with thin walls. A thin cuticle is present. The lower epidermis is similar, except that the cells are smaller. Stomates are found on both surfaces, but are more numerous on the lower. The guard-cells are small, and at the same level as the epidermal cells. There are no guard-cell ridges.

The chlorenchyma is differentiated. The palisade tissue consists of 2 rows of cells, the cells of the outer layer being deeper than those of the inner. There are fairly large intercellular air-spaces between the palisadic cells. The spongy tissue consists of rounded or irregular cells fairly loosely arranged, so that there are numerous intercellular air-spaces. All the chlorenchymatous cells contain moderately large chloroplasts.

The vascular system of the leaf is not very well developed. In the bundle there is only a small amount of lignified tissue, and there is a good deal of parenchyma. The bundle is surrounded by a rather poorly defined sheath of small, thin-walled, colourless parenchymatous cells.

Between the bundle-sheath and the lower epidermis, and below the upper epidermis, there is some colourless, thin-walled, parenchymatous tissue, which forms an aqueous tissue. There are only minute air-spaces between these cells. Below the bundle the epidermal cells are smaller and the cuticle is somewhat thicker.

Stem.—The epidermis consists of small oval or rectangular cells, which have thin walls and a thin cuticle.

The cortex is composed of large, closely packed, thin-walled, more or less rounded parenchymatous cells. There are very small intercellular air-spaces. Many of the cortical cells contain small starch-grains, and a few contain crystal aggregates (sphaero-crystals) of calcium oxalate.

The endodermis is well marked, and consists of large cells with thin suberized walls.

The phloem forms a wide continuous band; the sieve-tubes are of fairly large diameter, and associated with them is parenchyma. The xylem forms a band of tissue only slightly wider than the phloem. The vessels are numerous and of large diameter, and their walls are not very thick. Separating the rows of vessels are wood-fibres.

The pith is solid, and consists of large thin-walled cells which are closely packed together, so that there are only very small air-spaces at the corners. Near the xylem the pith-cells are smaller.

FIG. 1.—*Hymenanthera dentata* var. *alpina*. Entire young plant ($\frac{1}{2}$).

12. **Hymenanthera dentata** R. Br. var. **alpina** Kirk.

Growth-form.—This plant is a low, much-branched, rigid shrub, 1–2 ft. high, with tortuous or zigzag interlacing branches; the branches are densely compacted, and end in stout spines. The leaves are alternate or fascicled, thick and coriaceous, $\frac{1}{6}$–$\frac{1}{3}$ in. long, linear-obovate, with entire or irregularly lobed margins. The petioles are very short. A young plant is illustrated in fig. 1.

Anatomy.

Leaf (fig. 2).—The upper and the lower epidermis consist of large more or less squarish cells with thin walls. There is a thick cuticle on both surfaces. Stomates are found on both faces of the leaf. The guard-cells are level with the upper surface of the epidermal walls, but are below the cuticle. The guard-cells have thickened walls, and the stoma is protected by the guard-cell ridges.

The chlorenchyma is rather feebly differentiated. The palisade tissue consists of 4–5 rows of oval cells with very slightly thickened cell-walls, and containing a small number of large chloroplasts. The 2 outer layers of palisadic tissue are compact, but the inner ones are not so closely arranged. There is also palisade tissue on the lower surface of the leaf. Here it is only 1–2 rows of cells. The spongy tissue consists of rather irregular loosely arranged cells, so that there are large intercellular air-spaces. These cells also contain large chloroplasts.

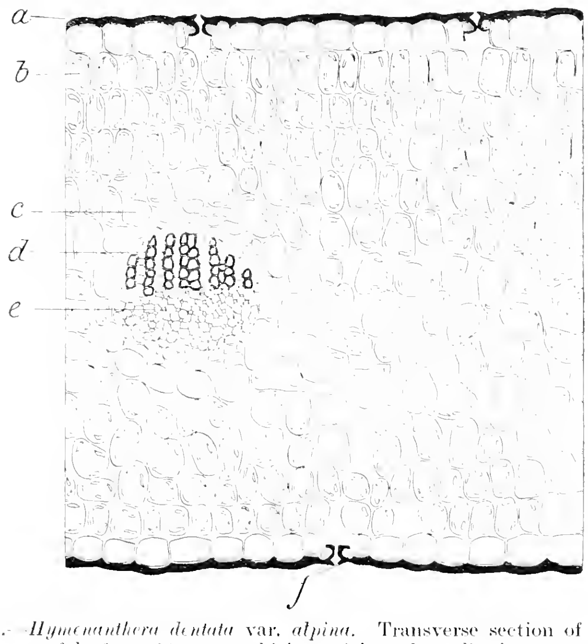


FIG. 2.—*Hymenanthera dentata* var. *alpina*. Transverse section of lamina of leaf (× 230). *a*, thick cuticle; *b*, palisade parenchyma; *c*, bundle-sheath; *d*, xylem; *e*, phloem; *f*, guard-cell ridge.

The vascular bundle is of the usual dicotyledonous type; the amount of lignified tissue in the xylem is small. Surrounding the bundle is a sheath of large thin-walled cells, which are practically devoid of chloroplasts.

Stem (fig. 3).—The cork forms a wide band, and consists of fairly large cells with thickened walls. Then comes the phellogen of thin-walled rectangular cells.

The cortex forms a layer of tissue 12–14 cells deep; its cells are oval and have thickened walls. There are numerous intercellular air-spaces, most of which are, however, small. Drops of oil are found in the cortical cells.

The pericycle fibres form small isolated groups. The cells are small and have very thick walls, so that the cell-cavities are almost obliterated.

The phloem contains a fairly large amount of parenchyma. The xylem elements are very regularly arranged. The xylem contains only a very small number of tracheae; it is composed almost entirely of wood-fibres and wood-tracheides. The fibres and tracheides have fairly thick cell-walls. The tracheides are pitted.

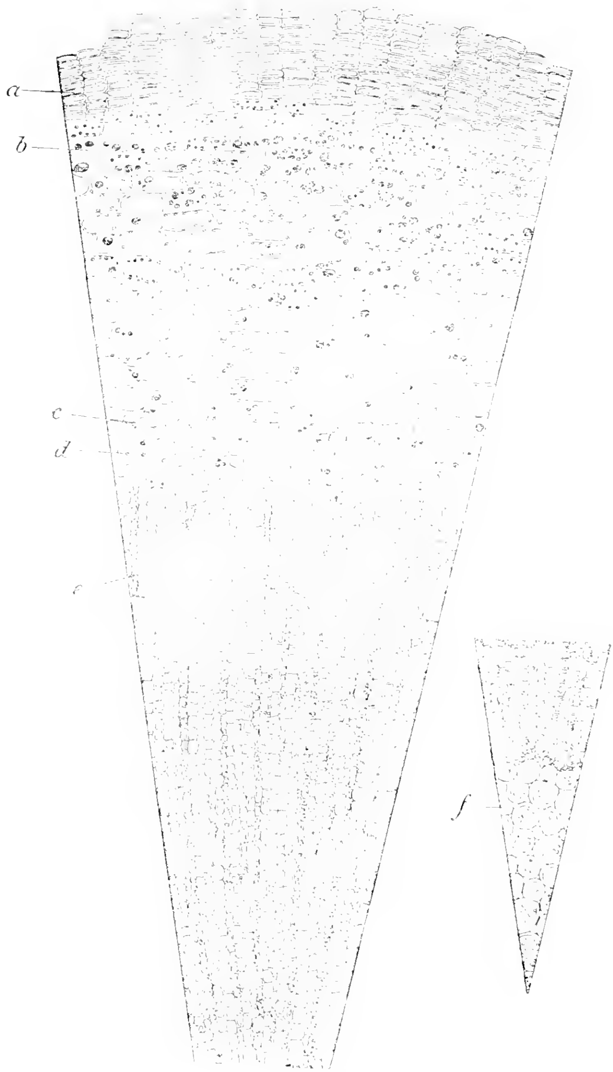


FIG. 3.—*Hymenanthera dentata* var. *alpina*. Transverse section of stem (× 175). *a*, cork; *b*, oil in cortical cells; *c*, pericycle fibres; *d*, phloem; *e*, medullary ray; *f*, pith with starch in cells.

The medullary rays are fairly numerous; they are uniseriate and have thickened lignified walls. The cells contain starch.

The pith is solid, and consists of very closely packed rounded or polygonal cells with thickened lignified walls. These cells contain numerous starch-grains.

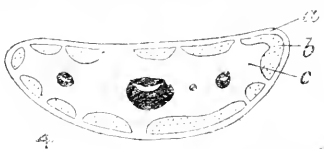
13. Pimelea Suteri T. Kirk.

Growth-form.—"A small much-branched shrub, 4–12 in. high; branches spreading or suberect, often tortuous: the younger ones sparingly pilose with rather long straight silky hairs; bark, dark red-brown or black. Leaves crowded, shortly petiolate or nearly sessile, erecto-patent, about $\frac{1}{3}$ in. long, narrow linear-lanceolate, subacute, coriaceous, concave above, both surfaces glabrous or rarely with a few lax hairs, margins and apices ciliated with long straight hairs."

Anatomy.

Leaf (figs. 4, 5).—Fig. 4 gives a diagrammatic view of the transverse section, while fig. 5 shows a portion of the section in detail.

Both the upper and the lower epidermis consist of narrow rectangular cells, which have their lateral and internal walls slightly thickened and the external ones considerably thickened. There is a cuticle on both surfaces. Stomates are found on both surfaces, and are slightly sunken below the thickened epidermal walls. The guard-cells have thickened walls, and the opening is protected by guard-cell ridges.



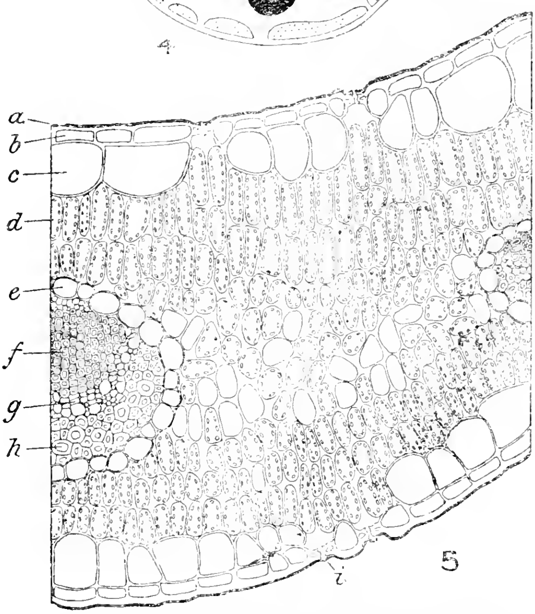


Fig. 4.—*Pimelea Suteri.* Transverse section of leaf (diagrammatic) (× 36). *a*, epidermis; *b*, mucilage-cells; *c*, chlorenchyma.

Fig. 5.—*Pimelea Suteri.* Transverse section of leaf (× 175). *a*, cuticle; *b*, epidermis; *c*, mucilage-sac; *d*, palisade parenchyma; *e*, bundle-sheath; *f*, xylem; *g*, phloem; *h*, sclerenchyma; *i*, stoma.

Below the epidermis, on both surfaces, there is a hypoderma of very large colourless cells: these form mucilage-sacs.

The chlorenchyma is differentiated. The palisade tissue is found on both sides of the leaf. It consists of 2–3 rows of cells, these being somewhat larger in the upper than in the lower palisade tissue. The walls are thin and contain numerous chloroplasts. Some of the cells contain tannin. The air-spaces in this tissue are small. Beneath the stomates the layer of mucilage-cells is interrupted by the palisade tissue. Beneath each stoma there is a fairly large cavity. The spongy tissue consists of somewhat irregular cells with numerous chloroplasts. The air-spaces are small. Most of the cells contain tannin.

Surrounding the vascular bundle there is a sheath of thin-walled parenchymatous cells which contain tannin. The xylem is formed of wood-fibres and tracheides of small diameter and with thickened walls. The xylem is very regularly arranged. The amount of phloem is small; the phloem parenchyma cells contain tannin. Beneath the phloem there is some stereome, consisting of small cells with very thick walls and small lumen.

Stem (fig. 6).—The cork forms a wide band 20–30 cells wide. The cells are large and have thick walls.

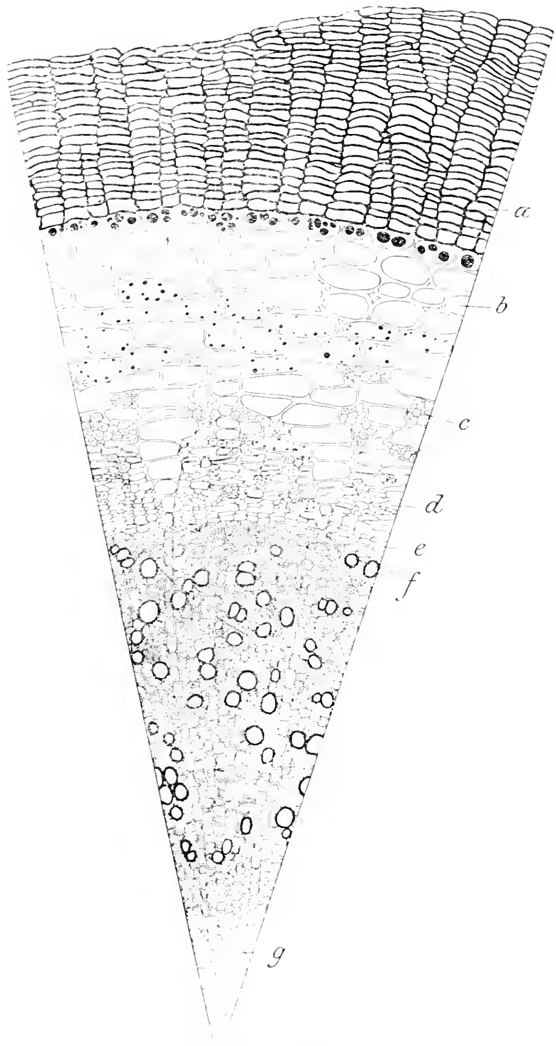


FIG. 6. *Pimelea Suteri.* Transverse section of stem (× 175). *a*, cork; *b*, cortex; *c*, fibres; *d*, phloem; *e*, cambium; *f*, trachea; *g*, pith.

The cortex consists of large oval cells, which have thick, somewhat mucilaginous, cell-walls. The tissue is compact, only small air-spaces being present. The cells of the outer part of the cortex contain tannin, and those of the inner part contain small drops of oil. There are numerous small groups of pericycle fibres, composed of very small cells with thick walls and small cavities.

The phloem is a practically continuous band (only interrupted by a few uniseriate medullary rays). The xylem contains numerous tracheae, but the bulk of the xylem is occupied by tracheides and by wood-fibres of small diameter and with small lumen.

The medullary rays are few; they are uniseriate, and the cells have lignified walls. The amount of pith is small; it consists of small roundish cells, most of which contain tannin.

14. Metrosideros robusta A. Cunn.

Usual Growth-form.—" A tall and stout forest-tree, 60–80 ft. or even 100 ft. high; trunk irregular, 3–8 ft. diameter or more; branches spreading, forming a huge rounded head; branchlets 4-angled, puberulous. Leaves decussate, 1–1½ in. long, elliptic-oblong or ovate-oblong or elliptic-lanceolate, obtuse, glabrous, very coriaceous; petioles short, stout, glabrous or puberulous."

Mineral Belt Growth-form.—A small, rounded, compact bush.

Anatomy.

Leaf (fig. 7).—The upper epidermis consists of small cells with thin walls, but with a very thick cuticle. The cells of this layer contain small

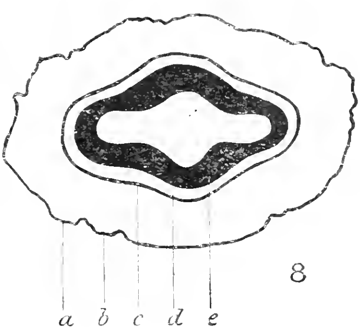


FIG. 7.—*Metrosideros robusta.* Transverse section of leaf (× 110). *a*, thick cuticle; *b*, epidermis; *c*, hypoderma; *d*, palisade tissue; *e*, xylem; *f*, phloem; *g*, oil-gland.

FIG. 8.—*Metrosideros robusta.* Transverse section of stem (× 24). *a*, thick cuticle; *b*, cortex; *c*, pericycle fibres; *d*, phloem; *e*, xylem.

drops of oil. The cells of the lower epidermis are smaller than those of the upper, and the cuticle is thinner and ridged. On both surfaces of the leaf are numerous large oil-glands; they are more numerous on the lower surface

Stomates are confined to the lower surface. The guard-cells are small, with thickened walls, and the stomates are protected by guard-cell ridges.

Below the epidermis there is a well-marked hypoderma; the upper hypoderma consists of 1 layer of large cells with thick walls, while the lower, a layer 1–2 cells thick, is composed of smaller cells, also with thick walls. All the hypodermal cells contain tannin.

The chlorenchyma is differentiated. The palisade tissue consists of 3 compact rows of cells, most of which contain tannin. The spongy tissue is composed of very irregular cells loosely arranged, so that there are large intercellular air-spaces. These cells have thickened walls, and many of them contain tannin.

The bundle-sheath consists of small, oval, thin-walled cells which contain tannin. Above the xylem and below the phloem there is stereome, consisting of small cells with thick walls, the cells adjacent to the phloem being smaller than those above the phloem. The xylem consists of wood-fibres and vessels of small diameter; these are arranged regularly in rows, which are separated by rows of small, thin-walled, parenchymatous cells which contain tannin.

Stem (fig. 8).—Fig. 8 is a diagrammatic view of a young stem.

The epidermis is composed of very small thin-walled cells; there is a thick cuticle.

The cortex consists of small thin-walled cells, more or less rounded in shape, the outer layers containing small chloroplasts. Most of the cortical cells contain tannin.

The pericycle fibres form a continuous ring round the phloem. The fibres are of small diameter, and their walls are very thick.

All the phloem parenchyma cells contain tannin, as do also the cells of the medullary rays and of the pith. The cambium is well marked, consisting of 3 rows of small regular cells. The xylem consists of vessels of fairly large diameter, and of wood-fibres of small diameter. The medullary rays are uniseriate, and their cells have thickened lignified walls.

The pith consists of rather small roundish cells which are closely arranged together. Some of the pith-cells contain crystal-aggregates of calcium oxalate.

15. Metrosideros lucida A. Rich.

Usual Growth-form.—"Usually a tall erect branching tree 30–60 ft. high, but often dwarfed to a small bush in subalpine or exposed localities; bark pale, papery; branchlets and young leaves silky. Leaves 1½–3 in. long, elliptic-lanceolate or lanceolate, acuminate, very coriaceous, pale glossy-green above, dotted with oil-glands beneath, narrowed into a short stout petiole."

Mineral Belt Growth-form.—A small, rounded, woody bush, with leaves ¾–1½ in. long.

Anatomy.

The structure of both stem and leaf corresponds with that in *M. robusta*

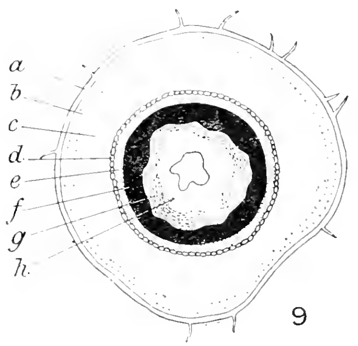
16. Epilobium pedunculare Hook. f.

Growth-form.—A small herb, with slender prostrate branches 2–6 in. long, which root at the nodes and are sparingly branched. The branches are almost glabrous. The leaves are opposite, ⅛–¼ in. long, orbicular-ovate, rounded at the apex, fleshy and entire, and with a very short petiole.

Anatomy.

Leaf.—The upper and the lower epidermis consist of more or less rectangular cells with thin walls, except for the external ones, which are slightly thickened. A thin cuticle is present. Stomates are equally numerous on both surfaces; the guard-cells are small, and level with the surface.

The chlorenchyma is differentiated. The palisade tissue consists of 3 layers of cells with thin walls, and containing numerous chloroplasts; these cells are closely packed together. The spongy tissue is composed of more or less irregular thin-walled cells, forming a compact tissue with only very small intercellular air-spaces. The chloroplasts are not nearly as abundant in this tissue as in the palisadic. At intervals in the mesophyll there are canals which are surrounded by a layer of epithelial cells. Raphides of calcium oxalate are found in the mesophyll.



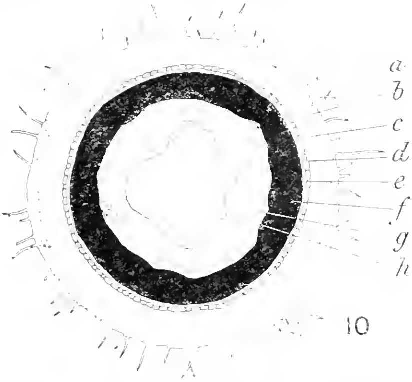


FIG. 9.—*Epilobium pedunculare.* Transverse section of stem (× 36). *a*, epidermis; *b*, cortical chlorenchyma; *c*, colourless cortex; *d*, endodermis; *e*, phloem; *f*, xylem; *g*, pith with starch; *h*, pith without starch.

FIG. 10.—*Epilobium pubens.* Transverse section of stem (× 36). *a*, epidermal hair; *b*, cortical chlorenchyma; *c*, colourless cortex; *d*, endodermis; *e*, phloem; *f*, xylem; *g*, pith with starch; *h*, pith without starch.

The vascular bundles are small, and contain only a small amount of lignified tissue. Below the midrib there are small more or less rounded cells, which contain a very few chloroplasts. This forms a water-tissue. In the vicinity of the vascular bundles the lower epidermal cells are smaller and have thicker walls.

Stem (fig. 9).—The epidermis is composed of small cells, which in transverse section are squarish or round. These cells have thickened walls, and there is also a cuticle, which is, however, only thin. Some of the epidermal cells are produced into thin-walled unicellular hairs, which contain protoplasm. Stomates are present, but are not numerous; the guard-cells are small, and level with the surface, as in the leaf.

The cortex forms a fairly wide band, about 9 cells wide. The outer portion consists of small cells with thickened walls, and containing a few chloroplasts. The inner part of the cortex consists of larger roundish or polygonal thin-walled cells which are compactly arranged, so that there are only very small air-spaces. These cells contain starch-grains. The endodermis is well defined; it consists of a single layer of large oval or rectangular cells with suberized walls.

The phloem forms a continuous ring round the xylem; the phloem parenchyma cells contain small starch-grains. The xylem forms a band only slightly wider than the phloem; it consists of vessels and of wood-fibres.

The pith consists of thin-walled more or less circular cells, with small air-spaces between them. The cells adjacent to the xylem are small, and contain starch. There is a large pith-cavity.

17. Epilobium pubens A. Rich.

Growth-form.—The plant is a small herb, with stems 3–8 in. high, slender, simple, decumbent and woody at the base, erect above, terete, uniformly clothed with a short fine pubescence. The leaves are alternate, $\frac{1}{4}$–$\frac{1}{2}$ in. long, ovate, obtuse, narrowed into slender petioles, pubescent on both surfaces, thin and toothed.

Anatomy.

Leaf.—This is thinner than in *E. pedunculare*, and the veins are more prominent. The upper epidermis is formed of large cells, more or less rectangular in transverse section; the walls are thin, except the external ones, which are somewhat thickened. A thin cuticle is present. Some of the epidermal cells are produced into unicellular hairs, which contain protoplasm and which have thin cutinized walls. The lower epidermis is similar to the upper, except that the cells are smaller. Stomates are confined to the lower surface, where they are very numerous. The guard-cells are small, and are slightly raised above the surface of the epidermis.

The palisade tissue is composed of 2 rows of thin-walled cells closely packed together, so that there are only very small intercellular air-spaces. These cells contain chloroplasts, which are smaller and much less numerous than in *E. pedunculare*.

The spongy tissue consists of about 4 rows of more or less rounded thin-walled cells, which are somewhat loosely arranged. Raphides of calcium oxalate are present in the mesophyll. Many of the mesophyll cells, especially those of the palisade tissue, contain drops of oil. Canals are present, as in *E. pedunculare*, but they are more numerous.

The vascular bundles are larger than in *E. pedunculare*, and the xylem contains more lignified elements. Around and below the bundles is a water-storage tissue, which consists of thin-walled, polygonal, closely packed, colourless cells.

Stem (fig. 10).—The epidermis consists of small oval or rectangular cells, with all walls thickened and with a fairly thick cuticle. Many of the epidermal cells are produced into straight unicellular hairs, which contain protoplasm and have thin cutinized walls. Stomates are not numerous; they are level with the epidermis, and the guard-cells are small.

The outer layers of the cortex (about 3 rows of cells) consist of oval cells, with their walls slightly thickened and with small intercellular air-spaces. These cells contain a few chloroplasts, and some of them contain oil. The rest of the cortex consists of larger more irregular cells. The endodermis is well marked, and is composed of a layer of large cells with thin suberized walls.

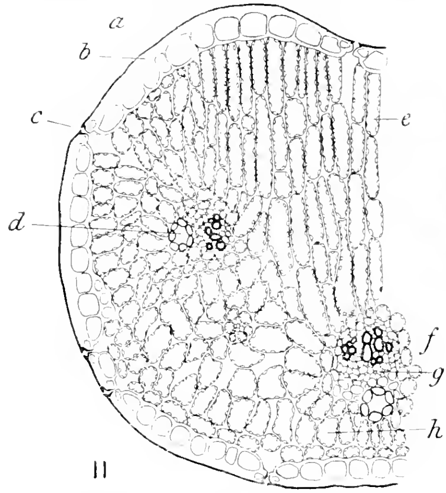
The phloem forms a narrower band than in *E. pedunculare*, and the xylem is wider, but is of the same type.

18. Anisotome filifolium (Hook. f.) Cockayne and Laing.

Growth-form.—This is a slender aromatic herb. The stems are about 4–8 in. high, smooth and striate. The leaves are 3–6 in. long, and are flaccid; the blades are very variable in size, and are ternately divided into narrow filiform acute segments $\frac{1}{2}$–$1\frac{1}{2}$ in. long. The petioles are long, slender, sheathing at the base; the sheaths are short, broad, and membranous.

Anatomy.

Leaf (fig. 11).—The epidermal cells are large, those of the upper epidermis being a little larger than those of the lower; the cell-walls are thickened, the external walls being very much thicker than the lateral or internal ones. There is a cuticle on both surfaces. Stomates are found on both surfaces, being somewhat more numerous on the lower than on the upper face. The stomates are raised above the epidermal cells, but not above their thickened walls. The guard-cells have thickened walls, and the stoma is protected by guard-cell ridges.



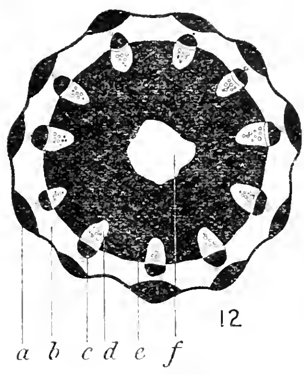


FIG. 11.—*Anisotome filifolium.* Transverse sections of leaf (× 175). *a*, cuticle; *b*, thickened epidermal walls; *c*, stoma; *d*, oil-duct; *f*, xylem; *g*, phloem; *h*, spongy tissue.

FIG. 12.—*Anisotome filifolium.* Transverse section of peduncle (diagrammatic) (× 175). *a*, sclerenchyma; *b*, cortex; *c*, pericycle fibres; *d*, xylem; *e*, lignified pith; *f*, pith-cavity.

The chlorenchyma is differentiated into palisade and spongy tissue. The palisade tissue is composed of 1–4 rows of cells (1 near the margin, 4 in the centre of the lamina). The cells are large and elongated, thin-walled and compactly arranged, and contain abundant chloroplasts. The palisadic tissue passes gradually into the spongy, which consists of rather irregular cells with thin walls and containing abundant chloroplasts. This tissue is loosely arranged, so that there are large air-spaces. There are large air-spaces beneath the stomates. Above the lower epidermis there is a layer of chlorenchymatous cells, which are smaller, more regular, and are closely arranged.

In the leaf there are 3 larger veins and 2 very small ones. They are surrounded by a sheath of small thin-walled parenchymatous cells, which contain only a small number of chloroplasts. Below each bundle there is an oil-duct, surrounded by 6–8 small epithelial cells. The amount of lignified tissue in the bundle is small.

Peduncle (figs. 12 and 13).—Fig. 12 gives a schematic view of the transverse section. In each ridge there is a group of lignified cells, and the whole of the central part is lignified. Fig. 13 shows the structure in detail.

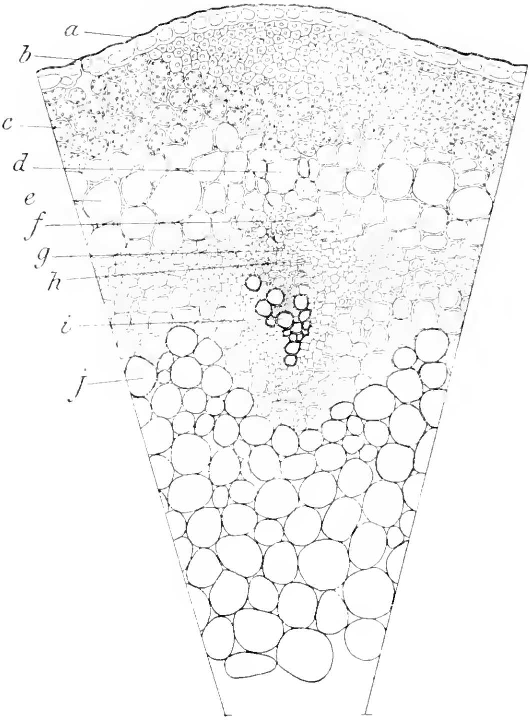


Fig. 13.—*Anisotome filifolium.* Transverse section of peduncle (× 175). *a*, cuticle; *b*, stoma; *c*, chlorenchyma; *d*, oil-duct; *e*, aqueous tissue; *f*, pericycle fibres; *g*, phloem; *h*, cambium; *i*, xylem; *j*, pith.

The epidermis consists of small cells, which are squarish above the ridges and are rectangular or oval in the furrows. The walls of these cells are thickened and lignified, and there is a cuticle. Stomates are found in the furrows. They are level with the epidermis; the guard-cells have thickened walls, and the opening is protected by guard-cell ridges.

Beneath the epidermis in the ridges there is a mass of sclerenchyma: this is composed of small cells with very thick walls and small lumen. Under the epidermis in the furrows are about 5 rows of chlorenchymatous cells. This band is also present under the sclerenchyma in the ridges; here it is about 2 cells wide. The outermost layer of this band of tissue consists of cells which are slightly elongated in a direction parallel with the surface, and which have slightly thickened walls. The rest of the chlorenchymatous tissue consists of more or less rounded cells with thinner walls. This tissue is very compact.

Inside this zone of tissue there is a band of colourless cortical tissue: this is composed of large roundish or polygonal cells, forming a compact tissue with only very small intercellular air-spaces. These cells are colourless, and form a water-storage tissue.

Above the phloem of the bundles there is a small group of pericycle fibres with thick walls and small cavities. Above the fibres there is a duct of large diameter, lined by about 8 epithelial cells. The phloem is a narrow band of small elements; the cambium, 2 rows of cells, can be clearly seen. The xylem consists of vessels of fairly large diameter and of xylem parenchyma.

All the ground-tissue internal to the water-tissue is lignified. The 3 or 4 rows of cells adjacent to the water-tissue are small, thick-walled, and compactly arranged. Passing inwards from this the cells become larger and their cell-walls thinner, but they are still lignified. There are large intercellular air-spaces where 3 or more cells meet. The stem is hollow.

19. Anisotome aromaticum Hook. f. var.

Growth-form.—A small aromatic herb, matted and depressed, 1–2½ in. high. The root is stout, long, and tapering. The stem is simple. The leaves are all radical, numerous, 1–6 in. long; the blade is linear and pinnate; the leaflets are in 6–12 pairs, ⅕–½ in. long, more or less incised; the lobes end in a bristle-like point. The petiole is short, stout, and broadly sheathing at the base.

Anatomy.

Leaf (figs. 14, 15).—Fig. 14 shows the form of the leaf, and fig. 15 gives a diagrammatic view of the transverse section.

The upper epidermis consists of fairly large squarish cells with thick walls. A thick cuticle is present, forming a minute papilla above each cell. There are no stomates on the upper surface. The lower epidermis consists of smaller cells than the upper; the walls are thickened, and there is a thick smooth cuticle. Stomates are confined to the lower surface, where they are slightly raised above the epidermis. The stoma is protected by guard-cell ridges. Beneath the upper epidermis there is a hypoderma, formed of thick-walled cells like those of the upper epidermis; these cells contain a few small chloroplasts.

The palisade tissue is formed of 2 rows of cells, which are small, thin-walled, closely packed together, and contain numerous chloroplasts. The spongy tissue consists of irregular cells, with the walls slightly thickened; they are loosely arranged, and contain numerous chloroplasts. The mesophyll cells just above the lower epidermis are much smaller, are rounded, and are closely packed together.

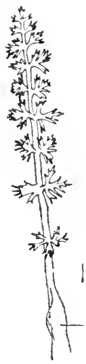
The vascular bundles are surrounded by a sheath of thin-walled parenchymatous cells, which contain a very few chloroplasts. The amount of lignified tissue in the xylem is small. Above the xylem and below the phloem there are ducts lined by a single layer of small epithelial cells. The duct below the phloem is much larger in diameter than that adjacent to the xylem.

Peduncle (fig. 16.)—The epidermis consists of very small rounded or squarish cells, with thickened walls and a fairly thick cuticle.

The outer 3 or 4 rows of cortical cells are small round cells, with very thick walls and no air-spaces between the cells. The remaining part of the cortex consists of larger cells, with thinner walls and small intercellular spaces between the cells. All the cortical cells contain chloroplasts.

Above each group of phloem there is a wide oil-duct surrounded by epithelial cells. The phloem elements are small, but the width of phloem band is much greater than in *A. filifolium.* The xylem is divided into 2 parts: (1) next to the phloem there is a band of wood-fibres; (2) a group of 5–10 vessels with xylem parenchyma.

The pith is composed of large thin-walled cells, but in the outer part the cells are smaller, and their walls are thicker and are lignified.



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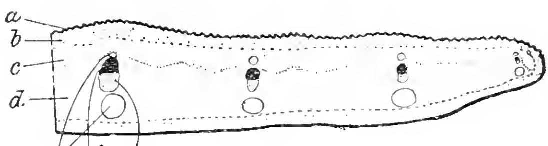

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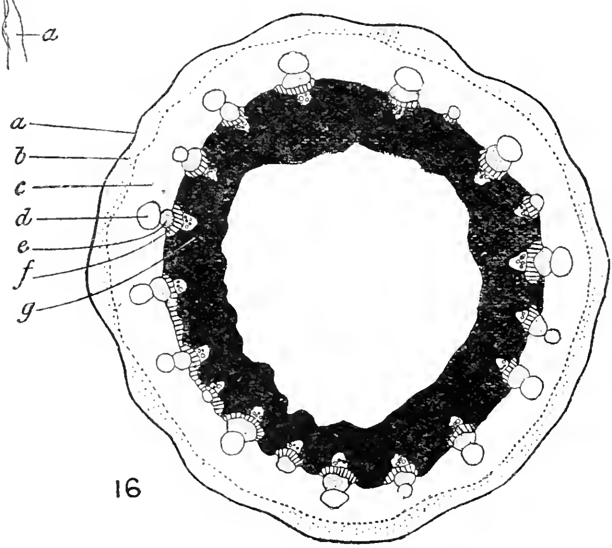

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FIG. 14.—*Anisotome aromaticum.* Entire leaf (× ½). *a*, sheathing base.
FIG. 15.—*Anisotome aromaticum.* Transverse section of leaf (× 36). *a*, cuticle; *b*, hypoderma; *c*, palisade parenchyma; *d*, spongy parenchyma; *e*, oil-duct; *f*, xylem; *g*, phloem.
FIG. 16.—*Anisotome aromaticum.* Transverse section of peduncle (× 36). *a*, cuticle; *b*, collenchyma; *c*, cortex; *d*, oil-duct; *e*, pericycle fibres; *f*, phloem; *g*, xylem.

20. Griselinia littoralis Raoul.

Usual Growth-form.—"A round-headed tree, 30–50 ft. high; trunk short, irregular, gnarled or twisted, 2–5 ft. diameter; bark rough, furrowed. Leaves 1–4 in. long, ovate or oblong-ovate, rounded at the tip, less unequal-sided at the base than in *G. lucida*, and sometimes almost symmetrical, pale yellowish-green, thick and coriaceous; veins obscure; petiole slender, $\frac{1}{2}$–1 in. long."

Mineral Belt Growth-form.—A woody shrub attaining a height of about 6 ft.

Anatomy.

Leaf.—The structure of the leaf has been described and figured by Miss Suckling (*Trans. N.Z. Inst.*, vol. 46, pp. 186–87, 1914). My specimens agree in leaf-structure with her description of the leaf of a well-illuminated tree, except that the hypodermal cells are larger than she figures.

Stem.—The epidermis is composed of small oval cells, which contain oil and which have thickened cell-walls, and in addition there is a thick uneven cuticle which is of a light-green colour.

The cortex is wide; the cells are oval and thick-walled. In the outer part the cortex is very compact, but in the inner part there are air-spaces between the cells.

The pericycle fibres do not form a continuous band round the phloem. The fibres are of small diameter, and their walls are so much thickened that the cell-cavities are almost obliterated.

The phloem forms a wide continuous band. The xylem consists of vessels and of wood-fibres, both of which are of fairly large diameter.

The medullary rays are nearly all uniseriate, with thickened lignified cell-walls. These rays are numerous There are also a few multiseriate rays 2–4 cells wide.

The pith is formed of round cells with thickened lignified walls, and containing abundant starch. Small intercellular air-spaces are present.

21. Gaultheria antipoda Forst. var.

Growth-form.—An erect much-branched rigid shrub 6–15 in. high. The branches are stout, sometimes glabrous but usually more or less clothed with a brownish pubescence. The leaves are alternate, shortly petiolate, about $\frac{2}{5}$ in. long, orbicular, obtuse, bluntly serrate, and very coriaceous. The leaves are glabrous, except the petioles, which are pubescent.

Anatomy.

Leaf.—The upper epidermis consists of small rectangular cells. A thick cuticle is present. The lower epidermal cells are smaller than the upper, and the cuticle is not so thick. Stomates are confined to the lower surface, and are protected by guard-cell ridges. Beneath the epidermis there is a hypoderma—1 layer of large cells with their walls slightly thickened.

The palisade tissue is composed of 3 rows of thin-walled cells, which contain numerous chloroplasts arranged along the lateral walls. There are no air-spaces between these cells. The spongy tissue consists of irregular loosely arranged thin-walled cells which contain numerous chloroplasts.

The vascular bundles are numerous. Each is more or less surrounded by stereome—small polygonal cells with very thick walls and small lumen. The parenchymatous elements of the bundle contain tannin.

Stem.—The epidermis is composed of small roundish cells with thickened walls and with a thick cuticle. Some of the epidermal cells are produced into long unicellular hairs, with thickened and slightly cutinized walls.

In the section of an older stem the corky layer is thick, and is composed of very small cells with thick walls

The cortex consists of large oval cells with thick walls. The outer region of the cortex is very compact, but the inner part has the cells loosely arranged.

The phloem is of the usual type. The xylem is composed of numerous vessels of moderately large diameter, and of wood-fibres with thick cell-walls.

The medullary rays are numerous and are uniseriate; the cells have their walls thickened and lignified. All the medullary-ray cells contain tannin.

The pith is composed of two kinds of cells: (1) Small more or less polygonal cells with thick walls, and containing tannin; (2) much larger thin-walled cells: in these the walls are only slightly lignified and the cells do not contain tannin.

22. Dracophyllum Urvilleanum A. Rich.

Growth-form.—A much-branched shrub 3–5 ft. high; the branches are slender and erect, with black or dark-brown bark. The leaves are erect, slender, 1–3½ in. long. The sheathing base is $\frac{1}{8}$–$\frac{1}{6}$ in. broad, brown, striate, and membranous; the blade is very narrow and coriaceous.

Anatomy.

Leaf (figs. 17, 18).—The upper epidermis consists of small roundish cells with thickened slightly lignified walls. A thick cuticle is present. Some of the epidermal cells are produced into short stiff unicellular hairs, which have extremely thick cutinized walls. The lower epidermis consists of slightly smaller cells than does the upper: these cells also have thickened lignified walls; and there is a thick cuticle. Stomates are found on both surfaces, but they are much more numerous on the lower surface. The guard-cells have thickened walls, and the opening is protected by guard-cell ridges.

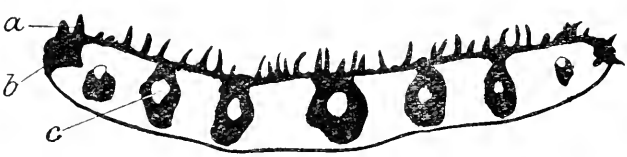


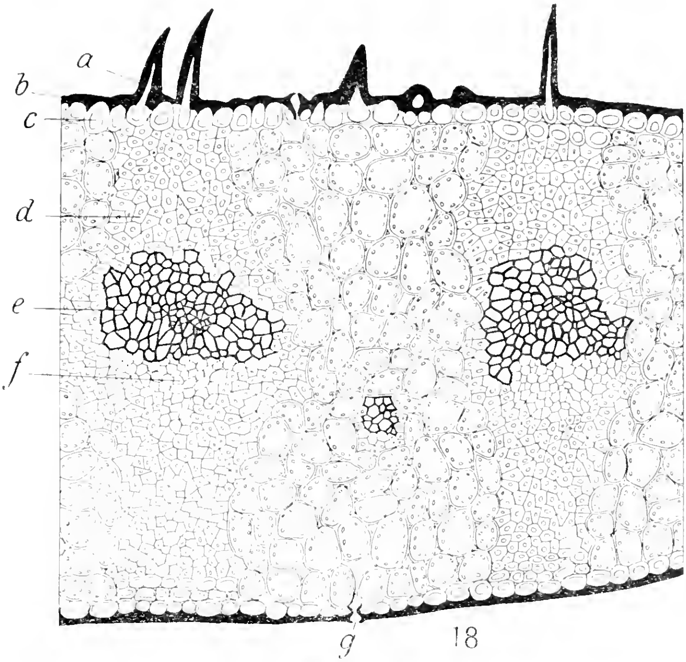
FIG. 17.—*Dracophyllum Urvilleanum.* Transverse section of leaf (× 48). *a*, cuticle; *b*, stereome; *c*, vascular bundle.

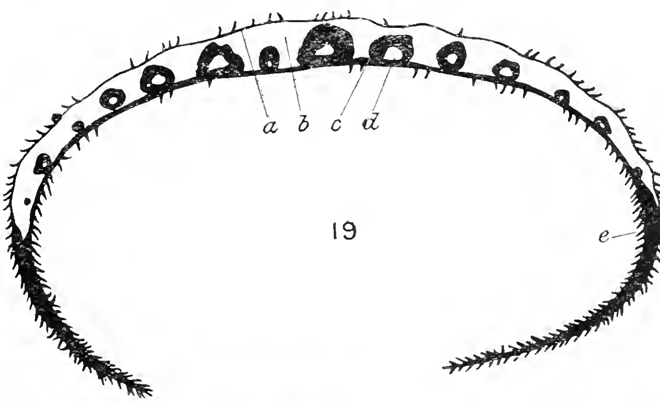
The chlorenchyma is homogeneous; it is a very compact tissue composed of large cells with their walls slightly thickened. Oil and tannin are present in many of the mesophyll cells.

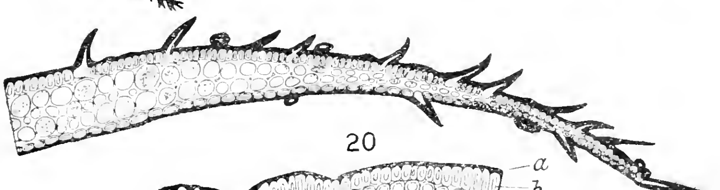
There are 7–9 vascular bundles; all the xylem elements are lignified, and the phloem parenchyma cells contain tannin.

Surrounding each vascular bundle there is a large mass of stereome; 3–5 of these bands of sclerenchyma extend right across the leaf, from one epidermis to the other. The groups around the bundles nearer the margins of the leaf are much smaller. The sclerenchymatous cells are 4–6-sided, and are very compactly arranged. The cells have very thick walls and minute lumen.

In the margins of the leaf there are 1–3 layers of larger sclerenchymatous cells.







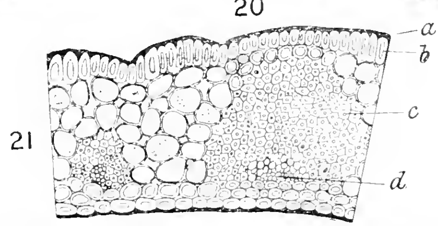


FIG. 18.—*Dracophyllum Urvilleanum.* Transverse section of leaf (× 230). *a*, bristle; *b*, thick cuticle; *c*, epidermis; *d*, stereome; *e*, phloem; *f*, xylem; *g*, stoma.
FIG. 19.—*Dracophyllum Urvilleanum.* Transverse section of sheathing leaf-base (× 36). *a*, cuticle; *b*, mesophyll; *c*, stereome; *d*, vascular bundle; *e*, lignified tissue.
FIG. 20.—*Dracophyllum Urvilleanum.* Transverse section of margin of leaf-base (× 175).
FIG. 21.—*Dracophyllum Urvilleanum.* Transverse section through middle of sheath (× 175). *a*, cuticle; *b*, epidermis; *c*, stereome; *d*, vascular bundle.

Sheathing Leaf-base (figs. 19–21).—This resembles the leaf in general structure, but differs in a few details: (1.) The cells of the outer epidermis are elongated at right angles to the surface. Like the epidermal cells of the leaf, they have very thick walls, but here they are not lignified. The inner epidermis is composed of roundish cells, with thickened lignified walls. (2.) There is a cuticle on both surfaces, but it is not so thick as in the leaf. (3.) Near the margins of the leaf all the cells, except those of the outer epidermis, have thickened lignified walls. (4.) There is a hypoderma of lignified cells on the upper surface.

Fig. 22.—*Dracophyllum Urvilleanum.* Transverse section of stem (× 175). *a*, thick cuticle; *b*, epidermis; *c*, dead cortex; *d*, pericycle fibres; *e*, suberized tissue; *f*, phloem; *g*, medullary ray; *h*, xylem; *i*, air-passage; *j*, pith.

Stem (fig. 22).—On the outside are the dead epidermal and cortical cells. The epidermal cells are small, thick-walled, and have a very thick cuticle. The cortical cells are irregular and thick-walled: their walls are suberized and also lignified.

Inside this layer are some fibres which form a more or less continuous band of small cells with very thick walls and small lumen.

Then comes a band of corky tissue; this is a moderately wide band, and is composed of small regular thick-walled cells.

The phloem is also a fairly wide band; the phloem elements are very regularly arranged, and the parenchymatous cells contain tannin. The xylem consists of vessels of small diameter with thickened walls and of wood-fibres, with very thick walls and small cell-cavities.

Medullary rays are numerous and are uniseriate; they have thickened lignified walls, and contain tannin. A few of the cells contain starch. The pith is wide, and is solid. The cells are small, and have thickened lignified walls. Many of these cells contain tannin. The cells are loosely arranged, with large air-spaces between them.

23. Dracophyllum rosmarinifolium R. Br.

Growth-form.—This plant is a depressed or prostrate much-branched rigid woody shrub, 3–18 in. high; the branches are stout, spreading, leafy at the tips. The leaves are erect, rigid, and curved, $\frac{1}{4}$–$\frac{3}{4}$ in. long; the sheathing base is short, $\frac{1}{8}$ in. wide; the blade is $\frac{1}{20}$ in. wide at the base, very thick and coriaceous, convex at the back and flat in front; the tip is trigonous.

Anatomy.

Leaf (fig. 23).—The structure of the leaf is the same as in *D. Urvilleanum*, the only differences being that the leaf is narrower and thicker. There are 3 large bundles and 4 smaller ones. Tannin idioblasts in the mesophyll are more abundant than in *D. Urvilleanum*.

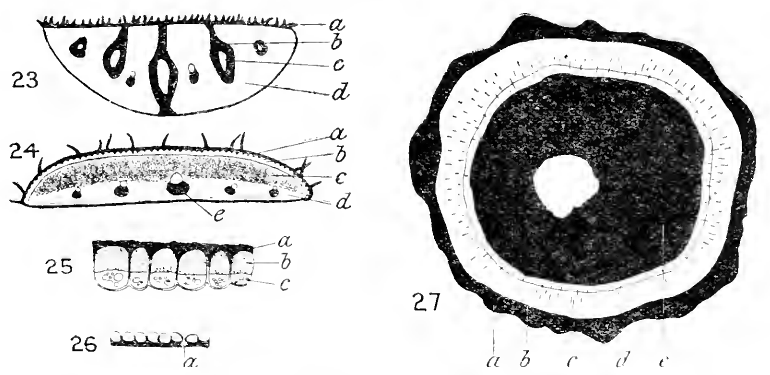


FIG. 23.—*Dracophyllum rosmarinifolium.* Transverse section of leaf (diagrammatic) (× 36). *a*, bristles; *b*, stereome; *c*, vascular bundle; *d*, mesophyll.

FIG. 24.—*Pentachondra pumila.* Transverse section of leaf (diagrammatic) (× 36). *a*, cuticle; *b*, epidermis; *c*, palisade tissue; *d*, spongy tissue; *e*, vascular bundle.

FIG. 25.—*Pentachondra pumila.* Transverse section through upper epidermis (× 175). *a*, cuticle; *b*, thickened cell-wall; *c*, cell-cavity.

FIG. 26.—*Pentachondra pumila.* Transverse section of lower epidermis (× 175). *a*, stoma.

FIG. 27.—*Pentachondra pumila.* Transverse section of stem (diagrammatic) (× 36). *a*, cork; *b*, cortex; *c*, radiating lines of suberized cells; *d*, phloem; *e*, xylem.

Stem.—On the outside there are dead brown cells, the remains of the old epidermis, cortex, and pericycle fibres.

The cork forms a wide zone of small compactly arranged cells. The cells have thick walls, which in the inner part of the zone are lignified as well as suberized.

The cortex is a very narrow band of tissue, composed of small round thick-walled cells which contain tannin and which are closely packed together, so that there are no air-spaces.

The phloem also is a narrow band of tissue. The phloem parenchyma cells contain tannin. The xylem is of the same type as in *D. Urvilleanum.* In addition to the numerous uniseriate medullary rays, there are 3 or 4 wide multiseriate rays. The cells of the latter do not have lignified walls, but they contain tannin. There are more wood-fibres with thickened walls in the wood of this plant than in *D. Urvilleanum.*

The pith is solid and like that of *D. Urvilleanum,* except that tannin is more abundant.

24. Pentachondra pumila R. Br.

Growth-form.—This plant is a much and closely branched dwarf shrub, 2–6 in. high; stems stout, woody, and procumbent; the branches are ascending, and are covered by a very dark-brown bark. The leaves are numerous, crowded, suberect, $\frac{1}{8}$ in. long, oblong to ovate-oblong, and with a callous tip.

Anatomy.

Leaf (figs. 24–26).—In shape the transverse section is like that of the leaf of *Dracophyllum Urvilleanum,* but in the latter the convex surface is the lower, and in this plant it is the upper.

The upper surface consists of large regular cells, which are slightly elongated at right angles to the surface of the leaf. The lateral and internal walls of these cells are thin, but the external walls are very much thickened. In addition there is a very thick rough cuticle. The lower epidermis consists of small regular cells. Their walls are only slightly thickened; and there is a thick cuticle, which is not, however, as thick as on the upper surface of the leaf. Stomates are confined to the lower surface; they are not frequent. The guard-cells are at the same level as the other epidermal cells, and their walls are only slightly thickened. The guard-cell ridges are small.

The chlorenchyma is differentiated. The palisade tissue consists of 2 layers of large typical palisade cells. The spongy parenchyma consists of smaller more or less irregular cells. All the mesophyll cells are thin-walled. There are air-spaces between the cells in both the spongy and the palisade tissue, but they are small. The cells contain numerous rather small chloroplasts, and many contain tannin. Oil-drops are found in some of the mesophyll cells and also in the cells of the upper epidermis.

The vascular bundles are small, and the parenchyma of both the xylem and the phloem contains tannin. Beneath each vascular bundle there is a small mass of stereome, consisting of small cells with very thick walls.

Stem (fig. 27).—The corky tissue forms a band of varying width: the cells are small, and have thick walls.

The cortex is a moderately wide band of very regular oval cells, which have thin walls and which contain tannin. This tissue has only very small intercellular air-spaces.

The phloem, xylem, and medullary rays are the same as in *Dracophyllum Urvilleanum.* The phloem parenchyma and the medullary rays contain tannin.

Scattered in the phloem and in the cortex there are more or less radial lines of small cells with suberized walls.

The pith is solid, and consists of large more or less polygonal cells with thickened lignified walls. These cells contain tannin.

Art. XIX.—*Further Notes on the Geology of the Trelissick or Castle Hill Basin.*

By R. Speight, M.Sc., Curator of the Canterbury Museum.

[*Read before the Philosophical Institute of Canterbury, 18th September, 1918; received by Editor, 30th December, 1918; issued separately, 26th May, 1919.*]

The following additional notes with regard to the Trelissick Basin are made as the result of further examination since my former paper* was published. The first matter concerns the existence of another detached block of limestone on the western side of the area at the base of the Craigieburn Range. This was hidden by bush during my former examination of the locality, but fire has swept over it and exposed the rock clearly to view. I should have observed it, however, had I ascended the Hog's Back Creek about a quarter of a mile above the turning it makes on striking the Hog's Back Ridge, as the bed crosses the creek and is exposed on its banks under the covering of shingle. The limestone here forms a heavy band, striking east-north-east, pointing towards the saddle between the Hog's Back Creek and Waterfall Creek in one direction, and in the other running towards one of the spurs of the Craigieburn Range. In the creek the bed is 100 ft. thick, dipping generally north-north-west at an angle of 85°, but is much contorted in places. It is well jointed, slightly crystalline, and distinctly coralline. When traced towards the south-west through the burnt bush the dip flattens out and has a general direction of south-south-east at an angle of 45°. The relations to the greywackes at the point where it abuts on the spur of the Craigieburn Range are obscured by bush and a covering of loose debris, but the general circumstances suggest a fault contact, and the relations to the limestone of the Hog's Back Ridge are also difficult to make out, but some strong deformation, either of faulting or acute folding, certainly occurs between them.

Another detached block of limestone occurs on the north side of the Long Spur, which divides the basin of the Hog's Back Creek from that of the Thomas River. This dips west at an angle of 45°, but at its southern end the strike turns round so that it becomes north-east. The rock is much brecciated. It is possible that this forms a syncline with the block of rock just referred to, the uppermost members of the Tertiary sequence being developed in a basin shape between them.

Near the southern end of the Hog's Back a fossil locality was discovered in the bed of the creek. The bed is 3 ft. in thickness where exposed, and consists of sand and shell layers, striking east, and dipping south at an angle of 75°—that is, parallel to the limestone of the Hog's Back in its vicinity. The following fossils were obtained: *Cucullaea ponderosa* Hutt., *Fulgoraria arabica elongata* (Swains.), *Paphia curta* (Hutt.)

My attention has been drawn by Dr. W. P. Evans and Mr. A. E. Flower, who were recently camping in the district, to another important fossil horizon in the Thomas River. This occurs in the bed and on the north bank of the stream just opposite the junction of the little creek that flows past the farm and joins the Thomas in the vicinity of the old wool-scouring works. The strata consist here of sands, sandy clays, and dark sandy shales with numerous specimens of *Ostrea ingens.* Underneath the oyster-bed are

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* R. Speight, The Stratigraphy of the Tertiary Beds of the Trelissick or Castle Hill Basin, *Trans. N.Z. Inst.*, vol. 49, p. 321, 1917.

dark sandy shales, light-coloured and greenish-grey sands, sometimes glauconitic, in the upper part of which are very fragmentary fossil shells. The dark sands weather brown, and occasionally have lenses of crystalline calcite running through them. Farther down stream there is the same alternation of sands and shales with lignite, and in one of the beds of sand, about 2 chains above a fence crossing the creek, is a layer of shell-fragments which include *Struthiolaria tuberculata* and *Plejona huttoni pseudorarispina*. These beds pass down into the sands with numerous shell-fragments, to be referred to later.

The beds in the vicinity of the wool-scour strike north-west and dip south-west at angles of about 20°, and they continue to do so for a little distance up-stream, where lignite again occurs associated with greenish sands, but above this the strike must swing sharply round till it becomes east-north-east—that is, along the creek. As the beds are followed upstream, the dip becomes steeper, as much as 60°, in agreement with the strike and dip of the limestone, south of the road, forming the north-eastern corner of Castle Hill. The beds here consist of greenish and yellowish white sands and sandy shales, the latter occasionally carbonaceous. I was fortunate on this occasion to be able to locate exactly the bed of *Ostrea ingens*, first recorded by Park,* for the heavy floods during the last season had swept the face free from surface debris and exposed the fossil-bed clearly. I had repeatedly searched for the bed without success, and am glad to give confirmatory evidence of his interesting discovery. It was quite by oversight that I made no reference to this point in my original paper, and I regret the omission.

At the point where this bed is exposed the following series is shown on the face of the cliff, the sequence being in ascending order and the total thickness about 25 ft.: (1) impure lignite; (2) sandy shales; (3) greyish sands; (4) sandy shales; (5) greyish argillaceous sands; (6) oyster-bed, 12 in. to 18 in. thick, in dark argillaceous matrix; (7) greyish sandy shales; (8) greyish sands, weathering brown; (9) white sands.

Park is quite correct in his inference that this oyster-bed (6) is considerably higher than the beds developed just above the limestone gorge of the Porter, since this bed is probably at a higher level than that occurring opposite the wool-scour, which is undoubtedly at a higher level stratigraphically than that containing numerous *Struthiolaria*, which in turn overlies the limestone. However, the exact correlation of the two oyster-beds is a matter of doubt owing to the absence of continuous exposure and the slipped character of the country, especially the high banks of the Thomas, where they are overlain by gravels. Although shell-fragments were observed higher up the stream still, above the road-crossing, no other bed of oysters was located, although it may easily occur buried up by surface debris The occurrence of the *Ostrea ingens* indicates clearly that the beds associated with it are of Mio-Pliocene age.

Still another fossil horizon was located in the Porter River, about a mile above the limestone gorge, and just below the junction of the river with a rocky creek coming from Mount Torlesse. In the bed of the stream is a small exposure of greensands containing numerous specimens of the black oyster (*Ostrea angasi*). The beds strike north-east, and dip north-west 40°. Associated with this is another bed containing fragmentary shells in poor

* J. Park, Marine Tertiaries of Otago and Canterbury, *Trans. N.Z. Inst.*, vol. 37, p. 535, 1905.

state of preservation. A fragment of a gasteropod showed part of a suture-line with a well-defined band below it, suggesting the Cretaceous genus *Nerinaea*, which has recently been obtained in Southland by Marshall.

A special object of my recent visits to the locality was to collect fossils from the loose sands and concretionary bands above the limestones, beds which have been classed as "Pareora" by all who have examined the Castle Hill Basin. A full description of these beds, specially those occurring between the two gorges of the Porter River, was given in my previous paper, and so it is unnecessary to mention their lithological features any further; but the beds are also exposed in the bed of Broken River below the road-crossing, in the Thomas, in Home Creek near its junction with the Porter, and in a tributary coming in on the north side of Whitewater Creek, and elsewhere. Collections were made in four of these localities. It is unfortunate, however, that the great majority of the fossils are in a poor state of preservation. Between the two gorges of the Porter there are two distinct horizons yielding shells. In the lower of these the following were obtained:—

Cardium ? sp.
Cerithium hectori Harris.
Comminella inflata (Hutt.).
* *Macrocallista multistriata* (Sow.).
* *Mactra discors* Gray.
* *Mesodesma australe* (Gmel.).
Paphia curta (Hutt.).
Polinices gibbosus (Hutt.).
Polinices ovatus (Hutt.).
* *Tellina eugonia* Sut.

In the lower horizon at Whitewater Creek, in the same stratigraphical position as the above, the following were obtained: **Calyptraea maculata inflata* (Hutt.). *Cerithium hectori* Harris. *Crassatellites attenuatus* (Hutt.).

In both these localities there is a well-defined upper horizon characterized by numerous individuals of *Struthiolaria*, which for that reason may be called the *Struthiolaria* bed. Between the Porter gorges the following were collected:—

Cerithium hectori Harris.
Crepidula striata (Hutt.).
Fastigiella australis Sut.†
Glycymeris globosa (Hutt.).
Glycymeris laticostata (Q. & G.).
Paphia curta (Hutt.).
Plejona (Athleta) huttoni pseudorarispina Sut.
Polinices gibbosus (Hutt.).
Struthiolaria tuberculata Hutt.

In beds in similar stratigraphical position in the tributary of the Whitewater the following were obtained:—

Cerithium hectori Harris.
Crassatellites attenuatus (Hutt.).
Crepidula striata (Hutt.).
Fastigiella australis Sut.†
**Mactra discors* Gray.
Polinices gibbosus (Hutt.).
Paphia curta (Hutt.).
Struthiolaria tuberculata Hutt.

* Recent. † New species described in this volume (p. 68).

In Broken River the following were obtained :—

***Calyptraea maculata inflata* (Hutt.).
Cerithium hectori Harris.
Crassatellites attenuatus (Hutt.).
Crepidula striata (Hutt.).
**Diplodonta zelandica* (Gray).
**Dosinia greyi* Zitt.
Hemiconus ornatus (Hutt.).
Struthiolaria tuberculata Hutt.

From Home Creek the following were obtained :—

Ancilla papillata (Tate).
* *Calyptraea maculata* (Q. and G.).
**Calyptraea maculata inflata* (Hutt.).
Cardium spatiosum Hutt.
Cerithium hectori Harris.
Chione speighti Sut.
Crassatellites attenuatus (Hutt.).
**Crepidula monoxyla* (Less.).
Cytherea enysi Hutt.
**Diplodonta zelandica* (Gray).
**Divaricella cumingi* (Ad. & Ang.).
Lima crassa (Hutt.).
Lima huttoni Sut.
Lima jeffreysiana Tate.
Mactra attenuata Hutt.
Modiolaria elongata (Hutt.).
Paphia curta (Hutt.).
Pecten aff. *chathamensis* Hutt.
Plejona (*Athleta*) *huttoni pseudorarispina* Sut.
Polinices gibbosus (Hutt.).
Solariella cf. *sulcatina* Sut.
Struthiolaria tuberculata Hutt.
Turritella ? sp.

An examination of these lists does not disclose any noteworthy difference between the fossil content of the lower set of beds in the Porter and Whitewater Rivers and that of the upper set, but the number of specimens collected is no doubt insufficient to detect with certainty any difference that may exist.

Of the thirty-five species enumerated in the combined lists only twelve are Recent—that is, 32 per cent.—a percentage which does not differ appreciably from that of Recent forms in the "shell-bed" of the Porter River or the tuff-beds interstratified in the limestone as recorded in my paper on the Trelissick Basin. In this paper it is maintained on stratigraphical grounds that there is no unconformity between the limestones and the overlying beds yielding the fossils enumerated above, and this contention is now supported by the palaeontological evidence.

In concluding these notes I have to express my indebtedness to the late Mr. H. Suter for kindly helping me with the identification of the majority of these specimens, and for describing the new species of *Fastigiella* included in the list.

* Recent.

Art. XX.—*Studies in the New Zealand Species of the Genus* Lycopodium: *Part III—The Plasticity of the Species.*

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

[*Read before the Philosophical Institute of Canterbury, 18th December, 1918; received by Editor, 31st December, 1918; issued separately, 20th June, 1919.*]

Plates IX–XIV.

Contents.

Classification of the New Zealand Species.

Species belonging to the sections *Selago* and *Phlegmaria*—

Lycopodium Selago Linn.
L. varium R. Br.
L. Billardieri Spring.
L. Billardieri var. *gracile* T. Kirk.

Species belonging to the sections *Inundata* and *Cernua*—

Lycopodium Drummondii Spring.
L. laterale R. Br.
L. ramulosum T. Kirk.
L. cernuum Linn.

Species belonging to the section *Clavata*—

Lycopodium volubile Forst.
L. fastigiatum R. Br.
L. densum Labill.
L. scariosum Forst.

General.

In the present paper I have gathered together all the facts which I have observed with regard to the general biology of the eleven species of *Lycopodium* which occur in New Zealand.

The New Zealand biological region provides an excellent field for the observation of the remarkable plasticity of the members of this genus. L. Cockayne (10, pp. 2–3) has pointed out how peculiarly fitted New Zealand is for ecological studies. In the particular paper cited he says, "Its vegetation is still in many places absolutely virgin; its climate varies from subtropical to subantarctic; some parts experience an annual rainfall of more than 500 cm. and other parts less than 30 cm.; the plant formations include mangrove swamp, rain-forest, heaths of various kinds, subglacial fell- and herb-fields, varied associations of rock and debris, subantarctic southern-beech forest, associations in and near hot springs, dunes, salt meadows, steppes, swamps, and moors—in fact, for an equal variety an ecologist would have to explore one of the larger continents in its entirety. Further, the isolation of the region for a vast period of time far from any other land surface; the absence of grazing-animals, the moa (*Dinornis*) excepted; the diverse floral elements (Malayan, Australian, Subantarctic, &c.); the strong endemism; the numerous small islands where conditions are simpler than on the larger ones; and, finally, the presence of many areas whose vegetation has been changed within a very few years through the farming operations of the settler . . . all these attributes much enhance the importance of New Zealand for ecological research."

Some or other of the species of *Lycopodium* are found in abundance in practically every part of this very varied region, and their range of variability is remarkable. Three species belong to the subgenus *Urostachya*. Of these *L. Selago* Linn. occurs on the mountain-ranges of both Islands, but more particularly on those of the South Island, both in exposed and in shady situations. *L. varium* R. Br., a terrestrial species which, as will be shown, has affinities both with *L. Selago* and with *L. Billardieri*, is also to be found throughout New Zealand in open places in high country, and some noteworthy varieties occur on the subantarctic islands. *L. Billardieri* Spring is a characteristic epiphyte, and occurs commonly throughout New Zealand in the mixed forest, and more particularly in the western botanical districts of both Islands where the rainfall is heavy. A small delicate variety of the last species, named *L. Billardieri* var. *gracile* T. Kirk, grows on tree-fern stems, and is especially abundant in the western districts of the South Island. The remaining eight species belong to the subgenus *Rhopalostachya*. *L. Drummondii* Spring, *L. laterale* R. Br., and *L. ramulosum* T. Kirk occur exclusively in swampy or peaty ground, the first-named in one restricted locality in the far north, and the other two more widely—*L. laterale* in the North Island, and *L. ramulosum* in the western botanical districts of the South Island and in Stewart Island. *L. cernuum* Linn. until lately has been known only from the northern half of the North Island, where it grows abundantly in *Leptospermum* scrub and in the neighbourhood of hot springs, but it has also recently been found in a very isolated locality at the northern extremity of the west coast of the South Island. These four species belong to the *Inundata* and *Cernua* sections of the genus. The four species *L. densum* Labill., *L. volubile* Forst., *L. fastigiatum* R. Br., and *L. scariosum* Forst. which belong to the *Clavata* section are found typically on open moors or amongst light scrub both at sea-level and at higher altitudes. Of these, *L. densum* is more common in the northern portion of the North Island, where it grows abundantly on clay lands, whereas *L. fastigiatum* and *L. scariosum* are to be found most abundantly in the mountain regions of the South Island. The two latter, with *L. volubile*, also grow luxuriantly on the west coast of the same Island in localities where the original vegetation has been disturbed by man. *L. volubile* occurs commonly throughout New Zealand in very varied habitats, and more especially in heavy scrub or at the edge of the forest where it can climb. It will be seen that the eleven species mentioned cover all of Pritzel's five main sections of the genus. The study of these species as they occur in New Zealand under the manifold varieties of climate, soil, and altitude should present favourable data for the study of the plasticity of the genus as a whole.

In many parts of New Zealand the vegetation is as yet quite virgin, but in many other localities the removal of the original forest by felling and burning, or the disturbance of the soil by alluvial gold-mining, road and railway cuttings, &c., has thrown open new ground for the various species of *Lycopodium* to occupy, and the rapid and luxuriant spreading of such species as *L. cernuum*, *L. ramulosum*, *L. laterale*, and also *L. volubile*, *L. fastigiatum*, and *L. scariosum*, over this new ground through spore-germination has provided excellent opportunities for the study of their prothalli and "seedling" forms.

An examination of Baker's, and more especially of Pritzel's, classification of the species of the entire genus brings into view the wide question of the relation of elementary species to the species of taxonomy. The main sections of the genus are well defined, and are in accord with the main characters of both the gametophyte and the sporophyte generations in the life-history of the species. In each of these sections certain well-defined type species are to be recognized, and around each of these type species are grouped a number of variant forms, having each a more or less limited distribution, to which specific names have been given. Many of these latter species will be distinct and true-breeding forms, but probably there will be found to be instances where a form which bears specific rank and which is restricted to some particular country or other will prove to be taxonomically identical with some other form which may not have been distinguished by a specific name and which belongs to quite another biological region, the two forms having arisen quite independently either as epharmonic or non-epharmonic adaptations. In his *Flora Antarctica* Hooker says, "The importance of the question whether two perfectly similar plants from remote quarters of the globe are considered as belonging to one species has induced me to canvass very fully the claims of many supposed forms of *Lycopodium* to the title of distinct species. In all such cases my first object has been to determine whether the plant inhabits various intermediate countries. When . . . they are found to do so there need be little hesitation in referring them, after due examination, to one plant; in such instances the supposition of a double creation of the same species, or of one of them being a variety of some other really distinct plant, which plant wholly resembles another from other countries would be confessedly a gratuitous assumption. Where, however, no intermediate stations can be detected these suppositions become more plausible" (18, pp. 115–17).

The genus *Lycopodium* has a remarkable distribution, some or other of the species occurring in every country, in practically all soils, and at every altitude. The persistence of such a very ancient Pteridophytic family to the present day, and its wide distribution, is probably due not to the different sections of the genus being representative of different parts of the old Carboniferous Lycopods, but rather to the extreme plasticity of the modern genus as a whole. This plasticity of both the gametophytic and sporophytic characters is clearly indicated by the study of the species which occur in New Zealand, and probably also of those in any other region. To quote L. Cockayne again (10, p. 13), "Nothing has been brought out more clearly by ecological studies in New Zealand than the extreme plasticity of many species and structures, and their rapid response to a change of environment. This is so great in numerous instances that the idea of 'normal' loses its meaning." With regard to the lycopodiums the experimental alteration of the environment will be a very difficult task to attempt, owing to the fact that the spores undoubtedly need very particular conditions for germination, and that the prothallus in many cases takes many years to grow. Therefore such a paper as the present, which contains no facts concerning the experimental cultivation of the prothalli and plants, cannot decide whether or not the varieties of the species described are actually true-breeding forms, although in some instances field observations can indicate with some certainty whether or not a particular variety is to be regarded as a hereditary polymorph. However, the details of field observations and of the general biology of the species will be of use, it is hoped, in indicating the degree of relationship of the species *inter se*, as also of the different sections of the genus to which they belong.

The five main characters in the *Lycopodium* plant which lend themselves well to a study of its variability are (1) habit of growth and external form, (2) stem-anatomy, (3) nature of fertile region, (4) form and structure of prothallus, and (5) form of young plantlet. A natural classification of the genus will necessarily have to take account of all these characters, and must not be based upon any particular one. Professor F. O. Bower's (4) remarks on this subject may here be quoted: "The true basis for a natural system of classification is not one or two characters arbitrarily selected, but as many characters as possible. These characters will be found to vary as we pass from type to type, and the question will arise as to the relative ages of the extremes in these characters."

On the whole, the five main sections of the genus are each found to show very consistently certain characteristic types of structure in each of the five particulars just enumerated. This would seem to indicate not only that these sections are natural ones, but also that the characters themselves are closely interdependent. The stem-anatomy corresponds with the habit of the plant, as also does the character of the fertile region; and the type of prothallus, along with the form of the sexual organs and of the young plant, varies with the habitat. The genus as a whole being so widely distributed, and the species possessing such noteworthy powers of being able to spread themselves in new situations, it is not surprising to find that all the main characters of the plant are in a highly plastic condition, and are by no means so fixed in form as would be expected if the different sections of the genus had been separate from a very ancient geological age. There will thus be instances in which a species, while showing most of the typical characteristics of the section to which it belongs, possesses also in some one character or other a well-marked peculiarity which will be interpreted either as an extreme adaptation or as an instance of the retention of a phylogenetic character.

The New Zealand species afford many instances of interesting variations, several individual species showing a remarkable range of variability in the form of such important organs as the prothallus and the strobilus. Besides the five main characters of the plant which are considered in this paper there are others, such as the form of the sporophyll, the development and form of the sporangium, the presence of a mucilage-canal in the leaf, and the development of bulbils on the stem, which will doubtless be of importance in indicating in conjunction with the main characters of the plant the natural position in the genus to be assigned to any particular species.

The facts brought forward in this paper concerning the varieties of the New Zealand species and their range of variability will thus have a double significance: they will provide new material for the study of the question as to whether or not epharmonic adaptations ever do become fixed and hereditary; and they will help to indicate the natural relationships which exist between the different sections of the genus, and between the individual species which are included within those sections.

SPECIES BELONGING TO THE SECTIONS SELAGO AND PHLEGMARIA.

Habit and External Form of Plant, and Nature of Strobilus.

It has long been recognized that as regards habit and external form these two sections are closely connected. The type species *L. Selago* and *L. Phlegmaria* are, of course, very distinct, the former being a short, upright, little-branched terrestrial form in which there is no differentiation between fertile and sterile leaves, the fertile zones alternating up and down the stems with sterile zones, and the latter being a much-elongated, pendulous, much-branched epiphyte in which there is a special sporophyll formation, the sporophylls being characteristically confined to the ends of the branches and the latter appearing as narrow whipcord-shaped strobili. But between these two extreme forms there are numerous species illustrating every grade of transition. The species which are grouped by both Baker and Pritzel under the heading *Subselago* possess the sporangia aggregated into quite easily recognizable terminal spikes which approach the *Phlegmaria* condition, although the transition from sterile to fertile leaves and from sterile to fertile regions of the stem in these species is very gradual. Also, included in both subsections *Euselago* and *Subselago* of Pritzel's *Selago* section are pendulous epiphytes and upright terrestrial forms, although on the whole there is seen to be a gradual transition in the section from the erect terrestrial form to the hanging epiphyte, this transition keeping pace with the transition in the fertile region from the *Selago* condition to the *Phlegmaria* condition. Again, in the *Phlegmaria* section are grouped forms some of which are robust and upright in growth, and others tender and pendulous; and of these the former possess short thick strobili in which the sporophylls show a more or less gradual transition from the sterile leaves, and the latter possess in some cases very distinct long whipcord-like strobili, while in others the fertile leaves may be not different from the sterile leaves. The New Zealand species which belong to these two sections present some very interesting transitions of this nature, which will be instanced.

It will be at once apparent that a classification which is based upon one character alone—as, *e.g.*, the nature of the fertile region—is bound to be unsatisfactory. The general habit of the *Lycopodium* plant and its external form must be considered along with the nature of the fertile region, for these three characters are closely interdependent. That these two sections together constitute a natural division of the genus seems to be suggested by the fact that they show certain common growth-features which are markedly absent from the remaining sections. In habit they are consistently orthotropic, so that their extent of growth is strictly limited. As a result of this orthotropic manner of growth it is found that throughout the two sections the roots are confined to the basal region of the plant, as many as six or seven roots appearing in the cortex of the stem in a transverse section taken at its base. Again, branching of the stem is dichotomous and in no case monopodial. Now, the study of the distribution of the species of these two sections as given by Baker or by Pritzel shows clearly that the terrestrial forms occur, on the whole, in colder regions and the epiphytic forms in warmer regions. It would seem, then, that the evolution of the subgenus *Urostachya* has been determined largely by climatic conditions. That this is so is seen to be more probable still from the fact that the external form of individual species is in a highly plastic condition, varying greatly according to the habitat. Whether we are to regard the *Selago* form as having been derived from the *Phlegmaria* form, or *vice versa*, must at present remain an open question. It will be decided only by a comparative examination of all the other *Lycopodium* plant structures, for it involves the question whether the genus as a whole is to be read as a reduction or as a progression series. Especially must it be considered in the light of fossil evidence derived from later geological ages than the Carboniferous. In the meantime, considering that the more complex members of the genus are those which show the greatest adaptation to the environment, the onus of proof must lie upon those who would trace in the genus a general reduction in form rather than a progression.

In the New Zealand biological region *L. varium* shows a remarkable variation in form according to locality.* In Plate IX, fig. 1, are illustrated three varieties. That named A is a plant which I have collected from the lower end of the Otira Gorge, where it grows abundantly in clumps on rocks and other exposed terrestrial positions. The Otira Gorge is situated on the western side of the Southern Alps, where the climate is exceedingly moist, at a height of about 1,500 ft. In Part I of these studies (16, pp. 254, 290) I have described the same form of this species as it occurs in enormous clumps on the floor of the excessively wet forest of Stewart Island. The plants are upright in habit, and the strobili characteristically curved. This habit is very similar to that of *L. strictum* Baker of the mountains of Madagascar, which is figured in Engler and Prantl (13, fig. 375). The plant of this particular form A is obviously akin to the typical form of *L. Billardieri*, differing from it in the rigid upright habit, the smaller size, and the short curved strobili, which are not quite so distinct as and are stouter than those of *L. Billardieri*. C on the same plate illustrates the same species as it occurs on the Dun Mountain, Nelson, in a drier, more exposed situation, and at a height of 4,000 ft. In this case the strobili in their tetragonous region are only from ½ in. to 1 in. in length, but the sporangia are continued still farther down the branches in the axils of gradually lengthening leaves. B shows two plants of this species as it occurs on the meadows of the Antipodes Islands.† In this particular variety the plants which occur in clumps stand only about 5 in. or 6 in. in height. They are very sparingly branched, and the fertile tips of the branches are very short and grade into the vegetative regions, as in the case of the form from the Dun Mountain. As well as these three forms of *L. varium* I have before me material of the same species as it occurs on Campbell Island, which was gathered by the Subantarctic Scientific Expedition of November, 1907. These plants are

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* See Postcript, p. 215.

† I am indebted to Dr. L. Cockayne for specimens of this form. Spirit specimens of *L. varium* from Campbell Island were kindly supplied me by Dr. Charles Chilton from material in the Canterbury College Laboratory. For the herbarium material of the Macquarie Island species, and also for that of most of the species in my collection from localities outside the New Zealand biological region, I am greatly indebted to Mr. T. F. Cheeseman.

only about 6 in. in height, and are very robust in form, with large leaves. None of the Campbell Island plants which I have seen show fertile regions, so that I suspect that they are not full-grown plants. They will, however, undoubtedly be identical with the plant from Campbell and Auckland Islands described by J. D. Hooker (18). He speaks of it as follows: "*L. varium*, in Lord Auckland's Group and Campbell's Island, is one of the finest of the genus; it grows nearly erect on the bare ground to a height of 1 ft. to 2 ft., branching upwards, copiously leafy, with large spreading leaves, bearing at the apices of the branches numerous pendulous or drooping tetragonous spikes 2 in. to 4 in. long. The stems of this species are often nearly the thickness of a swan's quill, with spreading leaves as broad as the middle finger. I have nowhere seen handsomer specimens of it than this island presents, and more constant ones, for it is confined to the woods, and does not ascend the hills, neither varying in the narrow belt it inhabits nor seeking other localities where it would be exposed to the influence of exciting causes."

There is also an interesting form from the hilltops of Macquarie Island gathered by Mr. H. Hamilton, and identified by Mr. T. F. Cheeseman as *L. varium*. This is shown in the present paper in Plate IX, fig. 2, B. In a letter to the writer with regard to this plant Mr. Cheeseman says, "I have for the present referred the Macquarie Island plants to *L. varium* because a few of the specimens have the branches narrowed towards their apices, with smaller leaves, thus approaching the spicate character of a true *varium*. It also differs from typical *Selago* in the larger, broader, and more coriaceous leaves. Still there can be no doubt that it comes very close indeed to *Selago*." This plant stands from 4 in. to 6 in. in height, and is copiously supplied with bulbils, the latter developing in profusion while still attached to the stem. The presence of bulbils would seem to be an argument in favour of relating this plant to *L. Selago*.

From these varieties it will be seen that *L. varium* stands midway between *L. Selago* and *L. Billardieri*, as Hooker pointed out. The external form of the plant approaches that of *L. Selago* in those localities in which the plant is exposed to a more rigorous climate, and on the other hand approximates to *L. Billardieri* in those varieties which occur in less exposed and shady situations. The character of the fertile region also varies along with the same change in the environment, the strobilus being less differentiated from the lower sterile portion of the stem in those varieties which are found in exposed positions.

It will be convenient next to consider the forms of *L. Selago* as they occur in New Zealand. In Plate IX, fig. 2, A, are shown two plants of *L. Selago* which were collected by me in damp beech forest at Lake Rotoiti, Nelson. This is a drawn-out, largely unbranched, rather straggling form, green in colour, with comparatively large spreading leaves, and is very similar in appearance to that which is figured in the frontispiece of Professor F. O. Bower's *The Origin of a Land Flora*. The sporangia are very apparent in numerous fertile zones over almost the entire length of the stems, but the number of bulbils borne on the stems is quite small. C (Plate IX, fig. 2) is this species as it occurs in open tussock country on the hills around Cass, in western Canterbury, at an altitude of 1,500 ft. and over. This is a very common form in all such situations. It is much shorter and more rigid than the shade form described above, and is more profusely forked. The leaves are short, ascending, and densely crowded, giving a cylindric appearance to the whole stem. In the lower parts of the stem, however, they are larger and spreading, and in those regions the appearance of the stem corresponds more with the form A. In form C, however, the leaves are generally more or less reddish in colour, the particular plant figured being a bright golden red. The number of bulbils present is much greater than in the case of the forest form, but is not nearly so great as in the case of the Macquarie Island plant (Plate IX. fig. 2, B). There is a tendency for the sporangia to be confined to fertile zones in the upper half only of the stems where the leaves are of the short form. The tips of the branches where the sporangia are full assume quite markedly a special strobilar appearance, as will be seen by an examination of C, but this is only a pseudo-strobilar formation. However, it is instructive to compare the tendency, as seen in this form of the species, for the sporangia to be confined to the upper half of the stem with what Cheeseman says (as quoted above) with regard to the Macquarie Island plant. On the summit of Browning Pass, on the Southern Alps, at an altitude of 5,000 ft., I collected specimens of *L. Selago* which showed two very distinct forms. These are figured in Plate X, fig. 1, A, B. B corresponds very closely with the tussock-country form just described; but A, while it is similar to the former in its much-branched nature and short form, is yet very distinct. It is more flaccid in growth, and the leaves are large, green, and spreading, as in the forest form of the species. The upper parts only of the stem are fertile, and there is a very scanty development of bulbils. Now, the form figured A grew among grass in a small cavity in the ground partly sheltered by rocks, whereas that marked B grew in a more exposed position on the surface of the ground, but only a couple of feet distant from the other. This species must be in a very plastic state to be sensitive to such a small change in the environment.

To pass now to *L. Billardieri*. When growing as an epiphyte it presents a very constant form. The plants occur in clumps and are pendulous, being in extreme cases as much as 4 ft. or 5 ft. in length. They are abundantly branched in all regions of the stems, so that the whole clump is quite bulky in appearance. In the lower parts of the stem the leaves are large and spreading, but there is a progressive diminution in their size in the ultimate branches until the strobili are reached. The latter, however, are quite distinct from the adjacent sterile regions of the branches, by reason of the fact that the sporophylls are at once broadly ovate in shape, with a well-marked keel, and are closely imbricating, and are also consistently arranged in four orthostichies. The phyllotaxy of the strobili, joined with the presence of the keel on the sporophylls, gives the strobilus a very distinct tetragonous form. In Plate X, fig. 2, A, is shown a much-forked fertile branch, alongside of which is the upper sterile part of the stem to which it was immediately attached. C in the same figure is the fertile portion of a branch of *L. Phlegmaria* Linn. from Fiji, from which it can be seen that the differentiation between fertile and sterile regions is more distinct than in the case of *L. Billardieri*. A specimen of *L. Phlegmaria* from the New Hebrides Islands which I have also in my collection shows the same very sharp distinction between sterile and fertile regions, although in this case the sterile leaves are tenderer and the strobili are markedly finer and more thread-like than in the Fiji form. Also in both these tropical forms of *L. Phlegmaria* the sporophyll keel is much less developed than in *L. Billiardieri*, so that the strobilus is cylindric rather than tetragonous in form. In the extreme north of New Zealand I have frequently found *L. Billardieri* growing terrestrially amongst *Leptospermum* scrub on the kauri-gum lands. These plants are from 2 ft. to 3 ft. in height, and the

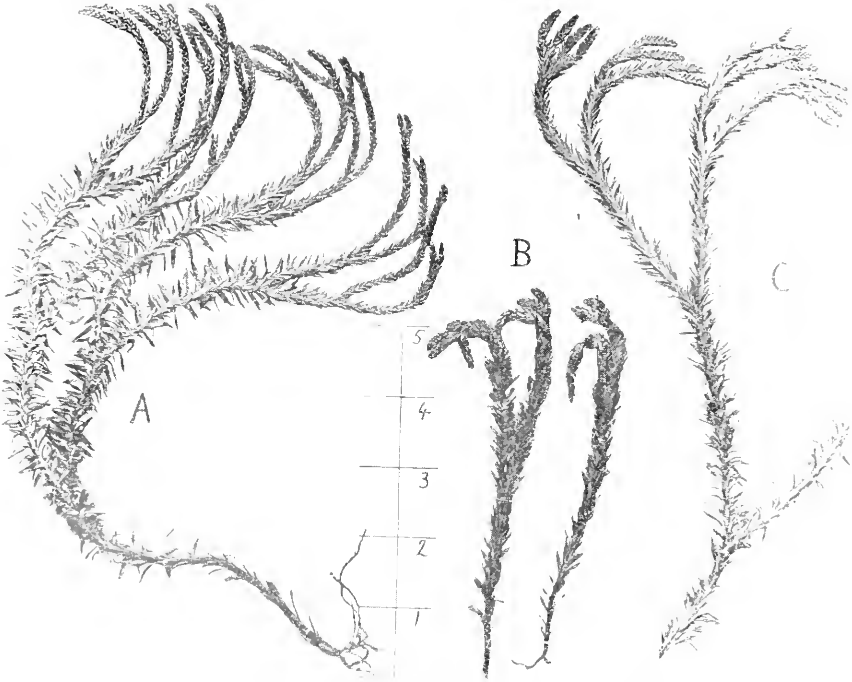

Fig. 1. A, *L. varium*: Complete fertile plant from Otira Gorge, Westland. B, *L. varium* var. *polaris*: Two fertile plants from Antipodes Island. C, *L. varium*: Upper portion of fertile plant from Dun Mountain, Nelson.

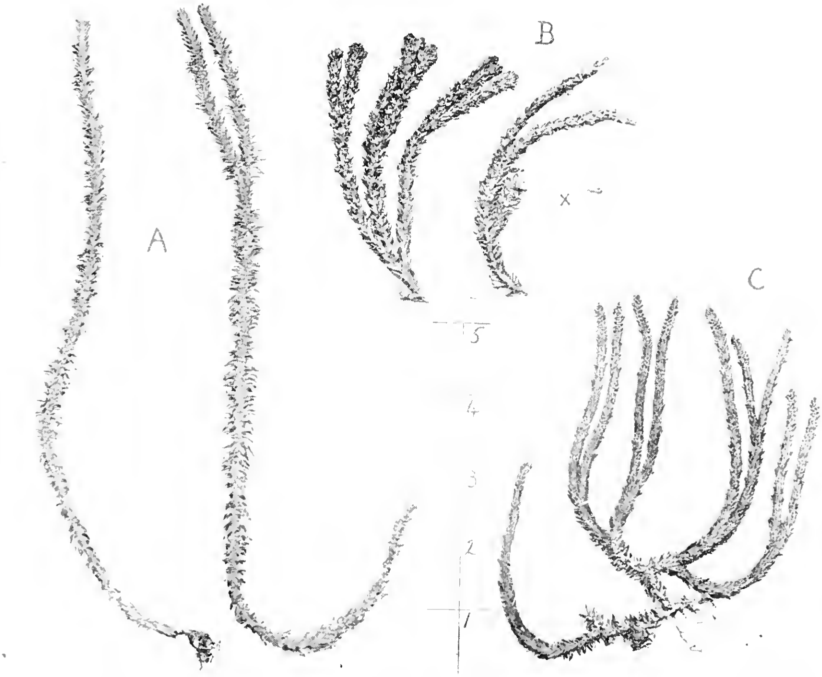

Fig. 2.—A, *L. Selago*: Two fertile plants of mesophytic variety from Lake Rotoiti, Nelson. B, *L. ?varium*: Macquarie Island variety. C, *L. Selago*: One complete fertile plant of xerophytic variety from Cass, Canterbury.

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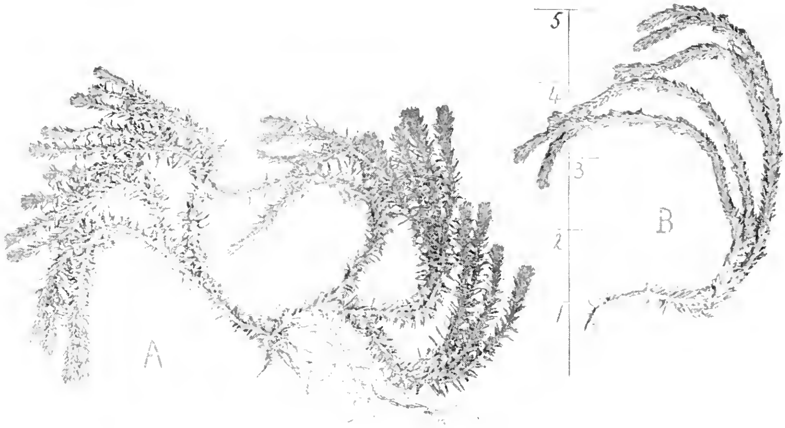


Fig. 1.—*L. Selago*: Variety from Browning Pass, Southern Alps, showing two forms.

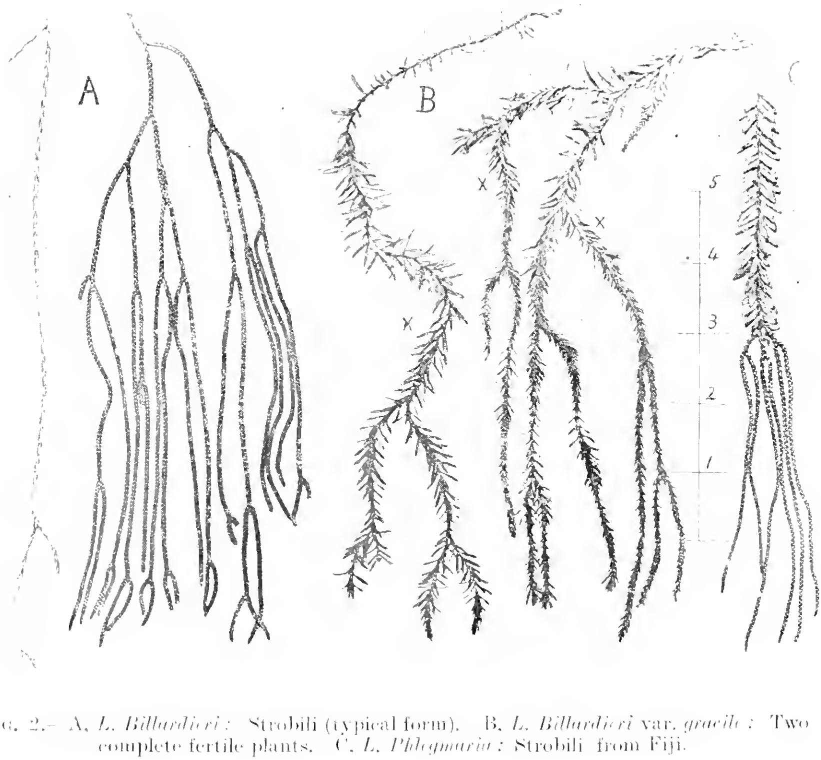


Fig. 2.—A, *L. Billardieri*: Strobili (typical form). B, *L. Billardieri* var. *gracile*: Two complete fertile plants. C, *L. Phlegmaria*: Strobili from Fiji.

strobili are shorter than in the epiphytic form and are curved over. On the whole, I should judge that in form they come nearer to the typical *L. Billardieri* than to *L. varium*—even to that form of the latter which I have above described from Otira Gorge and from Stewart Island. Possibly we are to explain the existence of this terrestrial variety of *L. Billardieri* by the fact that the original epiphytic plants were forced to accommodate themselves to a terrestrial habit through the destruction of the old kauri forest which took place probably a century or so ago. At any rate, they represent a variety not far removed from *L. Billardieri*, and thus make almost perfect the chain of forms which can be traced from *L. Billardieri*, and, indeed, from the type species *L. Phlegmaria*, through *L. varium* to *L. Selago*.

Perhaps the most interesting variety of *L. Billardieri* is the form which is known as *L. Billardieri* var. *gracile*. This I have found growing very commonly on the trunks of the tree-fern *Dicksonia squarrosa* in the coastal bush in the Western Botanical District of the South Island. This was first described by T. Kirk (23, pp. 376–77), and is there illustrated. In the present paper two plants are shown in Plate X, fig. 2, B. This variety is a very graceful, slender, flaccid plant, and always quite distinct from *L. Billardieri*. It is seldom more than one foot in length, and is sparingly branched. The fertile leaves show a wide range of variability in form. In some specimens they are in no wise different from the sterile leaves, although it must be noticed, as we saw in *L. Selago*, that the leaves are always largest towards the base of the stem. In others the fertile leaves are more bract-like, and the fertile regions then approach somewhat nearer to the typical *L. Billardieri* form. The two plants figured show well this varying character of the fertile regions, in the case of the plant on the right the various forms of the sporophylls occurring in intermixed zones on the same branch. The whole of the upper region of the stem is fertile, there being no intermixture of fertile and sterile zones as in typical *L. Selago*, but the fertile region generally extends to half-way or more down the plant. In the figure the limit of the fertile region on the two plants is indicated by crosses.

Sir Joseph Hooker states both in his *Flora Tasmaniae* (20, pp. 155–56) and in his *Flora Novae-Zelandiae* (19, pp. 52–53) that *L. varium*, which in its ordinary state is very distinct, passes into *L. Selago* on the one hand, and, on the other, when it inhabits warmer latitudes, grows dependent from trees, is much branched, more slender and flaccid, and becomes *L. Billardieri*. In his *Flora Antarctica* (18) he expands more fully this view of a chain of forms uniting *L. Selago* through *L. varium* with *L. Billardieri*, drawing his illustrations largely from the varieties of *L. varium* as they occur in Tasmania. In the same place he also says that "the variations from it [*i.e.*, *L. varium*] to *Phlegmaria* are not obscure, the variations of that plant being excessive." In his paper cited above T. Kirk discusses the relation of the New Zealand forms *L. varium*, *L. Billardieri*, and *L. Billardieri* var. *gracile* to one another, and concludes, "I am compelled to consider *L. Billardieri* as merely one of the varieties of *L. varium*." He proposes the following arrangement of the principal forms: *L. varium* Br. (*a*) *varium* (the ordinary New Zealand form), (*b*) *polaris* (Campbell and Auckland Island form), (*c*) *Billardieri*, and (*d*) *gracile*. This arrangement certainly has the advantage of emphasizing the natural steps in the evolution of the forms concerned, although such a form as *L. Billardieri* deserves specific rank. It places the form *gracile* also in the right position as a variation from *varium* rather than from *Billardieri.* The variety *gracile* is always quite distinct from *L. Billardieri*, and it would be a more startling reversion from that species, with its very distinct strobili, than it would be from *L. varium*, which, as has been emphasized above, is not so far removed from the *Selago* condition, unless, indeed, we are to take the view that the whole genus is to be read as a reduction series. It may be mentioned here that W. Colenso described the form now known as *L. Billardieri* var. *gracile* under the name *L. novae-zealandicum* (11, p. 275), noting that it grows as an epiphyte on fern-trees. He describes it as "a small species of the *Selago* section, apparently pretty closely allied to *L. taxifolium* Sw.," and he speaks of *L. varium* as being its nearest New Zealand congener.

Stem-anatomy.

I will now pass on to consider the stem-anatomy of the mature plant of the New Zealand species of the sections *Selago* and *Phlegmaria*. Here also a high degree of plasticity will be apparent, although the entire subgenus *Urostachya*, so far as it has been investigated, can be seen to be characterized by a consistent type of both stelar and cortical anatomy which is markedly distinct from the type of stem-anatomy of any of the other sections of the genus.

It will be necessary to make first some general statements. Owing to the plant being orthotropic in growth, of very limited size, and also more or less branched, it will be clear that in comparing the anatomy of these species care must be taken to section the different stems in corresponding parts of the plant. At the extreme base of the stem the stele has not attained its full development, and is also more disturbed by the giving-off of the roots than it is above. The typical form of the stele is best seen a little higher up the stem, though still in its lower half. Again, as is well known, the general configuration of the xylem and phloem groups and plates is by no means stable, even in a short length of the stem, so that it therefore becomes necessary to compare a number of sections of the stem of any individual plant in order to arrive at a fair idea as to its particular stelar anatomy.

I hope to develop in this paper the conclusion, which I arrived at in a previous paper (16, p. 302), that, notwithstanding the fact that the genus *Lycopodium* includes several distinct types of stelar structure and also manifold variations of those types, yet the lines upon which the *Lycopodium* stele has evolved can be recognized, having been determined for each natural division of the genus by a combination of the inherited constitution with the acquired habit of growth of that division. Each of these natural divisions shows a very distinct type of stelar and of cortical structure, so that this character becomes of value in checking the conclusions arrived at from the study of the other characters as to which section a particular species should be referred to. The sections *Selago* and *Phlegmaria* possess a stelar structure of the stellate or radial type, although at the extreme base of a plant this is sometimes obscured. The protoxylem groups are very massive and the protophloem very small, and except in the largest forms there is comparatively little wide-sized metaxylem formed. The phloem also shows very little differentiation of conspicuous sieve tubes in the smaller species.

Fig. 1 is a drawing of the stele of the Macquarie Island plant shown in Plate IX, fig. 2, B, which has been identified by Cheeseman as *L. varium*. The massive xylem bands radiate from a common centre, which is occupied by large-sized metaxylem. The phloem is much less in quantity than the xylem, and the cells composing it are very uniform in nature. They show abundant contents. The actual protoxylem elements are, as is the case throughout the genus, situated at the extreme periphery of the xylem, but the protophloem is not always so easily recognized. At the base of the stem there is a very marked disposition of the xylem and phloem in parallel plates. There are three parallel plates of phloem, and between these two plates of xylem, while outside each of the two flanking phloem plates there is a single massive xylem group. Whether or not there is a constant relation subsisting between this parallel arrangement

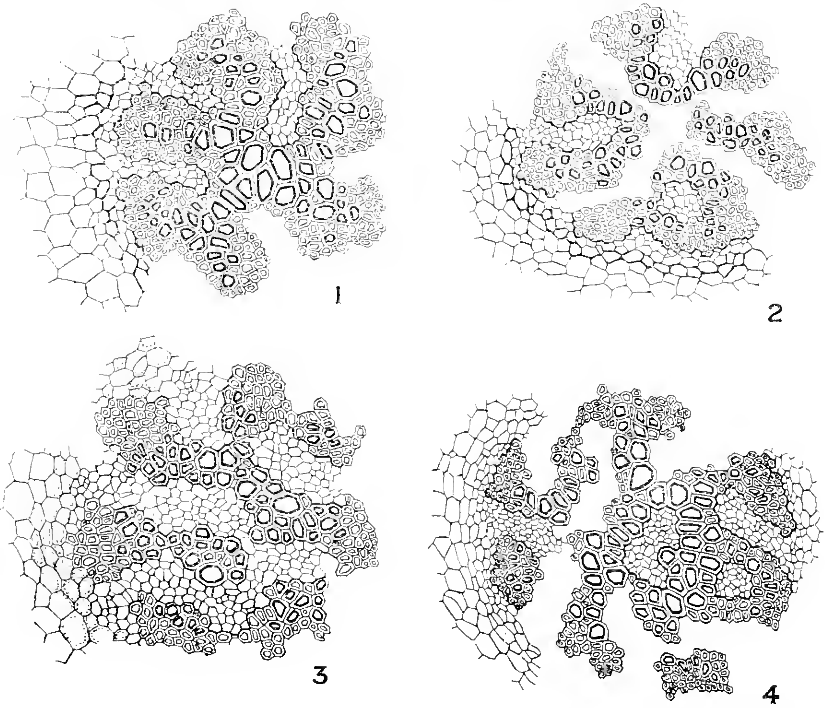


FIG. 1.—*Lycopodium varium.* Transverse section of stele in middle region of stem of the Macquarie Island variety. × 137.
FIG. 2.—*L. varium.* Transverse section of stele in middle region of stem of the Antipodes Island variety. × 137.
FIG. 3.—*L. varium.* Transverse section of stele in middle region of stem of the Campbell Island variety. × 137.
FIG. 4.—*L. varium.* Transverse section of stele towards lower region of stem of the Otira Gorge variety. × 90.

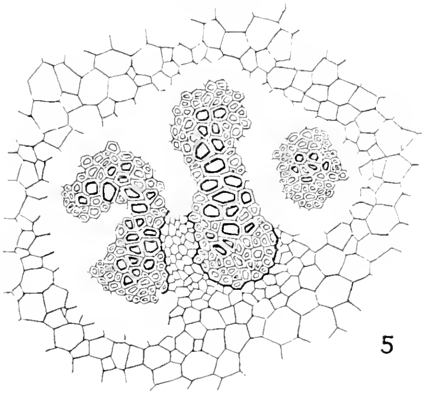
and the forking of the stem in its lower region or the giving-off of roots I was not able to determine. There is a very narrow pericycle, two cells only in width, while immediately outside it there is a single layer of cells showing slightly cutinized and red-staining walls. This latter will be the innermost layer of the small-celled inner cortex, which is here only from two to three cells in width. The broad middle cortex is composed of large-sized and thin-walled cells forming a loose spongy tissue with air-spaces, while there is externally a broad zone of smaller, somewhat sclerenchymatous cells which practically alone gives to the stem its rigidity.

The stele of the Antipodes Island form of *L. varium*, which is shown in Plate IX, fig. 1, B, is illustrated in fig. 2. This is practically identical in all particulars with that of the Macquarie Island plant, although in fig. 2 it will be seen that the phloem and not the xylem radiates from a common centre; also, there is a close correspondence in the nature of the three cortical zones. There is a decided tendency at the base of the stem towards the formation of one or more plates of xylem and phloem extending right across the stele, and lying parallel with each other. I noticed in my sections that this was most marked at a point where the stele was about to fork; but this point needs further investigation.

In fig. 3 is shown the stele of the Campbell Island form of *L. varium*. It will be remembered that this plant is described by Hooker as the largest form of *L. varium* seen by him. Probably in the full-grown stem the stele will be even larger than shown in this figure, but it will be clear from a comparison with figs. 1 and 2 that with the growth in size of the stele the simple radial form becomes more complex through the connecting across of some of the phloem bands or by the isolation of groups of phloem or of xylem into islands. This is the particular form of *L. varium* whose stele is figured in Part I of the present series of papers (16, fig. 87). The protophloem is clearly to be distinguished, and there is a large amount of phloem. The cells of the latter tissue are uniform in size, but those which lie immediately adjacent to the xylem bands show abundant contents, while those placed centrally in the phloem groups and bands are empty. There is a very distinct pericycle two to three cells in width, the cells of which show abundant contents. Thus along with the luxuriant growth of this variety of *L. varium* there go both a change in the configuration of the stele and also a tendency towards a greater differentiation of the tissues composing it. The larger girth of the stems of this particular variety is due to the presence of a very wide soft middle cortex. The outermost, usually thick-walled cortical zone is here very poorly developed, as we would expect from the habitat of the plant.

The largest variety of *L. varium* which I examined was that which occurs at Otira Gorge and Stewart Island (fig. 4). In accordance with the size of the plant the stele is even larger than that of the Campbell Island form, and there is a greater disposition towards the formation of phloem and xylem islands. The typical radiate or stellate disposition of the vascular tissues is thus broken up, but that the stem-anatomy is essentially identical with that of the smaller forms of *L. varium* is quite clear both from an examination of it as it occurs in the smaller branches and also from an examination of the histology of the several tissues of the stele and cortex. In some of the larger phloem plates in the Otira Gorge plant there is a central row of cells that remain empty and are in clear contrast with the rest of the phloem, which flanks the central row, and which shows abundant contents. This is more marked still in the case of the Stewart Island plant, where the centrally-placed phloem cells are sometimes comparatively large in size. This feature is quite consonant with the robust growth of this variety from the two localities named, and especially with that from the latter place. The outer cortical zone in this variety is strongly sclerenchymatous. In both cases a considerable number of roots appear in transverse section in the middle cortex at the base of the stem, as many as six being noticed in some sections.

The stem-anatomy of *L. Selago* in all the varieties in which it occurs in New Zealand corresponds closely with that described above for the smaller forms of *L. varium*. At the base of the stem the xylem and phloem commonly extend across to form parallel plates. This is shown in fig. 5, which represents a section of the stele of the xerophytic variety collected on Browning Pass and illustrated in Plate B, fig. 1, B. The same tendency was observed in the basal region of the stem of the shade variety from Lake Rotoiti. Higher up the stem in this species the arrangement is distinctly radial. In the case of the shade variety collected from a woody gully in the neighbourhood of Cass the centre of the stele in the lower part of the stem was occupied by an island of phloem, as is shown in fig. 6. Fig. 85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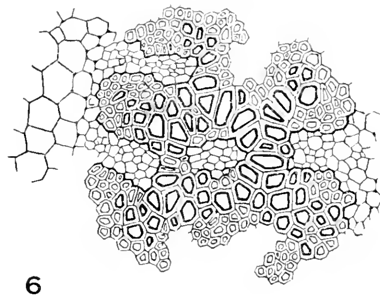
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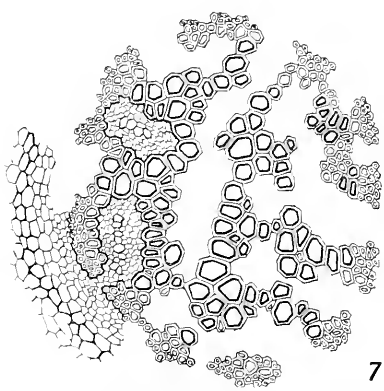
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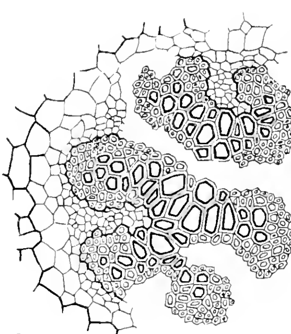
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FIG. 5.—*Lycopodium Selago*. Transverse section of stele near base of stem of the xerophytic Browning Pass variety. × 137.
FIG. 6.—*L. Selago*. Transverse section of stele towards base of stem of the mesophytic Cass variety. × 137.
FIG. 7.—*L. Billardieri*. Transverse section of stele towards lower unbranched region of stem of the typical epiphytic form. × 90.
FIG. 8.—*L. Billardieri* var. *gracile*. Transverse section of stele towards lower region of stem. × 137.

in Part I of these Studies illustrates the stele of the same material. Higher up the same stem it was found that sometimes the xylem and at others the phloem bands are joined up at the centre, there being thus a tendency towards the temporary formation of one or two more or less parallel plates of vascular tissue. Both xylem and phloem bands and groups are typically massive. The cortex is differentiated into three zones, the outer being more or less sclerenchymatous, the middle delicate and spongy, and the very narrow inner zone small-celled. The walls of the inner layer of the latter are usually slightly cutinized. One or more roots are to be seen in transverse section at the base of the stem of all the varieties mentioned.

On the other hand, the stelar anatomy of the epiphytic *L. Billardieri* corresponds very closely with that of the largest varieties of *L. varium* described, albeit on a still larger scale. A transverse section of the lower unbranched portion of the stem of this species is shown in fig. 7. It will suffice to draw attention briefly to the fact that in this case we have an extreme illustration of the tendency to the grouping of the xylem and the phloem in temporary islands and curving bands which is to be observed in all the large stems of the species of the *Phlegmaria* section. There is an extensive development of large metaxylem, and most of the phloem groups and bands show large centrally-placed empty sieve tubes. The inner layer of the middle cells of the cortex have obviously cutinized walls, there is a spongy middle zone of thin-walled parenchymatous cells with copious air-spaces, and the epidermal cortical zone is strongly sclerenchymatous. At the extreme base of a large stem as many as six roots are to be seen in transverse section in the middle cortex. The root stele as seen in the stem cortex is of the typical form so consistent right through both *Selago* and *Phlegmaria* sections—viz., a single large crescentic group of xylem with the bay between the two horns occupied by a single phloem group. The root originates from the stem stele by the giving-off of two groups of xylem from two adjacent plates and of a group of phloem from the intermediate phloem plate, the two xylem groups almost immediately joining to form the single crescentic group.

The stele of the delicate plant named *L. Billardieri* var. *gracile* corresponds exactly with that of the smaller forms of *L. varium*. This is shown in fig. 8. The configuration of the stele is variable, at one time the plates of tissue being strictly radial, and at another a continuous plate either of xylem or phloem extending right across the stele. In the lower part of the stem one or two roots are to be seen penetrating the middle cortex.

From the study of the chain of forms which occur in New Zealand connecting *L. Selago* through *L. varium* with *L. Billardieri* it will be seen, first, that there is a definite type of stelar anatomy characteristic of the whole series, and, secondly, that a gradual change takes place in the vascular arrangement from a strictly radial form in the smaller-growing species to a form in larger species in which the radial or stellate arrangement is broken up by cross connections, which result in the isolation of some of the xylem and phloem into islands. Moreover, there is a well-marked and gradually increasing tendency in larger and larger forms to the differentiation of the phloem into sieve tubes and phloem parenchyma. This is quite in accord with Jones's description (21) in his study of the anatomy of the stems of twenty species of *Lycopodium*. In the case of *L. serratum* Thunb. and *L. reflexum* Lam., both of which species belong to the *L. Selago* cycle of affinity, Jones's figures of the stem stele show that along with the fact that in general habit the two species named grow more robustly than *L. Selago* the arrangement of the vascular tissues is no longer simply radial, but the general configuration of the more abundant xylem and phloem is broken up by cross connections, with the consequent formation of phloem islands. His figures of the stele of the strongly growing epiphytic species *L. squarrosum* Forst., *L. Dalhousieanum* Spring, and *L. Phlegmaria* Linn are closely similar to that of the large New Zealand epiphytic *L. Billardieri*.

Thus it may be assumed that the general type of stelar structure which has been shown in the present paper to hold throughout the whole chain of New Zealand forms holds also for the whole of the subgenus *Urostachya*, and that all modifications of this type as seen in the different species of the subgenus are merely the result of the particular size of each species and of its habit of growth, which, as has been shown above, varies with the environment. In his paper cited above Jones arrived at rather different conclusions. He would classify all the species he examined, in so far as their anatomy is concerned, into two groups, "the second containing a number of epiphytic forms, and the first plants with horizontally-growing stems, while species with erect stems may be included in either group" (21, p. 31–32). He would link the group of *L. Selago* with the *clavatum* type. My own conclusions, derived from a thorough study of the New Zealand species, are that, using the sections of Pritzel's classification, which are certainly more natural than those of Baker, there are three main strains of stelar anatomy to be traced in the genus *Lycopodium*, the first of which is characteristic of the sections *Selago* and *Phlegmaria*, the second characteristic of the sections *Inundata* and *Cernua*, and the third of the section *Clavata*. This, it seems to me, is in accord with Jones's own figures and descriptions of the stelar anatomy of the species examined by him, and also goes hand in hand with the other main characteristics of both sporophyte and gametophyte.

Prothallus, Sexual Organs, and Young Plant.

In my previous paper already cited (16, p. 264) I have given a short general description of the external features of the prothallus of *L. Billardieri*. Since this was written I have found in the neighbourhood of Hokitika, Westland, an additional large number of specimens of the prothallus of this species, also a very large number of prothalli of *L. Billardieri* var. *gracile* from two or three localities in the same neighbourhood, and about a dozen specimens of the prothallus of the Otira Gorge variety of *L. varium*. Anticipating here what I hope to describe more fully in a further paper with regard to these prothalli, I may say that they are all closely alike. The majority of the specimens found of all three species show, on the whole, longer processes than those figured in the above-named paper, figs. 1–6. There is in each complete prothallus a more or less bulky central region on which the sexual organs and paraphyses are formed, and from this arise the long vegetative processes, which are richly covered with long rhizoids. The ends of some of these processes sometimes also become more bulky and bear antheridia. There is, however, a wide range of variability in the general form of the prothallus, brought about by the greater or lesser bulkiness of the central region, and also by the varying development of the processes both as regards numbers and length. In all cases the first stages in the development of the prothallus from the spore result in the immediate formation of a cone-shaped tissue-body, which by elongating and thickening becomes the central portion of the mature prothallus, and on this the processes arise adventitiously. Thus the first-formed region of the prothallus of these three species conforms to the fundamental structure plan of the *Lycopodium* prothallus, although the mature prothallus is variable in form. In the case of all the three New Zealand species mentioned I dissected out numerous detached prothallial processes which were evidently developing independently; and also not a few of the mature prothalli bore evidence of the fact that they had originated not directly from the spore, but from such detached processes.

Treub (30) has described the prothalli of the four following tropical epiphytic species: *L. Phlegmaria* Linn., *L. carinatum* Desv., *L. nummularifolium* Blume, and *L. Hippuris* Desv. Of these four species, *L. Phlegmaria* and *L. nummularifolium* belong, according to Pritzel's classification, to the *Phlegmaria* section, *L. Hippuris* to the *Euselago* subsection, and *L. carinatum* to the *Subselago* subsection of the *Selago* section. They thus cover between them all the main divisions of the subgenus *Urostachya*. According to Treub's conclusions, the prothalli of all these four species are alike, belonging to that form of the *Lycopodium* prothallus known as the *Phlegmaria* type. That of *L. carinatum* is exactly like that of *L. Phlegmaria*. The prothallus of *L. Hippuris*, however, is much larger and thicker, and that of *L. nummularifolium* very much thinner and more delicate, than that of the type species.

Miss Edgerley (12, pp. 104–9) has described the prothallus of the New Zealand species *L. Billardieri*, and her results are in close accord with my own. It corresponds very closely with that of *L. Phlegmaria* both as regards external form and internal structure. There are, however, two characteristic differences to be noted. In the case of *L. Phlegmaria* the paraphysis is composed of a linear row of as many as a dozen cells, and it may also branch, whereas in *L. Billardieri* it is much simpler in form, is always unbranched, and is generally only three cells in length. Also, although I have examined a very large number of prothalli of the three New Zealand species mentioned above, I have never observed any vegetative buds of either of the kinds described by Treub as occurring freely in the prothallus of *L. Phlegmaria*. But in the New Zealand species short club-shaped richly-stored resting vegetative processes commonly occur.

The prothallus of *L. Selago* has been described by Bruchmann (5), and presents some exceedingly interesting modifications of form. Bruchmann says (5, p. 85), "This variety of form of the prothalli seems to be dependent mostly on the soil in which they are produced. The elongated cylindrical forms are found especially in firm soil, in which they strove towards its surface mostly in a vertical direction. In loose soil, especially near the surface, I came across more thickset and flat forms of prothalli." Moreover, besides the subterranean forms of prothallus of this species, he found some which grew wholly or partly at the surface of the earth, and which in their upper part showed a thoroughly green colouring. Such prothalli lived as semi-saprophytes, and by their manner of life formed, as Bruchmann himself says, "an interesting transition between the assimilating and the merely saprophytic forms" of the *Lycopodium* prothallus. Every complete prothallus, whether of the elongated or thickset form, shows at the original end a tiny, usually bent point, which is the region immediately developed from the spore, and which develops above into the cone-shaped tissue-body. The prothallus is abundantly supplied with long rhizoids; and many-celled paraphyses, similar to those described by Treub in *L. Phlegmaria*, are present, along with the sexual organs. Spessard (25) has recently given a short account of the prothallus of *L. lucidulum* as it occurs in America. It is a cylindrical elongated body, bearing paraphyses at its uppermost end.

In discussing the different types of *Lycopodium* prothallus Lang (24, pp. 305–6) says with regard to that of *L. Selago*, "The two forms of prothallus found in *L. Selago* give the clue to the more specialized saprophytic types, which in the deeper-growing subterranean species retain the radial symmetry while becoming modified in shape. On the other hand, the type of prothallus growing in rotting wood has lost the radial symmetry, and consists of cylindrical but more or less clearly dorsiventral branches." Curiously enough, Bruchmann himself does not read any signs of the transition existing between the different types of prothallus from the significant variability of that of *L. Selago.* He gives to the prothallus of this species the rank of a new type, and concludes also at the end of his paper (5, p. 108), "From the above facts it follows that the above-treated-of *Lycopodium* groups, characterized especially by their generative generation, do not stand to each other in near relationship—that is to say, not in such as one would expect with plant species that are found in the same genus. This knowledge leads to a separation of the lycopodiums into groups, or, better still, into genera." However, the facts known concerning the gametophyte generation of the species which comprise the subgenus *Urostachya* undoubtedly point to the fact that the two sections *Selago* and *Phlegmaria* are closely related; and, seeing that the species *L. Selago* is probably to be regarded as the primitive type of the subgenus, if not, indeed, of the whole genus, it follows that the *Phlegmaria* type of prothallus, which has been found to occur in all the main divisions of the subgenus where the species have an epiphytic habit, has arisen as a modification of the *Selago* type in accordance with that habit of growth. One variation in the prothallus of the New Zealand species, however, is not in accord with the view that the series *Selago-varium-Billardieri-Phlegmaria* represents a linear series—namely, the paraphysis in the prothallus of *L. varium* and *L. Billardieri* differs markedly in size from that of *L. Selago*, whereas the *L. Phlegmaria* paraphysis is similar to the latter. This isolated fact would indicate that evolution in the form of the prothallus in the subgenus *Urostachya* has proceeded along several parallel lines, and that there are to be traced, as Lang suggests (24. p. 313), "instances of independent adaptation to similar conditions."

I am not prepared in this paper to enumerate the variations in the form of the sexual organs to be observed from a study of the different types of prothallus as they occur in New Zealand, or to discuss the question of their modification from the ancestral type in accordance with the form and habit of the prothallus and sporophyte. Such a study has been suggested to me by Professor Charles Chamberlain, of Chicago, in a letter in which he points out the great interest that would come from seeing "what the resultant between the force of heredity and the influence of environment might have on the antheridium and archegonium and young embryo," and I hope to be able at some future time to carry out the suggestion.

The "seedling" plants of the New Zealand species which belong to these two sections conform to the type described by Treub in *L. Phlegmaria* and by Bruchmann in *L. Selago.* I have noticed no variations in the New Zealand species. Bower (3, pp. 346–47) has expressed the view that this type of embryo is the least modified in the genus. However, we can see in the variation in length of the hypocotyl according to the depth at which the prothallus grows another indication of the great plasticity of the *Lycopodium* plant, which is to be noticed in almost every organ.

SPECIES BELONGING TO THE SECTIONS INUNDATA AND CERNUA.

In these sections there is less variability to be observed in the habit and external form in the New Zealand species than in the last two sections. However, in the gametophyte generation and the young plant there are certain interesting modifications.

The sections *Inundata* and *Cernua* comprise comparatively few species. The species which belong to the former are fairly widely distributed, but are confined to boggy and marshy habitats. I venture to propose that the composition of the *Cernua* section as arranged by Baker, and by Pritzel following him, should be altered in accordance with our increased knowledge of the main characters of the species which have hitherto been included in it, certain of these species, such as *L. densum*, *L. volubile*, and possibly *L. obscurum* and *L. casuarinoides*, being removed to the section *Clavata*, while *L. ramulosum*, and possibly also *L. diffusum*, should be removed from the latter section and placed near to *L. cernuum*. This suggestion has been previously made by me (16, p. 301).

The reason for this is that the *cernuum* type of prothallus, a protocorm stage in the embryo plant, and the "mixed" type of stelar structure undoubtedly go hand in hand, and that although the species which show these characters do not altogether show a close similarity in general habit of growth and in external form, yet the presence of the first-named characters should be given chief position in determining the limits of the *Inundata* and *Cernua* sections. Now, Baker and Pritzel in their classifications of the genus have both described the species *L. cernuum* and *L. densum* as upright, tree-like forms. This is quite misleading. It is only the lateral branches in these two species which are erect. There is a trailing main stem which in the case of the former species is snake-like in growth, spreading aboveground for as much as 12 ft. to 15 ft. in a series of loops, and rooted to the ground at each node, and in the case of the latter species is a subterranean rhizome which attains an extreme length of 8 ft. to 10 ft. The species *L. laterale* also, which is placed near *L. cernuum* by Pritzel, is described by him as nearly or quite erect. This also is an incorrect description, for whereas the aerial branches are more or less erect, the main stem is a short much-branched underground rhizome which ramifies extensively in the soil. One rather suspects that the supposed upright habit of growth of these species has been one of the reasons which led the two systematists into grouping together such really widely different species as *L. cernuum* and *L. densum*. For the same reason, the great point that is made by Jones (21, p. 32), that "the fact must not be overlooked that the banded structure is well marked in the stem of the erect-growing species of *L. obscurum*," likewise loses its significance in view of the fact that in this species also the main stem is subterranean and creeping, and that it undoubtedly belongs to the *Clavata* section. The type of prothallus and young plant and also the stelar anatomy of *L. densum* and *L. volubile* indicate that these species, as well possibly as the two species *L. obscurum* and *L. casuarinoides*, should be included in the section *Clavata*. This, then, would leave in the *Cernua* section only the type species *L. cernuum* with all its varieties, and the species *L. laterale* with its congeners *L. ramulosum* and *L. diffusum*.

The fact that one or two species in the *Inundata* section—*e.g.*, *L. contextum* Mart. and *L. cruentum* Spring—show the *Selago* habit in the fertile region is open to various interpretations. Either they have preserved unaltered a phylogenetic character; or perhaps it is an indication that the whole genus is really to be read as a reduction series, and that in these particular species, as also in the case of the New Zealand plant *L. Billardieri* var. *gracile*, mentioned above, actual transitions in the process are to be seen. However, isolated instances such as these are not to be interpreted apart from the main evolutionary tendencies to be observed in the genus as a whole.

SECTION INUNDATA.

There is only one species in New Zealand which belongs to the *Inundata* section, this being *L. Drummondii*. I have gathered this species on the sphagnum peat-bog at the outlet of Lake Tongonge, Kaitaia, North Auckland, the only locality where it has been found in New Zealand. It will be convenient to consider this species by itself.

External Form of Plant, and Nature of Strobilus.

In Plate XIV, at C, are shown two small specimens of this plant. It may attain a length of 7 in. to 8 in., and possess one to three spikes. The variation in form from the normal which I have observed in this species is that occasionally the cone, which corresponds in form to that of *L. carolinianum* figured by Pritzel in Engler and Prantl (13, fig. 378), may be interrupted. In some plants the lower half of the cone clearly belongs to the past season's growth, being dark in colour, with empty outstanding sporophylls, and there is a well-defined demarcation between this and the farther prolongation of the cone in the succeeding season. Again, in other instances there is a sterile zone as much as ½ in. in length separating the two portions of the cone. In Plate XIV, C, the left-hand specimen shows an interrupted cone, the point of demarcation between the two seasons' growth being indicated by a cross. Also, in some specimens the erect fertile branch which generally appears as a very distinct peduncle to the cone, with leaves in scattered whorls, shows instead throughout a greater or lesser portion of its lower region crowded leaves such as are borne on the trailing stems. Thus, although in this species the fertile region is differentiated as a definite club-shaped cone, and even the erect branch on which it is borne is also differentiated as a peduncle, yet variations occur which indicate that this character is in a state of plasticity.

Stem-anatomy.

The stelar anatomy in the main stem is shown in fig. 9. It will be well for me to describe this in some detail here, as it is typical for all the New Zealand species which belong to the sections *Inundata* and *Cernua*. The general appearance of metaxylem and protoxylem, as well as the configuration of these tissues, is in striking contrast to that of the same tissues in the stem of the *Phlegmaria* and *Selago* sections. In *L. Drummondii* the metaxylem is somewhat feebly lignified, and does not show the presence of small-sized elements flanking the larger ones. Also the degree of coherence of the metaxylem elements one to another into plates or groups is much slighter, so that there is a very characteristic mixing of the xylem with the phloem. The protoxylem elements are much fewer in number in this species than in those of the *Selago* and *Phlegmaria* sections, where the protoxylem groups are exceedingly massive, but they are so extended

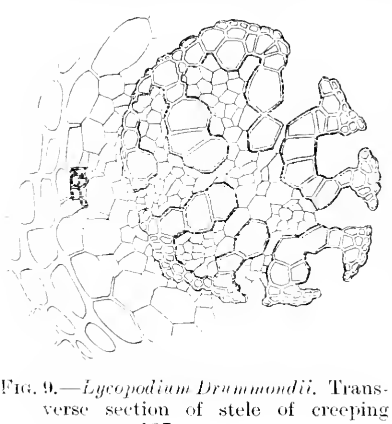


FIG. 9.—*Lycopodium Drummondii.* Transverse section of stele of creeping stem. × 137.

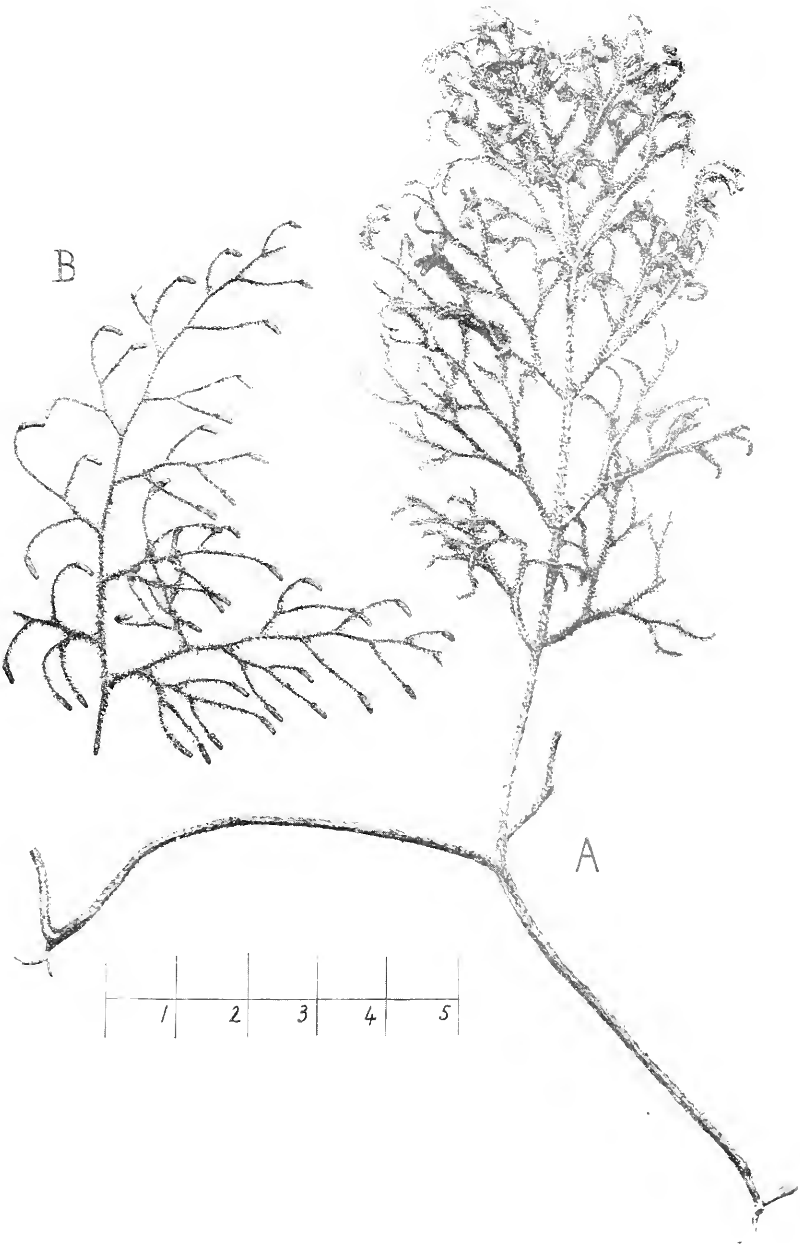
peripherally as to form an interrupted cylinder around the stele. They are also only feebly lignified. This nature of the xylem and protoxylem in *L. Drummondii* gives a very characteristic appearance to the stele as a whole, and one which is in marked contrast to its appearance in the other divisions of the genus. Moreover, it is found, as will be shown below, not only in the *Inundata*, but also in the *Cernua* section. In the ultimate branches, and in the fertile branch of *L. Drummondii*, the configuration of the vascular tissues is more definite, as would be expected where the vascular elements are much fewer in number, and the xylem might also be described as radial. The protoxylem groups, however, are just as much extended peripherally as in the larger parts of the plant, and the individual elements of the metaxylem are just as feebly lignified, so that it is apparent that right throughout the plant a consistent type of stelar anatomy and of vascular histology is to be found. Jones (21) describes the stelar anatomy of the strobilus of *L. inundatum* as radial, and notes that in the branches a striking tetrarch structure is obtained. In his figure of this he shows both xylem and protoxylem as being very broad at the periphery. This is very similar to what I have just described for *L. Drummondii*. The cortex in *L. Drummondii* shows an inner narrow more or less sclerenchymatous zone which is more strongly developed in the erect fertile branches, whilst the main cortical tissue consists of large spongy parenchyma with abundant air-spaces, grading off externally into a very ill-defined epidermis. I have been unable to find a mucilage-cavity in the leaf such as has been described in *L. inundatum*.

The Young Plant.

I was not successful in my search for the prothallus of this species, but along with the adult plants I discovered a large number of plantlets of all sizes which seemed to have originated vegetatively. All the specimens which I have preserved are of small size and are unbranched. They very early adopt the plagiotropic habit, and at once begin to develop adventitious roots. Such specimens as are complete show that at the base the plantlet is prolonged directly into its first root, and that the vascular strand is continuous throughout this root and the shoot. In one or two instances I could clearly trace a broken prominence where the shoot passes into the root, at which spot presumably the plantlet had been attached to the parent body. One specimen consisted of a small old piece of rhizome with its roots, and attached to the rhizome was one of these plantlets showing both shoot and root. From this specimen, and from indications on many of the others, I therefore judge that the plantlets are propagative shoots which arise on the older rhizomes at the season of the year when the latter are beginning to die off. They give evidence of no structure which can be likened to a protocorm. This is noteworthy, for we should rather expect to find that the embryogeny of this species would show a protocorm stage, and that even vegetatively produced plantlets would also possess this structure, as do those of *L. ramulosum*, which I have described elsewhere (17).

SECTION CERNUA.

Belonging to the section *Cernua* are the New Zealand species *L. laterale* *L. cernuum*, and probably also *L. ramulosum*.



A, *L. cernuum:* Fertile branch with one loop of the trailing stem (typical).
B, *L. cernuum:* Portion of fertile branch from New Hebrides Islands.

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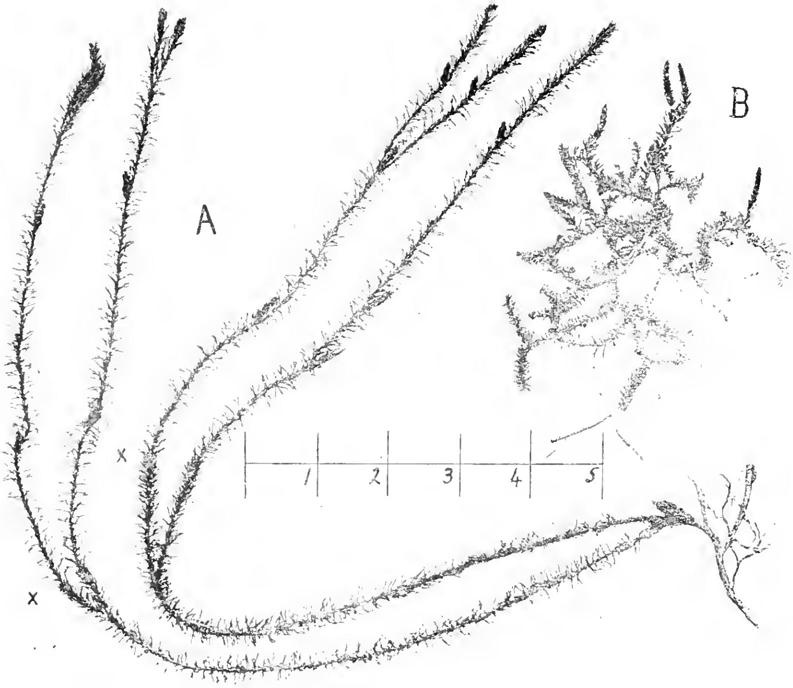


Fig. 1. A. *L. laterale*: Portion of underground rhizome bearing fertile aerial branches, slender variety. B. *L. ramulosum*: Complete fertile plant showing rhizomes and aerial branches.

Fig. 2. A. *L. volubile*: Portion of lateral branch showing vegetative and fertile regions. B. *L. scariosum*: Portion of creeping stem with two fertile erect branches.

External Form of Plant and Nature of Strobilus.

Of these *L. cernuum* is illustrated in Plate XI, A. This figure shows one loop of the main plagiotropic stem with two nodes on which roots are borne, and also a single erect fertile branch arising from the upper side of the main stem. The figure which Pritzel gives in Engler and Prantl (13, fig. 379, A) of the erect fertile branch of this species shows roots at its base. This is obviously wrongly figured. The only variation to be noted here in the external form of the plant is that the New Zealand variety is a very robust-growing plant, while certain tropical forms of the same species are much more delicate in all parts of the plant. This is well seen from a comparison of the two forms marked A and B in Plate XI, A being the New Zealand variety and B a variety from the New Hebrides. Specimens from Fiji and from the West Indies which I have in my possession correspond very closely with B, and Mr. Cheeseman informs me that this is also the form of the species as it occurs in Melanesia and north Australia. An examination of Pritzel's classification of the section *Cernua* shows that several of the species included in it are varieties of the typical form *L. cernuum.*

Two erect-growing aerial shoots of *L. laterale*, together with a small portion of the underground rhizome from which they arise, are shown on Plate XII, fig. 1, A. This illustrates well the form assumed by this species when it grows amidst tangled vegetation composed of *Leptospermum*. *Gleichenia*, &c. The aerial shoots in such a habitat are very slender, and attain an extreme height of 2 ft. to 3 ft. It is obvious that such shoots depend upon the surrounding vegetation to support them in an erect position, and that therefore they are abnormal in form. The specimen illustrated shows that the extreme height of these shoots represents the growth of two seasons, the point at which the second season's growth commenced being indicated by a cross. When growing on open, boggy hillsides, as it does commonly on the kauri-gum lands of the Auckland Province, the aerial branches of this species assume a much shorter, stouter, and less-branched form, and are reddish in colour. The rhizome, with its vascular tissues, also in this case is stouter. In this species the cones are typically lateral and sessile, but they are also sometimes borne on short, leaf-covered peduncles, and are then to be regarded as terminal. This variation in the position of the cones in *L. laterale* provides a transition to the next species, in which one of the chief distinguishing characters is the terminal position of the cones.

The species *L. ramulosum* is described by Pritzel as occurring in the New Zealand mountains; but its habitat is, on the contrary, wet ground at low altitudes, especially that of sphagnum bogs.* It was first described by T. Kirk (22) from Westland, and later still from Stewart Island. I have studied this species in both these districts, and have some interesting variations to record. A single plant is shown in Plate XII, fig. 1, B. Cheeseman figures it in his *Illustrations of the New Zealand Flora* (9), and a plant, incomplete in its lower regions, is also figured by Kirk (22, pl. 19, fig. B). In his first description of it Kirk says, "Not infrequently two spikes are produced from the apex of a branch, and rarely the fertile branch is overtopped by a luxuriant 'usurping shoot' so that the spike appears to be lateral, showing its close affinity with *L. laterale*, which is still further strengthened by the fact that in that species the spikes are not invariably sessile, but occasionally are developed on very short leafy peduncles." The most obvious point of difference between the two species is the usually prostrate and densely matted habit of *L. ramulosum*, and, as will be seen

* See Postcript, p. 216.

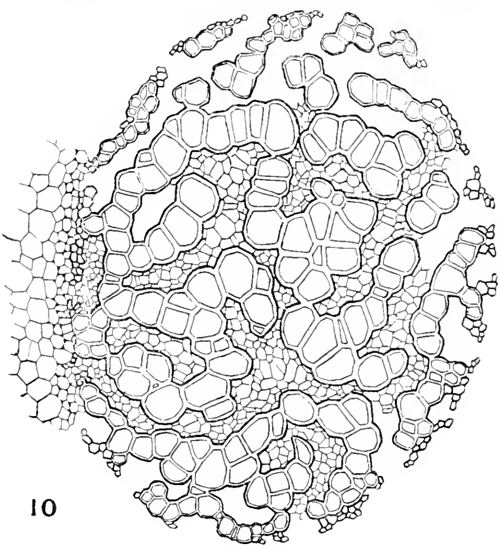
below, the prothallus of the latter is peculiar. Cheeseman (9, p. 250) states that *L. ramulosum* "is more closely allied to the Australian *L. diffusum* than to any other species, principally differing, as Mr. Baker has remarked, in its entirely terminal spikes, whereas in *L. diffusum* they are frequently lateral." It would seem, then, natural to place these three species very close together in the same section, and not to dissociate them, as both Baker and Pritzel in different ways have done. When growing on sphagnum bogs throughout Westland, where it is associated with *Gleichenia alpina* and *Cladium teretifolium*, the plants are closely intermatted, and their rhizomes penetrate the peaty soil in all directions. The aerial branches, by reason of the close nature of the vegetation which covers the ground, are more or less erect. When it is growing amongst thicker vegetation on a hillside I have often observed that *L. ramulosum* occurs in dense, mossy cushions, the intermatted aerial branches in these cases being particularly well developed and drawn out. On wet soil on which there is a very scanty mossy covering individual plants of this species assume a habit in which the branches are closely pressed to the surface, the cones alone standing erect, almost pedicelled. In this case the rosette form of the plant, produced by the continued dichotomies of the branches, is very striking. The main stems show a considerable range of variability in their form. They may be, in drier situations, above-ground and green, and covered with ordinary vegetative leaves, but on the bogs they function as subterranean rhizomes, white in colour, with scattered scale leaves. Again, the more deeply penetrating rhizomes in the latter situation are often quite naked and brown in colour. L. Cockayne (10, p. 17) has made the interesting observation that the cones of *L. ramulosum* "are absent or scantily produced in shade plants, but extremely abundant in those growing in bright light." He has suggested that this is a point which would lend itself well to experimental investigation.

It is apparent, then, that the habit of *L. ramulosum* is very variable, although in its typical form on sphagnum bogs it is quite characteristic. The external form of *L. laterale* also is in a plastic state, and the position of the cones in neither species is quite fixed. Thus in respect of these characters they are more or less closely allied, and also their affinity with the Australian *L. diffusum* seems to be clear.

Stem-anatomy.

In describing the characteristic nature of the vascular tissues of *L. Drummondii* I indicated that this mixed type of stele with the very extended protoxylems is that also of those New Zealand species of *Lycopodium* which belong to the section *Cernua*. It is very distinct from the first type described in this paper, which, as I have tried to show, holds, in spite of the many modifications in the external form of the plant, throughout the subgenus *Urostachya*, and also from the third type, which is characteristic of the *Clavata* section. It therefore should be given prominence to, along with the character of the prothallus and of the embryo plant in the sections *Inundata* and *Cernua*, as a character to be taken into account in a natural classification of the genus.

In fig. 10 is shown the vascular cylinder of the main rhizome of *L. cernuum*. It will be seen both from the amount of vascular tissue and from the scale of the magnification that the stele of this species is an exceptionally large one. For that reason it shows even more clearly than do the other species the nature of the mixed type of structure. Both metaxylem and phloem are much broken up into curving bands and isolated groups, and the protoxylem is markedly extended around the periphery of the stele. The protoxylem and metaxylem elements are poorly lignified. The metaxylem elements are large and are all of one size, there being no small flanking tracheides present. In fig. 10 it is apparent at several places that the metaxylem elements are separating from each other. In accordance with the larger size of the phloem groups there is a distinct differentiation between centrally placed large phloem elements and flanking phloem parenchyma, the latter in the region immediately behind the apex of the rhizome showing abundant contents. In the nature of its cortical tissues this species differs considerably from *L. Drummondii*. There is an outer zone of sclerenchyma which includes the epidermis, while the rest of the cortex is thin-walled but not of a spongy nature. Immediately surrounding the vascular cylinder the cortex is small-celled, as will be seen in fig. 10. The pericycle



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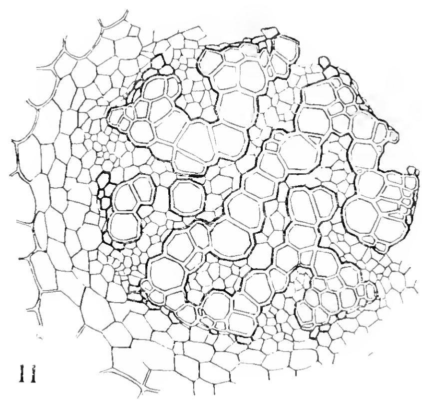

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FIG. 10.—*Lycopodium cernuum*. Transverse section of stele of main trailing stem. × 60.

FIG. 11.—*Lycopodium laterale*. Transverse section of stele of rhizome of strongly growing variety. × 90.

in the mature stem is very indistinct, but in the region immediately behind the rhizome apex it is seen to consist of a single layer of cells adjoining the protoxylem, showing abundant cell-contents. The cells of the innermost cortical layer show quite distinctly thickened angles: this will be the endodermis.

Fig. 11 is that of the stele of the more strongly growing variety of *L. laterale*. This is somewhat larger than that of the tall slender form, but otherwise does not differ from it. Behind the stem-apex the peripherally extended nature of the protoxylems is very marked, but in the mature stem it is not quite so clear, owing to the fact that the smallest protoxylem elements are very feebly lignified, and also become crushed, and so are not always easily recognized. The vascular tissues are quite clearly of the mixed type. The cortical tissues are very similar to those of *L. Drummondii*, there being an inner slightly sclerenchymatous zone, which is more strongly developed in the aerial branches, merging outwards into a thin-walled spongy tissue which is continued right up to the epidermis. In dissecting out the rhizomes of this species from the soil and cleaning them it was noticeable how very easily the white spongy outer cortex could be stripped away from the central core. In the ultimate branches I found a tetrarch condition of the stele. The four extended protoxylems and the four compact groups of phloem which alternate with them are very distinct, but the few large metaxylem elements, even in these small branches, are continually changing their disposition.

Mention has been made of the two kinds of underground stem of the species *L. ramulosum*. Those which penetrate the soil most deeply are brown in colour and smooth, being devoid of scale leaves. They are thicker than the white scaly rhizomes, and their vascular cylinder is proportionately larger. Fig. 12 shows the stele of the larger kind, while the figure given in Part I of these Studies (16, fig. 94) is that of the smaller form The cortical tissues differ considerably from those of *L. laterale*. There is an inner, thin-walled zone, which in the large more deeply growing rhizomes is relatively wide and contains much starch, a median sclerenchymatous zone, and an outer, thin-walled region in which there are abundant air-spaces. The vascular tissues correspond in nature and arrangement to those of the other species in this section of the genus. Practically surrounding the main vascular tissues there is a ring of flattened and distorted cells. In sections of the mature rhizome it is difficult to determine the exact nature of this ring, but from a study of sections taken immediately behind the apex of the rhizome it is clear that the original protoxylem has contributed to the greater part of it.

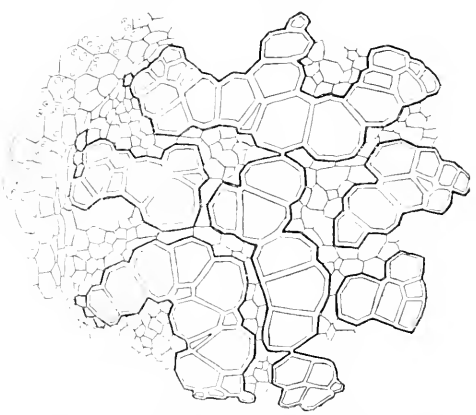


FIG. 12.—*Lycopodium ramulosum.* Transverse section of stele of deeply penetrating rhizome. × 137.

It is evident, then, that the vascular anatomy of the four New Zealand species described above as belonging to the sections *Inundata* and *Cernua* belongs to a common type which is best described as "mixed," this being seen best in *L. cernuum*. In all these species, although the habit is plagiotropic, branching takes place all around the stem, so that no directive tendency is present towards a dorsiventral disposition of the vascular tissues as in the species of the *Clavata* section. The mixed nature of the vascular tissues, however, is not merely the result of the all-round branching; it is present from the early seedling stages of the plant, and goes along with certain characteristic features in the histology of the xylem and protoxylem, and it is best regarded as part of the inherited constitution of this division of the genus. The only variation in the nature of the vascular tissues is that in *L. cernuum* the phloem shows considerable differentiation, this arising probably simply from the large size of the plant and of its vascular tissues. The stem-anatomy of only one other species belonging to these two sections has been examined—viz., that of *L. inundatum*, described and figured by Jones (21). His figure of the tetrarch structure and broad protoxylems in a small branch of this species corresponds very closely with what I have observed in the corresponding parts of the plant of all four New Zealand species. The cortex in the New Zealand species varies very markedly. The position of the sclerenchyma zone in *L. cernuum* is outermost, in *L. ramulosum* it is median, and in *L. Drummondii* and *L. laterale* it is innermost. There is a distinctly spongy region of the cortex in the three latter species which is quite in accord with the nature of their habitat. The external position of the sclerenchyma in the stems of *L. cernuum* is perhaps to be explained by the fact that these are above-ground, and that this species seeks drier situations than do the other three. It is not quite so clear, however, what is the particular physiological reason for the median position of the sclerenchyma in the cortex of *L. ramulosum* unless it be because in this species the innermost cortex is used as a storage zone.

The Prothallus.

The prothallus of these two sections, so far as it is known, belongs to the *L. cernuum* type, and this is one of the main arguments which determines that the two sections together form one of the natural divisions of the genus. However, the prothalli of all the species that have been examined show striking variations from the typical form, and in the case of the three New Zealand species, *L. cernuum*, *L. laterale*, and *L. ramulosum*, there is a wide range of variability in the form of the prothallus in each individual species. In fact, in these species there is a far greater degree of plasticity shown by the gametophyte generation than by the mature sporophyte. This is to be expected, for whereas on the one hand the species are limited in their distribution, and hence the sporophyte is under a comparatively constant set of external conditions, on the other hand the prothallus, being very delicate in nature and combining the chlorophyll condition with the saprophytic, must necessarily show considerable variation from the typical form in accordance with the varying depth at which the spores germinate. In these two sections of the genus, in contradistinction to what obtains in the other sections, the prothallus lasts for only one season. The spores germinate only in consistently damp, loose soil, more especially that which possesses a thin covering of short moss. Being partly dependent upon the presence of light, they cannot germinate at any great depth in the soil, but yet amongst the moss and other delicate debris of vegetable matter there is, of course, a considerable range of variation in the conditions under which the development of the prothallus must take place.

The prothallus of *L. inundatum* has been described by Goebel (14). This corresponds fairly closely with the *L. cernuum* type. Treub (30) has described the prothallus of *L. salakense*, a species which is apparently a variety of *L. cernuum*. This he says belongs to the *cernuum* type, but it is not so closely similar to it as is the prothallus of *L. inundatum*. Several filaments may develop from the primary tubercle, one of these afterwards developing into the main prothallus-body. There are no foliaceous lobes produced on the crown.

Treub has given a very full account of the prothallus of *L. cernuum*. I have not had access to his original papers, and hence am not aware whether or not he has described in the case of any of his specimens the variations in structure which I have found in the prothallus of this same species as it occurs in New Zealand. In a previous paper (16, p. 266) I noted that the length of the shaft varies greatly in the case of different individuals, it being comparatively long in some and in others almost absent, and stated that this arose simply from the fact of the variation in depth at which the spores germinate. With regard to the internal structure of the prothallus, I must anticipate here what I hope to describe more fully in a future paper. The lower primary tubercle not infrequently consists of two distinct swellings, and not one only. The extreme basal end of the prothallus constitutes the original tubercle, but the second swelling is separated from this by a slight constriction and occupies a position higher up one side. In some prothalli the development of this second laterally placed swollen region gives a somewhat lopsided appearance to the prothallus. This will be seen in fig. 21 of the paper cited above (16), and also in fig. 13, which is that of a similar prothallus of *L. laterale*. In some of the short prothalli the two swellings appear side by side, together forming the basal part of the prothallus, the crown of lobes arising from both together: this, of course, serves to impart a thickset appearance to the prothallus as a whole. Contrary to what botanical writers, quoting from Treub's original papers, have stated with regard to the internal structure of the primary tubercle in *L. cernuum*, I find that a well-marked differentiation of fungus-inhabited tissues is there to be seen, though, of course, to a much less extent than in the prothalli of the *clavatum* or *complanatum* types. The outer peripheral layer of cells is for the most part only one cell in thickness, and this contains the spherical coils of fungal hyphae. Those cells of the interior of the tubercle which immediately abut on the peripheral layer are very distinctly elongated at right angles to the latter. They are narrow, and in transverse section are roundish in outline, and in this layer the fungus occupies a position in the cell-walls. In fact, this layer may be compared to the palisade cells in the vegetative part of the *clavatum* or *complanatum* prothallus. In some cases I noticed that the cells of this interior tissue contained abundant small bodies which I took to be starch-grains. Apart from those instances in which there is a second swollen fungal region occupying a lateral position, I have not observed the fungus penetrating into the region of the shaft. The two fungal tissues occupy the whole of the first-formed tubercle, but in the case of the second swelling they are, as I have said, laterally placed. If now prothalli of this species occurred in which the fungal regions extended in this way farther up the main body of the prothallus, not only in one localized position but uniformly all around it, leaving a central core of undifferentiated cells, we would have a condition approaching that of the prothallus of *L. complanatum* in its basal region, as described by Bruchmann. I have not observed such cases in the prothallus of this species, but what has just been described becomes of some significance in this connection when compared with the further variations in the prothallus of *L. ramulosum* to be described below. In the case of the *complanatum* and *clavatum* types of prothallus the main characteristic is that the fungal tissues have become so important a part of the prothallus-body that their development is not left to the mere spreading of the fungus to additional regions of the prothallus, or to the successive infection of those regions from without through the rhizoids, as is obviously the case in *L. cernuum* and *L. laterale*, but proceeds uniformly from the meristem, the vegetative part of the prothallus consisting of one large swelling and not several small distinct ones. On re-examining my serial sections for the purpose of this paper I found that in one or two instances the second fungal swelling was associated with the development of assimilating lobes arising laterally on the prothallus-shaft and on the opposite side of the swelling. The prothallus of *L. cernuum* is thus in a somewhat plastic condition, and the variations in form which are to be observed make it easier to institute comparisons between this type of prothallus and those of the other sections of the genus.

In my previous description of the prothallus of *L. laterale* (16, p. 265) I noted that, as in *L. cernuum*, the shaft is variable in length, the shorter prothalli having thus a somewhat solid, compact appearance, and that the leafy expansions on the crown of the prothallus of *L. laterale* are less lobe-like and more filamentous than in the case of the other species. Another character noted was that these assimilating outgrowths occur also normally in a lateral position on the shaft of the prothallus. The presence of a long, narrow, club-shaped process attached to the tubercle of two of the prothalli was also mentioned, and I was inclined to regard this as the actual first-formed portion of the prothallus and not as a branch arising from the "primary" tubercle. As in the prothallus of *L. cernuum*, the fungal zone may extend for a certain distance up one side of the shaft, giving rise to a second swelling distinct from the lower one. In none of my preparations did I find that the interior cells of the swollen areas which adjoined the fungus-infected peripheral cells were so clearly differentiated as a distinct fungal tissue as they are in the largest prothalli of *L. cernuum*. The fungus extends between these cells, in one particular instance as far as into the lower region of the shaft. These cells have without doubt a definite arrangement, with their long axes at right angles to the peripheral layer, but in longitudinal and transverse section they appear little differentiated in form from the other cells of the shaft. Thus the fungus zone in this species is of the same nature as that in *L. cernuum*, but it shows a somewhat less degree of differentiation of its tissues. I found one very young prothallus of this species entangled closely amongst the rhizoids of an older prothallus. It consisted of a filament nine cells long, the older half of this prothallus being but one cell wide, and the younger half two cells wide. At the base of the prothallus was to be seen the original spore, and four or five rhizoids were borne on the older cells. There was no suggestion of a primary tubercle, nor was the presence of a fungus to be seen, but all the cells showed numerous chloroplasts. This young prothallus may be compared with those of the same early stage in *L. ramulosum*, described below.

The prothallus of *L. ramulosum* is very variable in form (16, pp. 269–71), much more so than that of the other two species. The long-drawn-out forms have several swollen fungus-infected areas, bearing rhizoids, some of the largest prothalli showing as many as five such areas. Each of these fungus swellings has usually a group of assimilating lobes associated with it, and at the base of the lobes antheridia or archegonia are developed. Not infrequently the form of the prothallus is strangely altered owing to the fact that a somewhat massive body of tissue is formed at a place where a group of lobes is associated with a fungus area. Generally the last-formed uppermost part of the prothallus is the bulkiest, but two or even three such masses of tissue are often to be seen in these long-drawn-out forms of prothallus. In every case in which a young plant was attached to a prothallus it had developed from the uppermost of these bulky regions. One or two prothalli were found which had branched at the point of a swollen fungal region, the two branches being equally developed. As well as the long-drawn-out forms there are short, comparatively massive individuals. These correspond to such a group of lobes with its associated fungal region as has just been described, the development of the massive body of tissue having proceeded to an unusual extent. Sometimes it is seen that in these massive prothalli there has been an original first-formed, long-drawn-out portion which has withered away, but always the subsequent growth of the prothallus is confined to increasing the massiveness of the main tissues and does not result in any further extension in length. In many cases, especially at the actual crown of the prothallus, the group of lobes has withered, there being a consequent browning of the upper surface at this point. In some instances, instead of lobes being present, there are only feebly developed warty excrescences. Again, in other instances the lobes are fairly thick in form. Serial sections of the prothalli show that the fungus swellings are all identical in nature and correspond very closely with what is found in the prothallus of *L. laterale*. The peripheral cells contain the spherical masses of hyphae, while those in the interior of the swelling show the fungus only within the cell-walls. These latter cells have not assumed such a definite tissue-form in accordance with their particular function as is sometimes to be seen in *L. cernuum*. The initial stage in the formation of a fungus area is sometimes to be seen, one or two epidermal cells showing the presence of the fungus, but no swelling having yet taken place. In not a few prothalli, both of the massive and of the long-drawn-out form, the actual first-formed region nearest the original spore was to be seen. Moreover, several very young prothalli were found. There is first a longer or shorter filamentous stage, in which the young prothallus is only one cell wide, after which it proceeds gradually to increase in width as it lengthens. The prothallus is from the first quite green in colour, and infection by the fungus seems to take place subsequently to these early stages of growth. However, in one or two prothalli of the massive form I noticed that the original but very short filament passed immediately into the bulky fungus-containing tissue, the complete prothallus having very much the form of an inverted cone with the spore filament at its apex. The resemblance of this to the *clavatum* type of prothallus is obvious.

The prothalli of the three New Zealand species which belong to the section *Cernua* are thus seen to be in a condition of great plasticity. The main reasons for the modifications of the typical *cernuum* form seem to be the varying depth at which the spores germinate, together with the extent of infection by the fungus element, this resulting in all three species, and especially in *L. ramulosum*, in a form of prothallus more or less elongated, which develops rhizoids at intervals along its length, a form which may be well compared with that acquired by the humus-growing, wholly saprophytic prothalli characteristic of the *Phlegmaria* type. The various forms of the prothalli of *L. Selago* and *L. ramulosum* show how it is possible for both the much-branched *Phlegmaria* type and the compact, more massive *clavatum* or *complanatum* type to arise as modifications of the original form. The prothalli even of *L. cernuum* and *L. laterale* give indications of this. This, taken in conjunction with the fact of the great plasticity of the species as seen in all their main characters, and the occurrence of numerous transitional forms both between one species and another and also between one type and another, indicates that the main natural divisions of the genus correspond with its biological distribution, and that the different sections into which the species are classified by systematists bear a certain definite relationship to one another. Only a comparative examination of the chief characters of both gametophyte and sporophyte generation can show which particular characters are more fixed than others, and so indicate what is the nature of this interrelationship between the sections of the genus.

The Young Plant.

In all the species belonging to the two sections *Inundata* and *Cernua* whose embryogeny is known the embryo plant passes through a protocorm stage. Goebel has described this in *L. inundatum*, and Treub in *L. cernuum*. In two previous papers (15, 16) I have described the protocorm of *L. laterale*, and in the second of these papers I have given a fairly complete account of it not only in this species, but also in *L. cernuum* and *L. ramulosum*. Chamberlain (7) has also published an account of the protocorm of *L. laterale*. In Part II of these Studies (17) I have demonstrated the presence of a protocorm in adventitiously developed plants of *L. cernuum* and *L. ramulosum*, and have shown that the large protocormous rhizomes of the latter species can branch, give rise to two or even three stems, bud off bulbils, or by partial decay break up into a number of distinct portions, each of which can develop into a young plant. Goebel also has described adventitious protocorms in *L. inundatum*. There will be no need for me to repeat here the description of this organ as it occurs in the three New Zealand species, beyond pointing out the facts relating to its variability in form.

In the case of *L. cernuum* I have shown (16, pp. 283–84) that usually the growth in size of the protocorm ceases after the first three or four protophylls have been formed, but that in some instances a certain amount of lateral growth takes place, as many as seven protophylls being formed along the top of the extended protocorm before a stem-axis is initiated. Since that account was written I have examined another colony of young plants of *L. cernuum*, several of which showed very large protocorms quite comparable in size to the largest of those of *L. laterale* found by me. It is thus apparent that whereas under normal conditions this peculiar structure does not assume a large size in *L. cernuum*, yet under certain conditions, occasioned probably by a dry season, it may function for a much longer period and assume a much larger size.

In both *L. laterale* and *L. ramulosum* the protocorm is also very variable in size, although it is much larger than it usually is in *L. cernuum*. In the paper quoted above (16, pp. 277–83) I have set myself to show that the large size of this organ in *L. laterale*, and also in *L. ramulosum*, is merely a special adaptation suited to carry the young plant over the dry season. In all these New Zealand species which possess the delicate short-lived type of prothallus the young plants are formed during the spring and early summer. During the dry months of midsummer probably the majority of them die, except those in exceptionally favourable situations, or those whose protocormous rhizome has become sufficiently tuberous to be able to withstand a period of drought. Then, as the wet season comes round again, growth is resumed and a stem-axis is initiated.

According to this view the protocorm is a plastic organ whose form and importance is mainly dependent upon external conditions. This also suggests that the protocorm in general, as it occurs throughout the sections *Inundata* and *Cernua*, is a physiological specialization. This is the view taken by Bower (3, pp. 225, 355). Goebel also (14) was not able to see any phylogenetic significance in this organ.

Thus there are certain consistently present characters in these two sections which indicate that they together form a natural division of the genus clearly marked off from the remainder. These characters are—a plagiotropic habit of growth with all-round branching of the trailing stem; a mixed type of stelar anatomy with exceedingly broad protoxylem groups; a delicate short-lived surface-growing prothallus; and a protocorm stage in the embryogeny. It may safely be assumed that a type of prothallus which possesses chlorophyll and is largely self-nourishing is less modified from the original type than are those which are wholly saprophytic in mode of nutrition. This assumption is made by most writers on the subject. It is not, however, necessary to assume that the delicate nature of the *cernuum* type of prothallus is also a primitive character. Such a type of prothallus demands a damp habitat. Another consequence of the delicate nature of the prothallus is that it becomes necessary for the young plant to quickly gain independence and establish itself, and hence probably arose the protocorm as a physiological specialization. Such damp situations as are suitable for the development of this type of prothallus are liable to seasonal periods of drought, and hence the protocorm is further developed as a resting tuber. The mixed type of stelar anatomy is initiated by the fact that in the very young plant the leaf-trace system precedes the formation of the cauline cylinder, and thus the stelar tissues show from the first a loosely aggregated character. Moreover, in the older stems the branching of the stele in all four directions tends to continually disturb the tissues. However, this is not sufficient to account for all the peculiar features in this type of stele, which would seem rather to be an expression of the inherited constitution of this division of the genus. The plagiotropic habit and unlimited growth of the plant are a modification suited to assist it to spread over wide areas, and are able to counterbalance as means of vegetative propagation the uncertainties attached to the sexual reproduction of these species. Thus all these characters are largely dependent upon the environment, being under its direct influence, and with respect to them the different species show a high degree of plasticity.

Species belonging to the Clavata Section.

I have already enumerated certain reasons for removing the species *L. densum*, *L. volubile*, and possibly also *L. obscurum* and *L. casuarinoides*, from Pritzel's *Cernua* section, and placing them instead in the *Clavata* section, and for removing the species *L. diffusum* and *L. ramulosum* from Pritzel's *Clavata* section and placing them in the *Cernua* section. Such a rearrangement of these species would seem to be in accord with the facts known concerning their main gametophytic and sporophytic characters.

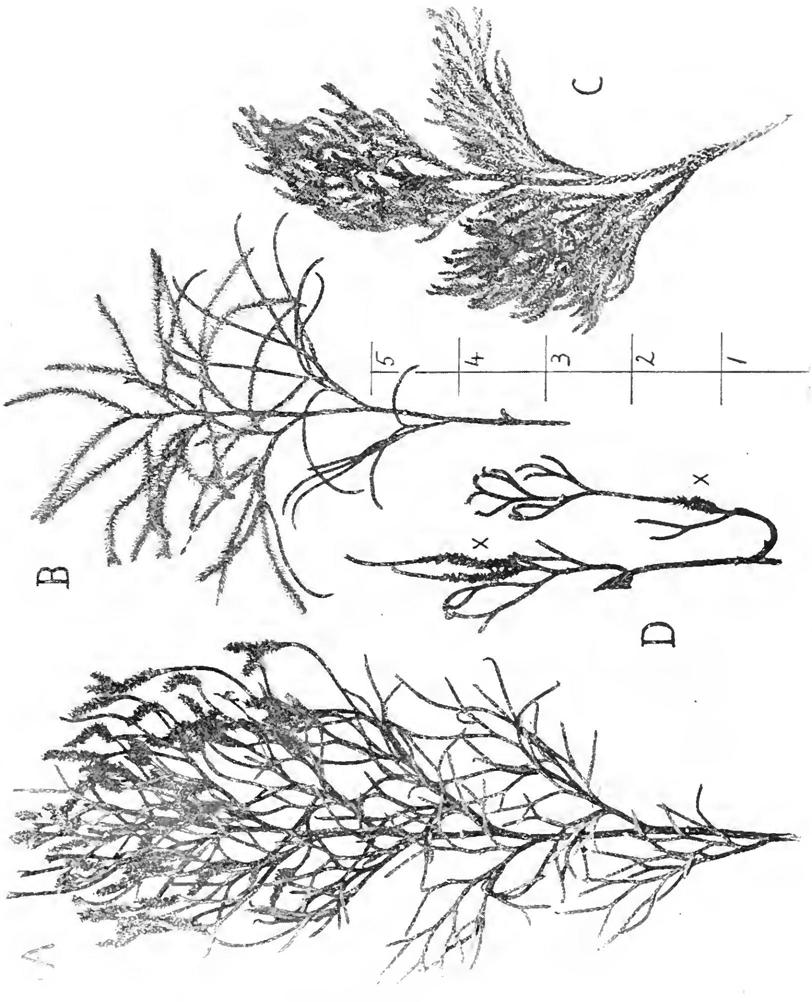
This section is marked by a number of very definite characters. The habit of growth of the species is strongly plagiotropic—indeed, so much so that several show a bilateral structure in the leaf-arrangement, with heterophylly, and, at least in the New Zealand species, the branching is always in the plane of the ground, and not all round the stem as in the species of the last section. The fertile regions are upright club-shaped cones borne on distinct pedicels, or numerous short cones at the tips of the densely-branched aerial branches, except in the case of *L. volubile*, where the scrambling habit of the plant has probably been accountable for a noteworthy modification. The stelar anatomy shows a characteristic dorsiventral disposition of parallel plates of xylem and phloem. The prothallus is large, compact, and deeply buried, and the young plant possesses a strongly developed foot. These characters clearly mark off the *Clavata* section from the other sections of the genus. It is, of course, obvious that these same characters are under the direct influence of the environment, even more so than in any of the other sections, and therefore we may expect to find not only variations in form and structure in the species themselves, but also indications that the section itself includes more than one strain. This seems to follow, for example, from the fact that there are two types of prothallus, and that, in the case of two of the New Zealand species, along with these types of prothallus there go two distinct types both of heterophylly and of strobilus-form.

External Form of Plant, and Nature of Strobilus.

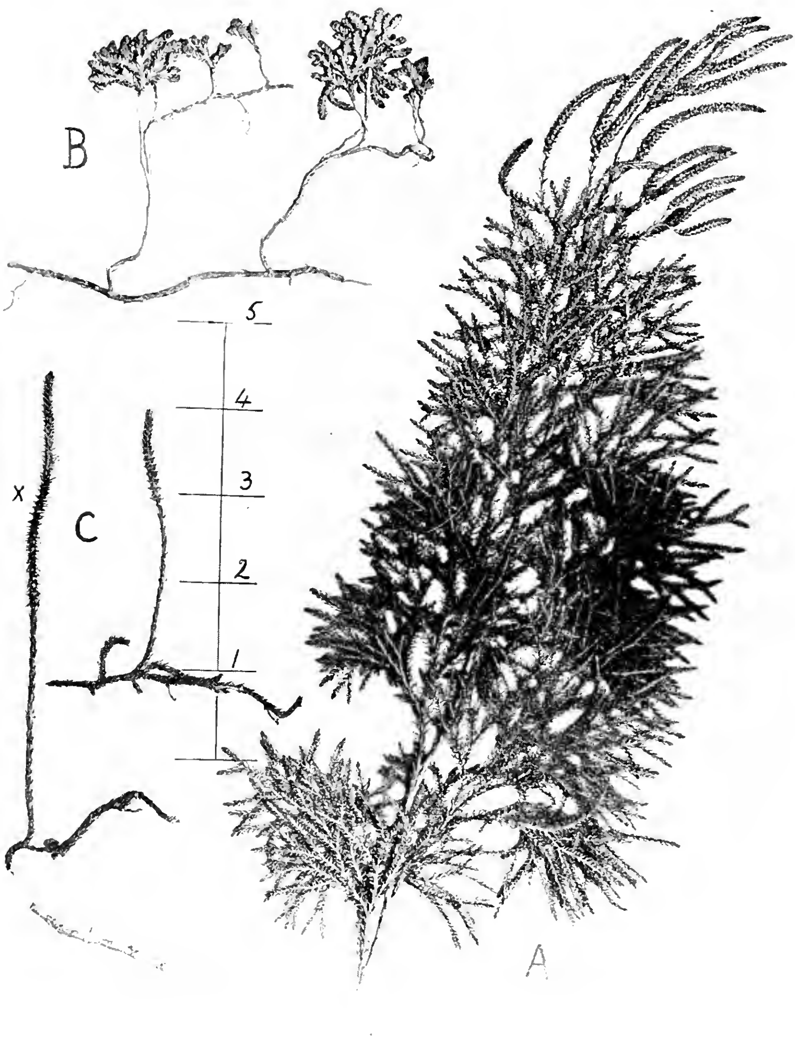
L. volubile has a scrambling and climbing habit, and its form and structure show various modifications in accordance with this. The following quotation is from an unpublished work by L. Cockayne on the Vegetation of New Zealand: " *L. volubile* is an interesting example of the transition of a creeping ground-plant through a winding liane, by way of a scrambling plant. This plant, as a creeper, in many places extends its slender, woody, stiff stems far and wide, rooting in the soil and raising them unsupported for 60 cm. or so into the air. Thus a prop may be gained, and, this happening, the method of climbing depends upon the nature of such. If the support be twiggy the liane merely scrambles through the branches, its lateral branchlets at about a right angle to the axis, the sporophyll-bearing branches and the hook leaves of the stem all functioning as climbing-organs, the last-named also aided by the flexuous stems. When the support, however, is smooth and with few projections the stem of the *Lycopodium* twines strongly, gripping the support tightly." In localities where this species is growing in luxuriant masses upon and amongst low vegetation, one frequently sees the growing shoots standing erect and unsupported to a height of as much as 3 ft. to 4 ft., the flexible ends of the shoots being curved similarly to those of a hop These shoots are thus able to lift themselves up in a vertical direction and so reach the lowest branches of small trees. Sometimes two or even three neighbouring shoots in such situations will twine tightly round each other, and so lift themselves up into the air to an even greater height. Although somewhat slender, the stems and branches are exceedingly rigid and strong, owing to the fact that the whole of the cortical tissue of the stem is strongly sclerenchymatous. When growing on the ground the characteristic foliage of *L. volubile* is luxuriantly developed, such specimens being commonly used for decorative purposes. When climbing, however, this foliage is generally very poorly developed, and frequently is entirely wanting, the branches being present simply as short peg-like projections scantily clothed with the acicular scale leaves. The hooks are present on all rapidly elongating stems and branches that are bare of the usual dorsiventral foliage. The hook is formed by a short downward prolongation of the base of the ordinary acicular scale leaf. They point backwards from the elongating region of the stem, and, when the stem is scrambling or twining, serve to take the weight of its lower parts.

I have elsewhere (15, p. 366) described the characteristic heterophylly of this species. Not infrequently in sheltered places throughout Westland I have come across mature plants in which the dorsal and ventral scale leaves, which are normally very reduced in size, are longer and more spreading, the laterally spreading large leaves at the same time tending to the acicular form. This is of the nature of a reversion foliage, and such plants have an exceedingly beautiful, feathery appearance. When the plants are scrambling over scrubby vegetation the adventitious roots are sometimes of great length. They may be as much as 3 ft. to 5 ft. in length, and a very characteristic feature during the wet season is the thick envelope of mucilage which covers from 3 in. to 12 in. of the growing root-tip before it reaches the ground. This mucilage envelope also occurs to a much less extent on the exposed root-tips of such other species as *L. cernuum*, *L. densum*, *L. scariosum*, and *L. fastigiatum*. The spikes are of a very characteristic form, which may be regarded as a direct adaptation in accordance with the scrambling habit of the plants. They are produced only when the plant can raise its lateral branches to a considerable height, and then the ultimate twigs on the entire terminal portion of such a branch become developed as long cylindrical pendulous strobili. Plate XII, fig. 2, A, shows a portion of such a fertile branch, at the point where the ordinary foliage passes into the fertile region. The terminal portion of the branch has been broken off at the point marked with a cross. Frequently on such branches fertile regions are intermixed with sterile, and *vice versa*, as also will be clearly seen in the figure. A close comparison may be instituted between the fertile region of this species and that of the pendulous epiphytic species of the *Phlegmaria* section, the obvious deduction being that in both cases the form of the strobilus is simply the result of the pendulous habit, and that the *Lycopodium* strobilus must be in a very plastic condition for this habit to appear in the *Clavata* section.

The main stem of *L. densum* is subterranean, but sometimes—as, for example, at the edge of a bank—it emerges from the ground and continues its growth, becoming green in colour. The aerial branches arise right and left of the main rhizomes, and at once bend sharply upwards, emerging from the ground with a stiff, erect, dendroid habit. There are three very distinct forms of aerial branches, which take their character from the nature of their foliage. These are shown in Plate XIII, at A, B, and C, that lettered B showing its own particular form of foliage in the upper portion of the branch and the foliage of form A in the lower portion. These three varieties of foliage are almost invariably quite distinct from one another, and do not grade into one another, being confined for the most part to separate branches. Where more than one variety does occur on the one branch, as in the specimen figured, the two forms nevertheless keep quite distinct. Now, all three varieties of foliage are commonly to be met with in practically every locality where *L. densum* occurs, growing side by side, so that it is obvious that the different forms are not by way of being adaptations to the environment. It would seem, then, that they are hereditary polymorphs, true-breeding races which possibly have arisen by mutation, and which hybridize. These three forms are by no means plastic in their nature, although individual twigs may very occasionally be observed which seem to show gradations in their foliage. When growing amongst tangled vegetation, more especially in hollows, the aerial branches may attain a great height. They are then very scantily branched; indeed, I have seen aerial stems as much as 9 ft. in height, some of which have been quite unbranched. The cones are very numerous, are short, and are borne solitarily at the tips of the ultimate branchlets very much after the same manner and appearance as in *L. cernuum*. Instances are to be met with sometimes in which there has been a vegetative prolongation of the cone, as at the points marked with a cross in Plate XIII, D. In this particular figure the lower of the two fertile regions thus indicated may well have been differentiated after the whole twig had been formed.



A, B, C, *L. densum*: Three varieties of foliage. D, *L. densum*: Abnormality in the fertile region.



A, *L. fastigiatum*: Fertile aerial branch of mesophytic variety, from lowlands, Westland. B, *L. fastigiatum*: Portion of rhizome with two sterile branches, xerophytic variety from Browning Pass. C, *L. Drummondii*: Two incomplete plants showing portion of creeping stem with fertile branch.

L. fastigiatum varies very much in the form of its aerial branches in accordance with the environment. Plate XIV, A and B, represent two extreme forms, the latter from Browning Pass at a height of 5,000 ft. and the former from Westland at practically sea-level. The form lettered B represents a portion of a plant as it grows commonly on the hard dense cushions of *Phyllachne clavigera*. The main rhizome is deeply buried in the rotting substratum of the cushion, and the lateral branches are also rooted and buried, but at a lesser depth. Arising from the lateral branches are the short tufted foliage shoots, which appear as little compact rosettes firmly resting upon the surface of the cushion. The cones are numerous, and stand erect on very short pedicels to a height of $\frac{1}{4}$ in. to $\frac{1}{2}$ in. The plant figured is sterile. This is an extreme xerophytic form, and is in marked contrast to that lettered A, which represents the species as it occurs typically around the alluvial goldfields in the very wet climate of the lowlands of Westland. In these localities the aerial branches attain a height of 1 ft. to 3 ft., and are often of a striking red or golden colour, handsomely branched, with a terminal bunch of long, club-like cones. On the Canterbury mountains, where this species occurs abundantly, I have often observed that when the plants are growing in a tussock-clump or amidst other sheltering vegetation the aerial branches are tall and slender and open-leaved, whereas those, perhaps of the same plant, growing in the open in the full light of the sun only a foot or two away are short, sturdy, and compact, with much thicker stems and closely imbricating leaves. This species occurs also commonly in subalpine *Nothofagus cliffortioides* forest, and there its habit is characteristically mesophytic. There is a certain range of variability in the form of the strobilus and its pedicel, even in individuals from the same locality. On some branches the tips of practically all of the ultimate twigs are fertile and there is no pedicel, there being a gradual transition from the vegetative leaves of the twig to the sporophylls. On other branches, again, the main axes of the branch are continued on as long scantily-leaved pedicels, bearing one or more long, club-shaped cones, which are often branched. The former condition is, generally speaking, characteristic of the xerophytic type of branch, and the latter of the mesophytic, although this distinction is not always kept. Among the mesophytic form of plants some very extreme examples of pedicel-formation are sometimes to be met with.

As in the case of the last-named species, the wet climate of the lowlands of Westland encourages a luxuriant growth of *L. scariosum*. Plate XII, fig. 2, B, shows a portion of the rhizome of this species with two small erect lateral branches bearing cones. The development of heterophylly in this species, as in the case of *L. volubile*, has been elsewhere described by the writer (15, p. 366). In *L. volubile* the acicular leaves are finer in form than in the other species, and there are about twice as many orthostichies. Heterophylly in *L. volubile* arises through two orthostichies on each lateral face of the branch approximating to one by being flattened in the plane of the ground, the leaves of these orthostichies assuming the larger form. At the same time the leaves of the two or three orthostichies placed ventrally and also dorsally become much reduced. All stages in the development of this dimorphism can be seen in young plants, and also in the reversion foliage which has already been noted as occurring in this species. In the case of *L. scariosum* it is the leaves of the two dorsally placed orthostichies which become flattened in the plane of the ground and assume the larger form, there being two to four orthostichies of much reduced scale-like leaves on the ventral side. The stages in the development of this form of distichous arrangement can also be seen in the young plants, but not so well as in *L. volubile*, since the heterophylly is developed rapidly and very early. When growing in dry situations—as, for example, at considerable altitudes—the lateral branches of the mature plant of *L. scariosum* are more or less flattened in the plane of the ground, but when amongst other vegetation they tend to assume a more upright position. This species occurs in wide, luxuriant spreads around the abandoned gold-mining claims throughout north Westland, and there the lateral branches are characteristically erect-growing, although the heterophylly is still strongly marked. Frequently, as a result of the upright habit of growth, the twigs of these branches show an all-round spread, and even the flattened falcate leaves are more outstanding, but inspection shows that both twigs and leaves arise in the characteristic dorsiventral manner. The long club-shaped cones are borne in great numbers, being raised up on pedicels 3 in. to 6 in. in height, which are formed by the continued growth of the main twigs of the branch. The appearance of these pedicels previous to the formation of the cones is very striking, standing stiffly up as they do in massed numbers above the dense foliage. The gradual transition from heterophylly to the spiral arrangement of ordinary acicular leaves can be well seen at the base of these pedicels. When growing amongst ferns and saplings at the edge of the forest, the lateral branches of this species sometimes become very long-drawn-out and adopt a semi-scrambling habit. Owing to the rapid growth the scale leaves are somewhat scattered along these branches, and in those regions in which the characteristic heterophylly has appeared its development has taken place irregularly. Instances are not infrequently met with of internodes showing, contrary to the usual rule, one, two, or even three dorsally placed orthostichies of scale leaves, the type of heterophylly then approximating to that of *L. volubile.*

Stem-anatomy.

As in the case of the two other natural divisions of the genus, the *Clavata* section shows a very characteristic and consistent type of stelar anatomy. This has been described by Jones (21) in the six species *L. clavatum*, *L. annotinum*, *L. complanatum*, *L. chamaecyparissus*, *L. alpinum*, and *L. obscurum;* by Boodle (2) in *L. volubile;* and by myself (15, 16) in the four New Zealand species which belong to this section. The central cylinder consists throughout of parallel plates of alternating xylem and phloem disposed dorsiventrally, surrounded by a pericycle. Consequent on the comparatively large size of the plant in the New Zealand species, the number of plates of vascular tissue is also large. The phloem is markedly differentiated into centrally-placed empty sieve tubes of large size and flanking phloem parenchyma with abundant contents. I have previously described (15) in *L. volubile* and *L. scariosum* the development of the dorsiventral structure characteristic of the mature stele from the radial structure characteristic of the young plant, showing that it is initiated in the developing plant at the point of branching, which in this section of the genus always takes place in the plane of the ground, and tends thereafter to be preserved in between the branchings. Assuming that this is the main cause of the dorsiventral structure, it is quite possible that it will be found in species which are not closely related, and thus this character taken by itself will not be a sure sign of natural affinity. Owing to the great plasticity of the genus *Lycopodium* as seen in all its main characters, the natural classification of the species must take all these characters into consideration, weighing one against another, and can only become an accomplished thing when the full life-history of many more of the more important species is known. This is, of course, true in a greater or less degree of every genus and family of plants, but it is especially true of the present one.

The stelar and cortical anatomy is very consistent in structure as it occurs in the case of each of the four New Zealand species, but certain small distinguishing features are worth recording. The text-figures illustrating the vascular structure of the four species show in each case the ends of two bands of both xylem and phloem with the protoxylem and protophloem groups, and also the adjacent pericyclic and cortical regions. As in the case of the other New Zealand species, semi-diagrammatic drawings of the complete stele have been given in another paper (16). In the stem of *L. volubile* (fig. 13) a very characteristic feature is the exceedingly large size of the sieve tubes. The chief metaxylem elements are also large, and are noticeably flanked on both sides of each band by small-sized tracheides. The pericycle is narrower than in the other species. Practically the whole of the cortex is strongly sclerenchymatous. Three zones can be recognized, however—an inner narrow, exceedingly strongly thickened zone, in which the cells have been flattened tangentially by mutual pressure and the cell-cavities almost obliterated; a broad median zone of circular, thick-walled cells, which passes into a narrow epidermal zone of thin-walled cells showing air-spaces and bounded externally by a strongly cuticularized epidermis. The whole stem and the vascular cylinder is much smaller in size than in the case of the other three species. The main features thus given of the stem-anatomy of *L. volubile*—viz., the comparatively thin stem, the woody cortex designed rather to impart a wiry quality to the stem than to act as a starch-storing tissue, and also the large open vascular elements—can be put into connection with the scrambling habit of the plant. In the large adventitious roots the configuration of the stele is strikingly stellate (16, fig. 93). There is no modification of the vascular tissues in the ultimate branchlets by the heterophyllous habit.

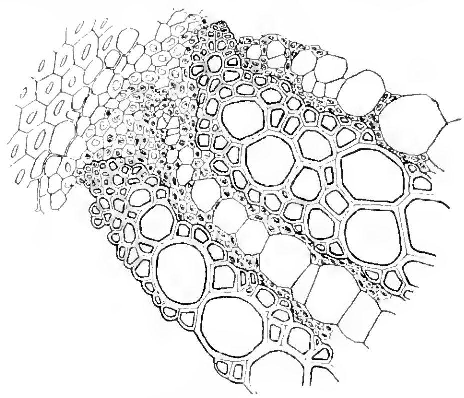


FIG. 13. — *Lycopodium volubile.* Transverse section of portion of stele of main stem. × 137.

The rhizome of *L. densum* is from two to three times as thick as that of *L. volubile*, and the vascular cylinder is very large. The cortex functions as a storing tissue. There is a somewhat narrow, strongly sclerenchymatous, inner cortical zone, while the rest of the cortex consists of much less thickened circular cells containing abundant starch. In the aerial stems the whole of the cortex is strongly sclerenchymatous. The same rhizomes which show the presence of starch in the cortex show also the cells of the phloem parenchyma to be practically empty, but immediately behind the rhizome-apex they have abundant contents. The sieve tubes are very much smaller than in *L. volubile*. There is a much scantier development of small-sized flanking xylem elements, but the main metaxylem tracheides are large (fig. 14). The dorsiventral structure of the main rhizome stele passes over into the lower regions of the aerial stems, but this is more or less quickly replaced there by the stellate or radial form. The largest aerial branches not infrequently possess towards their base a larger stele than do the main rhizomes. At the base of one such stem I found as many as twenty-one protoxylem groups, whereas the number in a full-grown rhizome is generally about seventeen or eighteen. In this connection reference may be made to Jones's remark with regard to the vascular structure in the stem of *L. obscurum* (21, p. 32). He says, "In any hypothesis which endeavours to explain the dorsiventral structure in the creeping stems the fact must not be overlooked that the banded structure is well marked in the stem of the erect-growing species of *L. obscurum*." There is no doubt that *L. obscurum*, as also *L. densum*, must be removed from Pritzel's *Cernua* section and placed in the *Clavata* section. *L. densum* is not an erect-growing plant, as stated by Pritzel, but is plagiotropic, and it is practically certain, judging from the sporeling plants which I have found, that the prothallus belongs to one or other of the deep-growing, massive types. Mr. Cheeseman has informed me that in both Bretton's and Asa Gray's manuals of the flora of the United States of America *L. obscurum* is described as possessing subterranean creeping "rootstocks." Moreover, Spessard (26) has found the prothallus of this latter species to be of the *L. clavatum* type. Even if the material of *L. obscurum* examined by Jones was not that of the main creeping stem but of the lateral branch, the fact of its dorsiventral structure would not be significant, since, as I have shown in *L. densum*, this frequently persists for some distance up a branch after having been carried over from the main stem at the point of forking.

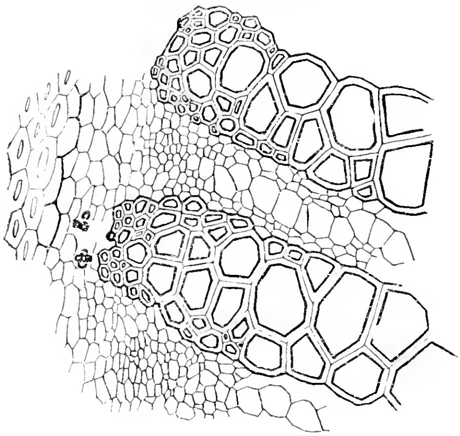


FIG. 14. — *Lycopodium densum*. Transverse section of portion of stele of main rhizome. × 137.

The main subterranean rhizome of *L. fastigiatum* is much shorter than that of the other three species, and is more slender than that of *L. densum* or *L. scariosum*. Two characteristic features of its vascular tissues are the small size of the xylem elements and the sieve tubes, and also the wide double-zoned pericycle. The nature of the pericycle in this species will be seen from fig. 15. It consists of two distinct zones, the inner of which is from four to five cells wide, and shows abundant contents, and stains a reddish-brown with safranin, and an outer zone three to four cells wide, also showing abundant contents, but staining purple with the haematoxylin Evidently this wide pericycle has been developed as a storage tissue, and the stored substance in both zones appears to be starch, although the reason for the different staining-qualities of these two zones is not clear. The cortex consists of an inner, narrow, very strongly sclerenchymatous region of exactly the same nature as in the rhizome of *L. densum*, and a broad median zone of much less thickened cells which are abundantly stored with starch. The outer region of the cortex in this species is peculiar. There is a layer of small-celled compact parenchyma, three to four cells in width, and bounded externally by a strongly cuticularized epidermis which is wholly without stomata, and this is separated from the median rather thick-walled cortical region by a layer of enormously large thin-walled empty parenchyma cells, two or three cells in width. It is rather difficult to say what is the significance of this peculiar wide-celled zone. Possibly it functions as a water-storing tissue. If the rhizome had been epigaeous it might have been interpreted as an aeration tissue. The outermost cortical zone easily tears away in this region, and in dried herbarium specimens of the Browning Pass form I have also noticed the same.

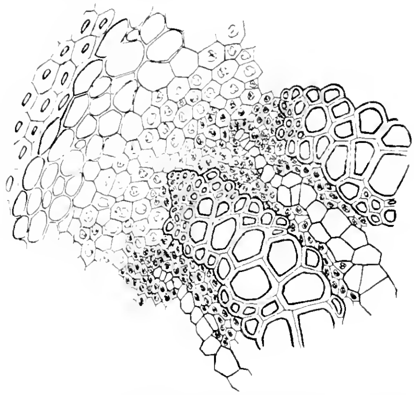


FIG. 15.—*Lycopodium fastigiatum*. Transverse section of portion of stele of main rhizome. × 137.

The main stems of *L. scariosum* are stout and epigaeous, and not very widely spreading. In point of actual size the stele is not much larger than that of *L. volubile*, but it contains twice the amount of vascular tissue, owing to the fact that the xylem and phloem elements are all very much smaller in size than in the latter species. This will be at once apparent from fig. 16, which should be compared with that illustrating the stele of *L. volubile*. In *L. scariosum* there is also an entire absence of the small tracheides flanking the large metaxylem elements, which present so characteristic a feature in the stele of *L. volubile*, and to a smaller extent also in that of the other two species. The number of protoxylem groups in the full-grown stem of *L. volubile* is from ten to sixteen, but in that of *L. scariosum* it is from eighteen to twenty-seven. The stout size of the rhizome is due to the very large cortex, which consists of an almost uniform tissue of not very strongly thickened sclerenchyma. There is no inner strongly sclerenchymatous zone such as exists in the other three species. I did not observe starch in the cortical tissues, although this may possibly be present at certain seasons

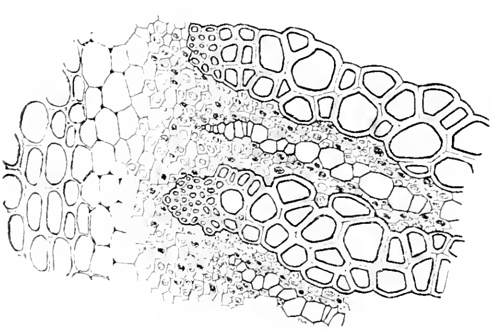


FIG 16. — *Lycopodium scariosum*. Transverse section of portion of stele of main stem. × 137.

of the year. The outer zone of the cortex is noteworthy, and may be compared with that in the rhizome of *L. fastigiatum.* It consists of a rather loose tissue of small roundish thin-walled parenchyma, three to five cells in width, showing air-spaces, and bounded externally by an epidermis which is only slightly cuticularized. There are abundant stomata present. In some places this aerating tissue seems to be in process of breaking down, while there are quite lengthy stretches in which there is seen to be the same development of enormously large irregular-shaped cells separating the outer from the main cortical zones, as also occurs in *L. fastigiatum.* It is possible that in *L. scariosum* this is an adaptation for aeration purposes, and that in *L. fastigiatum* is still persists although the rhizome has become subterranean. The subterranean habit has probably arisen as a modification from the epigaeous trailing stem, and there is no doubt that it is not an absolutely fixed character, as is seen from the case of *L. densum.* However, a simpler explanation is that in both *L. scariosum* and *L. fastigiatum* the peculiar large-celled tissue functions as a water-reservoir. As in the other three species, the aerial branches show a stellate configuration, and there is no modification of the stele in the strobili or in the heterophyllous regions of the plant.

There is thus seen to be a very characteristic form of stele in all the species which belong to the section *Clavata.* This type of stele gives evidence of a greater degree of modification than do the other two main types which occur in the genus. The habit and external form of these species also present the greatest degrees of modification, and it is obvious that the stelar anatomy is in direct correspondence with the habit. The four New Zealand species show some small but interesting peculiarities which can all be best explained by reference to the environmental factors. The stem-anatomy of this section of the genus is thus seen to be in a plastic condition, and some very interesting experiments could be conducted (though perhaps with difficulty) to determine whether or not these modifications are fixed characters. Whether or not the dorsiventral type of stele covers but a single cycle of natural affinity in the section can only be determined by a full study of the other main characters of the species concerned.

The Prothallus.

The prothallus throughout this section is large, compact, long-lived, and more or less deeply buried, and in its wholly saprophytic habit is clearly the most modified of all the *Lycopodium* types. There are two main types of this form of prothallus—viz., the *clavatum* type and the *complanatum* type; and of the seven species of this section whose prothalli are known five conform to the *clavatum* type and two to the *complanatum* type. Bruchmann (5, 6) has described the prothalli of *L. clavatum, L. annotinum,* and *L. complanatum,* and Lang (24) that of *L. clavatum.* Spessard (25, 26) has recently given a preliminary account of the prothalli of *L. clavatum, L. complanatum, L. annotinum,* and *L. obscurum* as they occur in America. The prothalli of the New Zealand species *L. volubile* and *L. scariosum* have been described by Miss Edgerley (12), by Chamberlain (7), and by myself (15, 16). I have also described (16) the prothallus of the other New Zealand species, *L. fastigiatum.*

These types of deeply buried prothalli, living under consistent conditions, do not show in any individual species such a range of variability as do those forms of prothallus which can reach the surface. In fact, the main variations from the normal which I have met with are related to the actual bulk of the prothallus or to the fact that, as in *L. volubile*, it occasionally grows at the surface of the ground and develops chlorophyll. The different species, however, show certain characters, more especially in the structure of the fungal zones, in which they differ from the other species of the same type. These might be viewed as variations from the two main stocks represented by *L. clavatum* and *L. complanatum*, or they may be taken as indicating that the adaptation of the prothallus to the subterranean, wholly saprophytic mode of life has occurred independently in a number of species.

A comparison of Bruchmann's account of the prothallus of *L. clavatum* with that of Lang shows that, although in the main the two descriptions are very similar, there are yet certain particulars in which they differ. These refer more particularly to the main fungal and store tissues. It will be worth while to notice these details, in view of the fact that, as will be seen below, some of the distinguishing details in the two New Zealand species are remarkably characteristic. Some of the differences manifest between Bruchmann's and Lang's accounts and figures are to be explained by the fact that the longitudinal sections which the latter figures and describes are not median. Lang himself in a footnote mentions that the first-formed conical projection at the base of the prothallus was not at first noticed by him and hence does not appear in his figures. On account of this, the layer of flat, elongated cells belonging to the central core, which Bruchmann describes as lying next to the starch-containing store tissue where the latter abuts on to the centrally placed core of large-celled empty tissue, does not appear in Lang's figures and is not mentioned by him, for in the sections on which he bases his description it was, of course, cut transversely. Also, Bruchmann's figures show a very much thicker subepidermal cortical fungal zone than do Lang's—at least, towards the upper half of the prothallus. Again, Bruchmann speaks of the starch-containing store cells as polyhedral in shape, but Lang says that they are not infrequently elongated in the same direction as those of the palisade layer. Bruchmann figures the palisade layer as a very clearly marked one in which the single row of palisade cells is very much elongated in a direction at right angles to the surface, but in Lang's figures the cells are much shorter and are sometimes in two rows. Now, all these differences can be accounted for by the fact that Lang's sections, not being exactly median, have cut the various cell-layers somewhat obliquely. These differences in the two accounts, therefore, must not be taken to show that the structure of the prothallus of *L. clavatum* is in a variable condition. A more important difference between the two accounts lies in the fact that Lang describes the presence of the fungus in the starch-containing store tissue as penetrating not within the cell-cavities but in the cell-walls, whereas Bruchmann says quite definitely that it stops short with the palisade layer, and in his figures he shows it to be altogether absent from the store tissue. Is it possible that the fungus enters this tissue in rather old prothalli only, and that this must be held to account for the difference? Lang's description in this particular agrees with my own observations on the prothallus of *L. volubile* and *L. fastigiatum*. There is no need for me here to enter into any of the other details of the prothallial tissues.

In the prothallus of *L. volubile* the most characteristic feature is the enormous development of the palisade layer. This layer constitutes generally by far the greater bulk of the whole prothallus. The cortical fungus layer corresponds with that of *L. clavatum* except that in the New Zealand species it is only from two to four cells in width. In a median longitudinal section the elongated cells of the palisade layer are seen to be from four to six deep. They overlap one another, and, contrary to what Lang has described in *L. clavatum*, they show the presence of dense fungal coils in all the cells, as well as the mycelium which inhabits either the cell-wall itself or the spaces between the cells. At its interior boundary the cells of the palisade layer are shorter in form, and where they abut on to the upper region of empty parenchyma cells the cells of the latter tissue are much flattened in form. Miss Edgerley, in her account of this prothallus. (12. p. 96) says that "the whole of the central part of the prothallium is occupied by large thin-walled parenchymatous storage cells, in which starch is stored in great abundance. The cells of this tissue bordering on the palisade layer are often smaller and more densely filled with starch-granules." I found no starch in any of the older or the young prothalli which I sectioned. Possibly this difference is to be accounted for by a difference in the season of the year in which Miss Edgerley's and my own prothalli were collected. The upper fungus-free region of the prothallus, which bears the sexual organs, is in full-grown specimens very irregularly developed into large rounded protuberances, which overlap the original saucer-shaped upper surface. The fungal zones extend into such of these protuberances as lie towards the rim of the upper surface. In such cases as these in some longitudinal tangential sections the prothallial epidermis and the cortical fungal zone extend almost entirely around the section, the whole of the interior being occupied by palisade tissue, while a very small upper corner of the section consists of the upper non-fungal tissue. The youngest prothalli sectioned consisted almost entirely of fungal tissues, more especially of the palisade layer, with a very feeble development of the upper non-fungal zone. There is no store tissue containing starch either in the young or mature prothalli such as Bruchmann figures in *L. clavatum*—in fact, the only starch which I found present consisted of a few scattered grains is some of the palisade cells. One very large prothallus, which grew at the surface of the ground, and whose upper region was vivid green in colour, showed a considerable divergence from the normal structure of the prothallus as just described. The palisade layer was four to five cells in thickness, but by far the major bulk of the prothallus consisted of the upper non-fungus-containing parenchyma. Moreover, this contained a large accumulation of starch both in the layer immediately underlying the small-celled, generative region and also around the meristem. The starch was also thickly accumulated around the "foot" of a developing plantlet. In the palisade cells there was an abundant accumulation of oil-globules and starch, and the epithelial cells of the "foot" of the young plant were densely crowded with contents. I have several times come across these green, surface-growing prothalli.

The nature of the fungal zones in the prothallus of *L. fastigiatum* is identical with that of *L. volubile*. The most striking feature in it is the enormous development of the palisade layer. In some of the largest prothalli sectioned lobing of the upper surface had taken place and the fungal zones had extended into these lobes, giving to the sections a very irregular appearance. Also, in the large prothalli the lip sometimes greatly grows over inwards, with the result that the fungal zones become somewhat superimposed upon one another, as has been described above in *L. volubile*. The youngest prothalli found by me were of two forms. The first were of the usual saucer shape, showing the first-formed conical projection on the lower surface. Those of the second form were dichotomously forked, as I have previously described (16, pp. 271–73), showing the two equally developed cylindrical branches inclined to one another at an acute angle, the point of the angle being the first-formed part of the prothallus. The usual fungal zones extend up the outside of the two branches, while their opposed faces, which are in point of fact the upper surfaces of the branches, consist of the empty large-celled parenchyma. There is a very marked groove at the extreme end of each branch, where the meristem is situated. This lies somewhat towards the inner side, so that the antheridia, which are present in large numbers, extend partly down the inner side of the arms. I have not up to the present been able to trace the next stages in the growth of the prothallus from this branched form, but enough has been said to show that it constitutes a very interesting modification of the usual compact saucer-shaped form, and possibly provides a transition between it and the branched epiphytic type in which the meristem is confined to the ends of the branches. One other variation from the normal must be described. I sectioned a fairly young prothallus of the saucer form, which showed absolutely no fungal infection or differentiation of its tissues into zones. The narrow outer layer of cells around the outer portion of the prothallus had collapsed, but I could see no traces of fungus in the collapsed cells. The rest of the prothallus consisted of quite uniform large cells of the usual parenchyma form. There was an abundant development of antheridia around the entire lip. I cannot now tell whether the prothallus was situated at the surface of the ground or not. It is, of course, possible that the whole of the fungal zones had been eaten away uniformly by an insect while the prothallus was still growing. The fact that the inner boundary of the palisade layer in this type of prothallus is always exceedingly well marked and even lends itself to such an explanation. I considered this peculiar instance worthy of record, not in order to include it here as a striking example of the plasticity of the *L. fastigiatum* prothallus, but so that it might be compared with any other instance of a fungusless *Lycopodium* prothallus, should such ever be found.

The other type of prothallus in this section is that of *L. complanatum* and of the New Zealand species *L. scariosum*. The following details of the structure of the former will be given, so that a comparison may be instituted with the New Zealand species. The prothallus is more or less carrot-shaped in form, with its lower region tapering even when fully grown, so that the zones of tissue in the vegetative region are much narrower than they are in the prothallus of the *clavatum* type. However, as a result of its greater length these tissues about equal in amount those of the latter type. The central core of cells is narrow, and the cells themselves are poor in contents and are elongated in the direction of the prothallus axis. The palisade tissue consists of very narrow, much-elongated cells, which show their greatest length in the thickest part of the prothallus. This zone, which is only one cell deep, serves as a store for reserve substances, there being no store tissue corresponding to that which is found in *L. clavatum*. In the lower region of the prothallus the palisade cells are empty, but higher up they are full. The fungal hyphae are found only in the cell-walls of this zone, and they sometimes form between the cells large oval spheromes. There is the usual fungal cortical tissue. This prothallus sometimes produces one or more secondary prothalli as shoots on the primary prothallus.

With regard to the prothallus of *L. scariosum*, Miss Edgerley says that the palisade layer is several cells wide; but I find that, whereas in sections which are not median the palisade tissue presents this appearance, in sections where it is cut exactly longitudinally it is found to be only one cell thick. These cells are exceedingly long and narrow, and occasionally divide transversely. Again, Miss Edgerley describes the cell-layer of the central core which abuts on to the palisade tissue as containing abundant starch and acting as a storage tissue. I was not able to find this in any of my sections, but, as in the case of the prothallus of *L. volubile*, this may be due to the fact that our specimens were collected at different seasons. On the whole, the main feature in which the prothallus of *L. scariosum* differs from that of *L. complanatum* is in the large, irregular size attained by the mature individual. Young or even half-grown prothalli sometimes show the tapering carrot form, but sooner or later this becomes modified owing to the enormous development of the centrally placed core-cells, which evidently must function as a store tissue. However, even very young prothalli sometimes show a rounded lower vegetative region instead of the tapering one, the first-formed conical region being in these cases quite blunt. This difference, then, is to be referred to the manner of development of the prothallus from the beginning. Whereas in *L. complanatum* the increase in girth is very gradual, in *L. scariosum* it is generally rapid from the actual point upwards. This may be occasioned possibly by the early development of the storage function of the central core of cells, or it may be due to a deeper constitutional difference between the two types. In this connection, however, it is significant to note that the type of heterophylly in both species is alike. In Part I of these Studies (16, figs. 49–52) I have figured several very irregularly grown large prothalli. As Miss Edgerley notes, the most striking feature in the large prothallus of this species is the relatively small proportion of the bulk of the vegetative region which is occupied by the fungal tissues, a feature in which it is strikingly different from that of *L. volubile* and *L. fastigiatum*.

It will thus be seen from a comparison of the prothalli of the species mentioned that as regards their fungal zones the two types are not very dissimilar. There are two main points of difference to be noticed: first, the increase of girth of the *clavatum* type from the original point upwards is more rapid, and hence the height of the prothallus is less than in the case of the *complanatum* type; and, secondly, the extent of the upper generative tissue in *L. clavatum* is greater than in the latter species, these two features being closely interdependent. The fact that in *L. clavatum* the upper generative region is more or less saucer-shaped at its surface, with a distinct rim, and is often accompanied in large specimens by a development of warty protuberances, whereas in *L. complanatum* it takes the form of a compact semicircular crown, would seem to be simply the physical result of the two types of growth. Lang suggests that "the flattened and still more the trough-like form which these older prothalli present may be an adaptation to facilitate fertilization" (24, p. 296). There is no doubt that this particular shape does serve this purpose, but I would be inclined to explain the difference in form between the two types in rather a different way. I have found that the prothalli of *L. scariosum* always occur at a greater depth than those of *L. volubile* and *L. fastigiatum*. In localities where the prothallus of *L. scariosum* and *L. fastigiatum* were growing together I always unearthed the latter from the layer of humus which immediately underlay the carpet of moss, &c., whereas the former had to be dug out of the deeper-lying clay. Not infrequently, too, I have found the prothalli both of *L. volubile* and of *L. fastigiatum* amongst the thick moss itself, where they show no adhering earthy matter at all, or even, as in the case of the former species, growing on the surface of the soil with the upper region of the prothallus exposed to the light, being then in their upper region a vivid green in colour. In Part I of these Studies (16, p. 262) I noted that the prothalli of *L. scariosum* often lie at a depth of 8 cm. to 10 cm. I have not been able to find in Bruchmann's papers any reference to the comparative depth at which he found the prothalli of the three European species. I would suggest that the two different types are an expression of the fact that the species of prothalli which conform to them grow respectively in a shallower and in a deeper stratum of soil, the deeper-growing prothallus having more thoroughly departed from the self-nourishing chorophyll habit. The fact that there are two such distinct types of prothallus in the *Clavata* section, and that along with these there go two distinct types of heterophylly, may perhaps show that more than one distinct strain of evolution is included in this section.

The Young Plant.

Heterophylly.—The development of heterophylly in the seedling of *L. volubile* and *L. scariosum* opens up the question as to what is the nature of the stimulus which calls forth this character. That it is an extreme instance of adaptation is beyond doubt. Heterophylly is present in the genus *Selaginella*, but it would be difficult to take the view that in the *Lycopodium* genus it is a phylogenetic character. Thus modern systematists have abolished Baker's subgenus *Diphasium*, in which he groups together the heterophyllous species, and have distributed these species according to their more natural affinities. Heterophylly is an adaptation which has appeared also in the section *Inundata*.

What has been the particular external stimulus to call forth this character? It is to be noted that heterophylly is not found in any species whose main stem is subterranean, and whose lateral branches accordingly emerge from the ground in a stiffly erect and tree-like form. *L. densum* and *L. fastigiatum* possess this latter habit. Their erect, tree-like aerial branches are obviously stimulated by the light in no one direction more than in any other. Certainly the aerial branches of *L. scariosum* frequently grow erect in the lowlands of Westland, as described above, and still possess the characteristic heterophylly, but this is simply on account of the luxuriant massed development of the plants in these localities. And, again, the species *L. Jussiaei* Desv. of South America, which is joined by both Pritzel and Baker with *L. scariosum*, shows more or less erect-growing branches along with the heterophyllous habit. But in both these species the flattened nature of the branching is preserved even in the more erect-growing branches, the case being very different with the dendroid, fastigiately branched shoots of *L. densum* and *L. fastigiatum*. Heterophylly, then, is an adaptation which goes hand in hand with the more or less flattened habit of the branches in which they are somewhat spread out in the plane of the surface over which they are growing. The particular stimulus to the development of the large leaves and to their dorsiventral arrangement is probably that simply of the light, which, falling more or less at right angles upon the branches, stimulates the leaves, which are tiny and needle-shaped and catch very little sunlight, to place themselves in such a position and to acquire such a form that they can intercept the maximum amount. In both *L. volubile* and *L. scariosum* the large-shaped leaves are not naturally borne in the lateral position but adapt themselves to it. In the case of *L. volubile* two neighbouring orthostichies on either side approximate to one, and in *L. scariosum* two dorsal orthostichies bend over one to either side. In both species the ventrally borne leaves, which catch no direct sunlight, become mere scales, and in *L. volubile* they become also very scattered and few in number.

In sheltered, shady places plants of *L. volubile* are found which show the reversion foliage. Here no direct sunlight falls on the branches, the light being diffuse, and the stimulus to a dorsiventral disposition of the leaves is almost completely lacking. The equal all-round-the-stem stimulus exerted by the diffuse light results in the tendency to a more all-round development of the leaves; or would it be more correct to say that the inherited constitution of the plant has the opportunity to assert itself over the acquired character? Which is the correct way to express it depends, of course, on whether or not the heterophyllous character which originally came about as an epharmonic adaptation has altered the hereditable constitution of the species. Some botanists, of course, are quite ready to believe that such a thing is possible, and that this takes place in nature more readily than is generally imagined, while others would hold that an epharmonic adaptation must inevitably revert as soon as the controlling stimulus is removed. In the young plants of *L. volubile* and *L. scariosum* the characteristic heterophylly appears while they are still erect in growth. In *L. scariosum* it appears almost from the very first, there being but a few scattered scale leaves formed before the characteristic dimorphism is in evidence, and there being practically no transition stages. In *L. volubile* the dimorphism of the leaves appears first when the plant has attained, compared with *L. scariosum*, a considerable size (16, figs. 97, 98). It appears first in some particular branchlet or other, and develops its characteristic appearance in gradual stages, so that a plantlet possessing six to ten branchlets will show probably every stage in the development. Since the heterophylly appears in the plantlet before it has adopted the plagiotropic habit, it would seem that, after all, this character has actually become fixed, and that this has become so to a greater degree in *L. scariosum* than in *L. volubile*, for it appears there much earlier in the ontogeny. I have not actually observed whether or not the young plants have their dorsiventral branches turned at right angles to the direction of the light, but I should judge that, if such were the case, heterophylly ought to begin in all the branches at the same time. However, the plantlets grow generally amongst thick moss and other vegetation where they get no direct sunlight at all.

The Plagiotropic Habit.—The sporelings of *L. volubile*, *L. fastigiatum*, and *L. scariosum* maintain an erect growth for a much longer period than do those of the species which belong to the *Inundata* and *Cernua* sections. The upright stems which arise from the protocormous rhizomes in *L. cernuum*, *L. ramulosum*, and *L. laterale*, and the stems of the vegetatively produced plantlets of *L. Drummondii*, almost immediately bend over and flatten themselves in the plane of the ground, and a strong adventitious root emerges at right angles from the stem and binds the latter to the ground. Whether or not it is the early development of the first adventitious root which compels the young plant to so soon adopt the plagiotropic habit, or whether rather it is the strong plagiotropic habit which determines that even the first adventitious root shall emerge at right angles from the stem at the point at which it is given off from the vascular cylinder, and that it shall not penetrate down the tissues of the cortex as it does in *L. Selago*, I am not able to say. The fact remains, however, that the species which belong to the *Inundata* and *Cernua* sections characteristically differ from those of the *Selago* and *Phlegmaria* sections in this respect, for in the *Selago* section, although roots do emerge at different points on the lower more or less sprawling adult stem, yet in the young plants they emerge at the base, and throughout the life of the plants they may be seen in transverse sections traversing longitudinally the cortical tissues of the stem. In the young plants of *L. volubile*, *L. fastigiatum*, *L. densum*, and *L. scariosum*, which belong to the *Clavata* section, there is a very marked erect stage in the ontogeny. Here the prothallus is subterranean, whereas in the *Inundata* and *Cernua* sections it is surface-growing, and thus necessarily the stem is erect before it can even develop its foliage. However, I have often observed that the naked subterranean stems on the deeply growing prothalli of *L. scariosum* may be straggling and bent; but this will probably be the result merely of the presence of stones, &c., in the soil around which the stem has to find its way. Thus in these plants the stem-axis emerges perpendicularly out of the soil. However, contrary to what takes place in the young plant of the *Inundata* and *Cernua* sections, the stem continues to grow erect. A young plantlet of *L. densum* found by me was no less than $4\frac{1}{2}$ in. in height, being in every respect truly erect. Besides the first-formed root there was present a second, the first "adventitious" root, which was borne on the underground portion of the stem just above the "foot." The young plants of *L. scariosum* frequently grow erect and branch to a height of $1\frac{1}{2}$ in. to 2 in., and those of *L. volubile* and *L. fastigiatum* to an even greater height. It will thus be seen that in the *Clavata* section there is in the ontogeny a strongly marked erect stage which precedes the adoption of the plagiotropic habit. The adventitious roots I found in no case to travel down through the cortical tissues of the stem, but they emerge immediately from it at right angles. Miss Wigglesworth (31), however, records an instance in a plantlet of *L. complanatum* in which she found one rootlet which had travelled for some distance down the cortex of the stem instead of pushing its way directly to the periphery. This must certainly be regarded as an abnormality. In the erect plantlets of all the New Zealand species the adventitious roots commence usually to arise on the subterranean portion of the stem just above the foot, and are also frequently to be seen projecting out at right angles from the aerial region of the stem. There can be no doubt that when these roots do reach the ground they help the plant to bend over and adopt the trailing habit of growth. I have not infrequently seen well-grown erect plantlets of *L. volubile*, which had branched several times, on which one or more strong, naked adventitious roots an inch or two in length, which had not yet reached the soil, were present immediately behind the tips of the branches, the terminal portion of one or other of the branches having begun to increase in stoutness in anticipation of its greater extension in length.

In the *Selago* section some of the species are stiffly erect, but in others the lower part of the stem is somewhat recumbent. *L. Selago* itself shows in the different forms in which it occurs in New Zealand both these habits of growth. *L. varium* also in its smallest forms is more typically erect than in the larger forms. Whatever may have been the extent of growth of the ancestral stock of the modern genus, herbaceous or more tree-like, the erect species that now exist do not possess the capacity of extensive growth. It would seem to be more probable that the modern species have sprung from an herbaceous stock than that from the whole genus the character of secondary growth, whether of vascular or of cortical tissues, has been completely lost without the slightest trace having been left behind.

In the *Selago* and *Phlegmaria* sections, owing to the fact that the primitive dichotomous nature of branching is the characteristic one, the plant is strictly limited in size. In the *Inundata* and *Cernua* sections both dichotomous and monopodial branching is to be found. The branching of the young plant of *L. cernuum*, *L. laterale*, and *L. ramulosum* is always at first dichotomous. In *L. ramulosum* this is more or less maintained throughout the life-history, the rosette form which arises as the result of the repeated dichotomies being very characteristic. This species shows an interesting transition from the subaerial to the subterranean habit of growth, the branches in some localities growing down into the soil and functioning as rhizomes. In *L. laterale* this has taken place to a greater extent, so that there the branches of the plant have become permanently subterranean. However, in this species also the growth of the plant is limited, for sooner or later these rhizomes emerge from the ground as the aerial shoots. The branching of the mature plant of *L. Drummondii*, however, is monopodial, and the plant itself is wholly above-ground, so that the way is open for it to spread extensively; but it never attains a greater length than 6 in. to 8 in. All the members of the *Inundata* and *Cernua* sections are very limited in their extent of growth, except *L. cernuum*, the replacing in them of the dichotomous by the monopodial habit of growth resulting in very little increase in the size. In *L. cernuum*, however, the case is different. Here too the branching is dichotomous in the young plant, but the adoption of the monopodial habit leads to the unlimited growth both of the main stem and of some of its lateral branches. This species alone of those which belong to these two sections spreads itself over dry localities, the others being all confined to a marshy habitat. It would seem best, then, to regard this character in *L. cernuum* as quite a recent adaptation, this species, at any rate with respect to its habit and external form, being by no means typical for the two sections. The trailing habit of *L. cernuum* is not so characteristically plagiotropic as is that of the species comprising the *Clavata* section. It provides in this respect a transition, for its main stem is more ascending than creeping. The apex is continually striving to ascend, and it is only through being weighed down to the ground through its own increase in length that the stem then puts forth a bunch of adventitious roots, the series of such loops in which the plant grows showing that it consistently maintains the ascending habit. Amongst the *Leptospermum* scrub in the gum lands of North Auckland, where this species grows most luxuriantly I have sometimes seen the stems scrambling over the vegetation. However, this is by no means so marked a habit as in *L. volubile*, in which latter species striking modifications have taken place as a result of this habit.

In the young plants of the species which comprise the *Clavata* section the monopodial habit of branching is present before ever the young plant becomes plagiotropic; in fact, in most cases there is no dichotomous branching at all (16, figs. 97–101). The terminal region of the main stem suddenly assumes a stouter form and puts forth an adventitious root. This most often takes place after the plant has begun to bend over. If we are to argue from the facts of the ontogeny we must certainly conclude that the plagiotropic habit of growth is a recent adaptation, and that the power of unlimited growth is the most recent feature of this habit. This is the conclusion also to which the facts relating to the *Inundata* and *Cernua* sections seem to lead us. There is one feature which probably is a still further adaptation, and that is the subterranean habit of growth of the main stem. In *L. volubile* and *L. scariosum* this has not taken place, but in *L. fastigiatum* and *L. densum* the young trailing stem early buries itself in the soil. This also is the manner in which the subterranean habit comes about in the developing plant of certain of the species of the *Inundata* and *Cernua* sections.

The "Foot."—In all the species which belong to the section *Clavata* the young plant possesses a very large "foot" by which it is attached to the prothallial tissues. This foot evidently functions as an absorbing-organ for a considerable time, for the epithelial cells show the presence of abundant contents even after the sporeling has attained a considerable size. This I have already indicated earlier in this paper in my description of a large surface-growing prothallus of *L. volubile*. Miss Wigglesworth (31) suggests that it may even function after the disappearance of the prothallus itself. Lang (24) figures the same epithelial layer in the case of the young plant of *L. clavatum*. Both Miss Wigglesworth and I have found that a strand of vascular tissue containing both xylem and phloem passes off from the main stele of the plant into the foot. The former has demonstrated this in the case of *L. complanatum*, illustrating it with a series of figures, but she states that she did not find this condition in the young plants of *L. clavatum*. In a previous paper (16, p. 285–86) I have described the presence of this foot strand in the young plants of *L. volubile*, stating that whereas in the smaller plantlets the strand consists of small thin-walled cells with abundant cell-contents, in older plantlets a few tracheides are also present. I also stated in the same place that in the exceptionally large "foot" of *L. scariosum* only in the sections nearest to the main stele was any small-celled tissue to be seen, and this contained no tracheides, and also that in the case of *L. fastigiatum* the strand was not developed to the same extent as in *L. volubile*. I concluded that "the development of vascular tissue in the foot of the young plant varies in extent in different individuals of the same species, and possibly this is dependent simply upon the size to which the parent prothalli may grow." It is evident, therefore, that in this organ also, as in the form and structure of the prothallus, the species composing the *Clavata* section are in a condition of plasticity.

Summary.

In this paper I have described the variations which I have observed to occur in the main characters of the New Zealand species of *Lycopodium*, and my aim has been to show that these characters must be regarded as being more or less in a condition of great plasticity. Also, at the risk of being tedious, I have noted, in order to institute comparisons, some of the facts relating to the plasticity of other species of the genus. These variations in form and structure can, of course, be viewed either as fixed characters or as characters which are maintained only so long as the controlling external conditions are present. This is a question which can only be settled by experimental cultivation of the plants and prothall concerned.

The modern genus shows certain main types of form and structure in accordance with which Baker, and more recently Pritzel, has classified the various species. That the latter's classification is a natural one seems to follow from the fact that these types do not relate to one character only, but that all the main characters of the plant, both gametophytic and sporophytic, are more or less consistently interdependent. The different types of the prothallus have been regarded by some botanists as almost unrelated to

one another, representing quite distinct Lycopodiaceous stocks. This was the conclusion arrived at by Treub from his study of the prothalli and young plants of several species belonging to the *Selago*, *Phlegmaria*, and *Cernua* sections, and by Bruchmann also from his study of the prothalli of several European species. Lang, however, pointed out (24) that in spite of the great differences existing between these types there was a common fundamental structure to be traced in all, and that the various modifications of this structure were all obviously in accord with the particular mode of life peculiar to each prothallial type. He stated his belief that it was the change from the self-nourishing chlorophyll condition to a saprophytic condition of life which has determined the lines upon which the *Lycopodium* prothallus has evolved, and he pointed to the variations which are known to occur in the prothallus of *L. Selago* as illustrating clearly how it has been possible for the more modified types of prothallus to arise. Further, taking into account the fact that the mode of life of the different types of prothalli, as exemplified in the twelve species whose prothallus was then known, was in close accord with the habit of the sporophyte generation, he suggested that it was possible that the genetic affinities of the species of *Lycopodium* will be found to coincide exactly with the biological divisions of the genus.

The facts which I have brought forward in this paper relating to the variations of the main types which occur in the New Zealand species, and also to the great range of variability which the individual species show under the manifold external conditions under which they are found in this biological region, seem to be thoroughly in accord with Lang's suggestion. Not only do the prothalli of these species provide transitions between the main types in the same sense as does that of *L. Selago*, but so also do the other main characters; in fact, these variations show that the whole genus is in a state of great plasticity, and that the various types of habit and external form of the sporophyte, of the nature of the fertile region, of the vascular anatomy, and of the form of prothallus and young plant, can be best explained only by viewing them together as adaptations which have proceeded more or less hand in hand.

At the same time, the eleven New Zealand species bring to light no new main types either of prothallus, of young plant, or of stelar anatomy. Our knowledge of these species serves to emphasize the fact that there are three main cycles of affinity to be distinguished in the modern genus—namely, the *Selago-Phlegmaria* group, the *Inundata-Cernua* group, and the *Clavata* group. In the different parts of this paper I have tried to institute a distinction between characters which are recent and adaptive and those which are phylogenetic, and in the light of these facts have expanded more fully the conclusions with regard to the interrelationships of these main groups which I reached in a former paper (16, p. 302). Stated briefly, these conclusions were that the *Selago* section must be held to comprise the most primitive and least modified members of the modern genus, and that the *Phlegmaria* and *Clavata* sections have been independently derived from it, the former being less modified than the latter. The *Inundata* and *Cernua* sections I suggested should best be placed in a group apart, as having been derived from ancestors common to themselves and to the *Selago* section but independently of the latter. I will now proceed to sum up the results of the present paper in terms of this thesis.

The statement that the *Selago* section comprises the most primitive members of the genus by no means suggests that with respect to all its characters it is primitive. The *Inundata-Cernua* group is generally held to possess the most primitive form of prothallus, being one which is least modified of all from the original self-nourishing chlorophyllous condition. Nor does this belief in the primitive character of the *Selago* section rest upon a basis of palaeontological fact, very little evidence of this kind being forthcoming, but it is founded upon the broad fact that in a genus which is in an exceedingly plastic condition the characters of this section show, on the whole, the least degree of adaptation to external conditions. The species of the *Selago* section are typically orthotropic in habit, and dichotomously branched. *L. Selago* itself shows very little differentiation between fertile and sterile regions of the stem, although in some forms the beginnings of this may be seen. Seeing that the strobilar habit had been thoroughly adopted by the Carboniferous Lycopodiales, it might seem natural to infer that the modern members of the *Selago* section were in process of losing it by reduction. However, from another point of view it would be unnatural to infer this, for the type species, *L. Selago*, is the most widely spread and highly variable of all the species of *Lycopodium*, and this would certainly not be the case if it occupied a position as the most recent member of a long reduction series. The most natural view would seem to be that *L. Selago*, with its congeners, has originated from a stock which did not possess the strobilar habit. The stelar anatomy in this section is typically radial, a type of stele which is undoubtedly as primitive as the circular protostele. The prothallus of *L. Selago* is in a much more plastic condition than are those of the *Phlegmaria* or *Clavata* sections. The latter are greatly modified in accordance with their respective modes of life, having practically abandoned the chlorophyll condition, and have acquired a definite and probably fixed form in relation to the saprophytic condition. The prothallus of *L. Selago* is very variable in form according as it occurs at or beneath the surface of the soil, and shows a transition stage between the chlorophyll and the completely saprophytic habit. Bower indicates the significance of this when he says, " A plant which shows such plasticity is clearly not far removed from the self-nourishing condition of the prothallus which was probably the primitive condition for them all " (3, p. 345). Lastly, the *L. Selago* type of embryo is the simplest and least modified of all the types in the genus, and may well be regarded as primitive. These, then, are the evidences of primitive simplicity which point to the *Selago* section as comprising the most primitive members of the genus, and from this as a premise the argument as to the relative position of the other sections can be built up.

A chain of forms links up the two typical forms *L. Selago* and *L. Billardieri* with respect to the external form of the plant and the differentiation of the fertile region, *L. varium* being an important connecting-link. The stelar anatomy is identical throughout the whole chain of forms, what modifications there are being dependent simply upon the size of the plant and occurring alike in both sections. In all the epiphytic species in which it is known, whether of the *Selago* or of the *Phlegmaria* section, the prothallus is of the branched *Phlegmaria* type. This is so in the rock-epiphyte *L. varium* and the tree-epiphytes *L. Billardieri* and *L. Billardieri* var. *gracile*. This form is regarded as bearing reasonable comparison with the form which is adopted by the prothallus of *L. Selago* when growing well below the surface. The form of the sporeling plant of the three New Zealand species is identical with that of *L. Selago*, the first leaves being large, and not scale-like, and similar to the mature foliage. The typical epiphytes are for the most part pendulous, although some, by reason of the strongly thickened cortex, are more rigid. *L. Billardieri* sometimes grows on the ground, and is then more or less erect, with shortened overhanging strobili. *L. varium* also provides a striking gradation in form from the stiffly erect to the pendulous habit. The entire genus is characterized by the fact that the roots are adventitious and arise behind the growing apex. In the sections *Selago* and *Phlegmaria*, in accordance with the habit of growth, the roots emerge at the base of the stem, penetrating down the cortical tissues in order to do this. In *L. Selago* the characteristic orthotropism is modified by the somewhat sprawling character of the lower region of the stem, and the roots emerge from the stem throughout this region. In *L. varium* and *L. Billardieri* the stem is more vertical, whether erect or pendulous, and the roots are borne only in a bunch at the base. The transition between the *Selago* and *Phlegmaria* conditions of the fertile region is strikingly exemplified in *L. varium* and *L. Billardieri* var. *gracile*, which may on the one plant show practically all stages between a wholly undifferentiated condition of the fertile region and a special sporophyll and special strobilar formation. At the base of mature xerophytic plants of *L. Selago* the leaves are of the larger form which is characteristic of the mesophytic variety, and in the embryo plant the first leaves are large and not scale-like. This would seem to indicate that the immediate ancestors of the species of the *Selago* type possessed leaves which were larger than the acicular or scale-like leaves of the common Lycopodiaceous form. The three New Zealand species which belong to the *Phlegmaria* section, as also many others, all possess the larger form of leaves. The fact that not a few epiphytic species have the acicular form of leaf may indicate that the large leaf is not merely a mesophytic character, but is an indication of the presence of more than one line of evolution in the *Phlegmaria* section. It is, of course, probable that the epiphytic habit has been adopted by species which are not immediately related, but that there have been parallel cases of adaptation to similar conditions, and it is possible that these species may have sprung not only from members of the modern *Selago* cycle of affinity other than *L. Selago* itself, but even from related forms now wiped out. However, in the New Zealand species we can trace a continuous chain from *L. Selago* to *L. Billardieri* through *L. varium*. Thus a comparison of the New Zealand members of the *Phlegmaria* section with *L. Selago* brings forward facts which are in close accord with the belief that the epiphytic species have all been derived from the *Selago* cycle of affinity, and that the evolution of the characteristic *Phlegmaria* plant-form, strobilus, and prothallus has been determined by the epiphytic habit. Moreover, the close similarity between the two sections in respect to their chief characters may be regarded as sufficient ground to justify the grouping of these two sections as one natural division of the genus.

When we turn to those species which are classified in the *Clavata* section we find that the main characters of both gametophyte and sporophyte are in a less variable condition than are those of the *Selago* and *Phlegmaria* sections. They have become more fixed in form and structure, and are all obviously in direct harmony with the mode of life. The individual species do not, on the whole, show such a wide range of variability in the external form of the sporophyte or in the nature of the fertile region as do, for example, the species *L. Selago*, *L. varium*, and *L. Billardieri*, although certain characteristic "fixed" features are to be found in almost every species. However, in the life-history there is to be found striking evidence of the fact that the mature form and structure of the plant is a more or less recent modification. In the young plant the habit is orthotropic for a lengthy stage. The stimulation of the cortical and stelar tissues to an increase in girth does not take place till after the stem has begun to assume the plagiotropic habit, and is then localized in its terminal region. This indicates that the character of unlimited growth from a broad apex has been an added feature in the phylogeny. The character of heterophylly makes a somewhat earlier appearance, though not so early in the sporeling of *L. volubile* as in that of *L. scariosum*. The stelar anatomy of the stem is primarily radial, as in the *Selago* and *Phlegmaria* sections, but this becomes modified to a characteristic dorsiventral arrangement by the restriction of the branching of the mature stem to one plane. The large size of the stele and the differentiation of the xylem and phloem into large conducting elements and flanking storage elements has come about simply through the extended growth of the plant, this being most marked in the scrambling stem of *L. volubile*. The subterranean habit of the main stems of *L. densum* and *L. fastigiatum* is an extreme modification and is only found in a few of the species. In some species—for example, *L. densum*—the cones are very numerous, every terminal branchlet in the upper portion of the erect aerial shoot being fertile. In this case the cones are quite short and are not always erect, and there is no suggestion of a pedicel. In other species—for example, *L. scariosum* and *L. fastigiatum*—there is a great restriction in the cone-formation, only the main branchlets being fertile. The cones are here long and club-shaped, and are raised on long pedicels through the continued growth of the axes of the branchlets. Moreover, the pedicels sometimes branch, and also sometimes even the cones themselves. This club-shaped condition of the fertile region must be considered the most modified form of strobilus in the plagiotropic species of *Lycopodium*, except that the pendulous strobili of *L. volubile* are an extreme modification. That the club-shaped cone is not a phylogenetic feature, but an adaptation only, seems to be indicated by the fact that in *L. fastigiatum* both the *densum* condition and the *scariosum* condition occur in a most marked degree.

The prothallus shows two main types which are adapted to a subterranean mode of life. It is noteworthy that whereas in *L. Selago* the form of prothallus which grows deepest is the branched form, while the compact massive form occurs at the surface, and also that in *L. Billardieri*, &c., the subterranean habit has resulted in a much-branched structure, in the species of the *Clavata* section the subterranean habit goes along with two types of prothallus, both of which show the compact and massive form in a most marked degree. The branching which occurs in the young prothallus of *L. fastigiatum* may be significant in this respect, as indicating that this type has not altogether lost the disposition to branch. In fact, in all the New Zealand species the form of the prothallus is not invariable, *L. volubile* and *L. fastigiatum* showing a lobing of the upper surface, and a pseudo-branching being found in some large individuals of *L. scariosum* (16). Bruchmann (5, 6) has shown also that the lip of the prothallus of *L. annotinum* may grow out into long frill-like protuberances, and that the prothallus of *L. complanatum* may bud. All these features, however, possibly have no phylogenetic significance at all, but are recent modifications. The prothalli of both the *Phlegmaria* and the *Clavata* sections have adapted themselves to a subterranean habit, and have departed from the chlorophyll condition, although the *clavatum* type has done this to a less extent than has the *complanatum* type. As regards the differentiation of the fungal tissues the terrestrial subterranean forms of prothallus show greater modification than does the epiphytic form, but, on the other hand, as regards external form the former have probably kept nearer to the ancestral type than have the latter. I will return to this again in discussing the prothallus of the *Inundata* and *Cernua* sections. It is quite likely that the immediate ancestral stock of the species which comprise the *Clavata* section were erect-growing forms which belonged to the *Selago* cycle of affinity. The stelar anatomy is fundamentally similar throughout, the characteristic differences being readily explained. The adoption of the plagiotropic habit presents no great difficulties of explanation, nor does the difference in the form of the strobilus. The presence of paraphyses on the prothallus of the *Selago* and *Phlegmaria* sections, while serving to emphasize the fact that these two sections together constitute a natural division of the genus, certainly serves also to distinguish between the prothalli of the *Selago* and *Clavata* sections. If this particular character can be considered as being amenable, along with so many of the other characters of the prothallus, to changes in the mode of life, its absence from the *clavatum* and *complanatum* types of prothallus will have no phylogenetic significance. But there is no doubt that it is to such small and constant features as this, especially those connected with both the sexual and asexual reproductive processes, that we are often to look for the most reliable indications of affinity or otherwise. On the whole, it is possible to relate the *Clavata* section with the *Selago* section, although the degree of relationship is clearly not so close as in the case of the *Selago* and *Phlegmaria* sections. In other words, whereas many of the species of the *Phlegmaria* section may be without much doubt linked up with certain of the modern members of the *Selago* section, and even with *L. Selago* itself, the species of the *Clavata* section have possibly been derived from the *Selago* stock at an earlier date, and even from forms of that stock not now existing.

Lastly, we must consider the evidence which is afforded by the variations in the New Zealand species of the *Inundata* and *Cernua* sections as to the natural position of this group. These two sections seem together to constitute a natural division of the genus which is just as clearly defined as is the *Selago-Phlegmaria* division. But there can be no doubt that the *Inundata-Cernua* group stands more or less apart from the rest of the genus, its chief distinguishing characters being the mixed type of stelar anatomy, the surface-growing chlorophyll-possessing prothallus, and the protocorm condition of the young sporeling. The species that are included in these two sections would seem to have departed from the primitive erect habit of growth less recently than have even the thoroughly plagiotropic species of the *Clavata* section, for they show practically no erect stage in the young plant. Moreover, the dichotomous type of branching has been in these sections very little replaced by the monopodial. The cones in *L. laterale* are laterally placed and are sessile, but they are not infrequently terminal, and the branching of the aerial shoots is dichotomous. *L. Drummondii* branches monopodially, and so especially does *L. cernuum*, more particularly in its aerial shoots, but in the young plants the branching is always dichotomous. The branching of the creeping stem in these sections is never confined to the plane of the ground, as it is in the *Clavata* section, but the aerial shoots arise dorsally. Thus the plagiotropic habit as seen in this group is different in nature from that in the *Clavata* section. In a genus in which the main character of the prothallus throughout is a greater or less adaptation to a saprophytic mode of life, the occurrence of a type in which the saprophytic condition is still subordinate to the chlorophyll condition must be regarded as a primitive feature. Included in these two sections are several forms of strobilar formation. In *L. contextum* and *L. cruentum* it represents a near approach to the undifferentiated *Selago* condition, and this may be regarded, along with the dichotomous branching of the stem and the chlorophyllus nature of the prothallus, as an indication of the ancient character of the *Inundata-Cernua* group. The long, erect, club-like pedicelled strobili, and the short unpedicelled numerous strobili borne at the tips of all the branches, both occur in this group, as also in the *Clavata* section. Possibly these two types represent extreme modifications, and, seeing that they both occur in the one species, *L. fastigiatum*, it is probable that they do not indicate any phylogenetic differences between the species.

The protocorm condition in the young plant has been found in all those species of the *Inundata* and *Cernua* sections whose embryogeny is known, but it has never been found in any other section of the genus. Treub considered that he had found an indication of this organ in the embryo plant of *L. Phlegmaria*, but this has never been established. The protocorm is thus a distinguishing character of the *Inundata-Cernua* division of the genus, and is always associated with the surface-growing chlorophyllous prothallus of the *L. cernuum* type. The monotypic genus *Phylloglossum* is also characterized by the possession of a protocorm, and Thomas has shown (29) that its prothallus is of the *L. cernuum* type. Treub elaborated the theory that the *Lycopodium* protocorm is an exceedingly primitive organ, and *Phylloglossum* came to be regarded as the most primitive of vascular plants. However, Bower and Goebel have both doubted that it represents a primitive condition in the phylogeny of vascular plants, regarding it rather as a physiological adaptation. In my accounts of this organ as it occurs in *L. laterale*, *L. ramulosum*, and *L. cernuum* (16) I have concluded on the one hand that it is a physiological development, but that on the other hand, occurring as it does throughout the whole *Inundata-Cernua* division, and being always associated with a type of prothallus which is regarded as little modified from the ancestral type, it must certainly be considered as primitive for this division. Further, the fact that Goebel has described adventitious protocorms in *L. inundatum* (14), and that I have also found them in *L. ramulosum* (17), would seem to indicate that this organ is not to be regarded on a par with the seedling "foot" as an adaptation which has altogether been governed by the nature of the prothallus with which it is associated, but that it is part of the inherited constitution of this division of the genus.

The prothallus in this group is always chlorophyllous and surface-growing, but it is remarkably variable in form, the different forms possibly resulting from the different depths at which the spores germinate. In *L. cernuum* and *L. laterale* the "shaft" may be somewhat elongated or almost suppressed, in the latter case the prothallus appearing more compact and massive in form. Very extreme forms are met with in *L. ramulosum*. Here the short form is relatively exceedingly massive and very much like a young prothallus of the *clavatum* type in external appearance, almost the whole of the bulk of the prothallus, except for the actual crown, consisting of opaque fungal tissues. The elongated form may show as many as five distinct fungal swellings along its length, each swelling being usually associated with a local group of assimilating lobes and sexual organs. This long-drawn-out form may also branch. The prothallus of *L. salakense* is also much elongated.

The question arises as to whether the ancestral type of prothallus was compact and massive or long-drawn-out and delicate in nature. Being situated at the surface of the ground, it would seem that the prothallus would be short rather than filamentous. This would be in accord with the fundamental structure-plan of the prothallus as seen in all the modern Lycopodiaceous types, in which the lower first-formed vegetative region has the form of an inverted cone, and appears especially likely from the fact that this form occurs not only in the *Inundata-Cernua* group but in *L. Selago* also when the prothallus is surface-growing. However, on the other hand, we are probably not to assume that the "primary tubercle" is a primitive feature, for it seems to be abundantly clear in the three species *L. cernuum*, *L. laterale*, and especially *L. ramulosum* that these tubercular swellings are due simply to the localized presence of a fungus element which was, of course, not an original feature of the prothallus. In the prothalli of the *Selago*, *Phlegmaria*, *clavatum*, and *complanatum* types the increase in girth from the spore upwards is always rapid, there being apparently no filamentous stage at all; but this can be readily explained by the fact that infection by the fungus seems there to take place from the very beginning. Also in *L. cernuum* this is apparently the rule, so that the tubercle constitutes the basal portion of the prothallus; but in *L. laterale* and *L. ramulosum* there is generally a well-marked filamentous stage. The young prothalli of both these species are green from the first and remain free from fungus for a considerable period, assuming during this stage the form of an elongated flat filament of cells which shows no localized tubercular swelling of its tissues. Even some of the largest and most drawn-out forms of prothalli of *L. ramulosum* are seen to have their basal region of this form (16, figs. 32B and 32D), the increase in girth of the prothallus having taken place very gradually and the infection of it by the fungus being not localized in one much-swollen region but distributed over several distinct areas. Thus it is probable that the primitive, wholly self-nourishing type of prothallus was filamentous rather than massive, and that the erect growth and radial build came later as the result of the more rapid development of the tissues consequent on the infection of the lower region by the fungus element.

The "mixed" type of stelar anatomy with much-extended protoxylem groups characteristic of the *Inundata* and *Cernua* sections is in striking contrast with the definitely radial type which is the primary stelar structure of the rest of the genus. This mixed type is initiated by the precedence of the leaf-trace system over the cauline cylinder in the young plant, but is marked throughout the whole life of the plant. This character, along with others that have been mentioned, gives to the *Inundata-Cernua* group a position definitely apart from the other sections of the genus.

Thus, although some of the main characters of the species of these two sections are probably recent and adaptive, especially as regards the external form and habit of growth of the sporophyte, others are undoubtedly primitive. Also, the possession of a protocorm stage in the embryogeny, and the mixed type of stelar anatomy, brand these sections as together standing very much apart from the other sections, which, as we have seen, are probably somewhat closely interrelated. Being thus primitive in some respects and modified in others, the *Inundata* and *Cernua* sections are best considered to be a natural division of the genus whose ancestors diverged from the ancestors of the *Selago* stock at a probably early period.

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POSTSCRIPT (MAY, 1919).

Since this paper was written I have observed in the southern-beech forest on Mount Greenland, Westland, *L. varium* growing in extensive patches on the forest-floor in a similar manner to what I have described as occurring in Stewart Island. In one instance the clump of plants grew on the edge of a rock, and instead of the plants being rigidly upright in growth, with the characteristic short-curved strobili of the typical

L. varium, they were lax and pendulous and long-drawn-out, and the fertile regions of the stem were as little differentiated as is the case in the plant *L. Billardieri* var. *gracile*. It was only the fact that *L. varium* was abundant over the whole locality and that *L. Billardieri* and the variety *gracile* were altogether absent which indicated that this particular clump of plants belonged to the former species, for in habit of growth they showed the *Billardieri* form and in the nature of the strobilus that of *gracile*. It would seem to follow from this that these three species are best to be distinguished from one another by the particular stations that they normally adopt, rather than by their habit of growth or nature of the fertile region, for the latter characters are very variable. It must be added, however, that the strobilus seems to be more fixed in form in *L. Billardieri* than in the other two species. This particular clump of *L. varium* was further noteworthy by reason of the fact that nearly all the pendulous fertile branches showed rejuvenation at their tips. These new shoots were precisely similar in appearance to young normally-developed plantlets, and presented a marked and sudden contrast to the fertile branches from which they arose. Moreover, close to the base of the new shoots one or more roots were borne, which, in the case of those branches which reached to the ground, had begun to ramify in the soil. It is possible that the large clumps of this ground-growing species owe their spread a great deal to this mode of vegetative propagation.

I have found, also, *L. ramulosum* on the summit of Mount Greenland, at a height of about 3,000 ft., associated in damp peaty places with *Cladium teretifolium*, very stunted *Leptospermum scoparium*, and cushions of *Phyllachne clavigera*. The *Lycopodium* was here densely matted, and of a very short, creeping, and much-branched form, the numerous cones being about $\frac{1}{8}$ in. long, and borne on stiffly erect branchlets $\frac{1}{4}$ in. to $\frac{1}{2}$ in. high. In sheltered spots in this locality the plants were, on the contrary, of a more lax and drawn-out form, and bore very few or no cones. (See Cockayne, 10, p. 17.)

Art. XXI.—*Notes on the Birds of South-western Otago.*

By Alfred Philpott.

[*Read before the Otago Institute, 10th December, 1918; received by Editor, 27th December, 1918; issued separately, 20th June, 1919.*]

While engaged in entomological field-work I have had frequent opportunities of observing the habits of our birds, and a series of notes taken during the last six years forms the foundation of the present article. While it is indisputable that many of the native birds are doomed to extinction, it is also true that others are adapting themselves to the changed conditions brought about by the settlement of the country and the introduction of other forms of life. Such species as the bell-bird, the grey warbler, and the fantail may be seen daily in plantations within a few minutes' walk of the centre of the town of Invercargill, and it is not unlikely that as time goes on these birds will become quite independent of the native forest.

In nomenclature I have followed that adopted by Mathews and Iredale in their "Reference List of the Birds of New Zealand," as summarized by Benham in the *Transactions of the New Zealand Institute*, vol. 46, p. 188.

BOWDLERIIDAE.

South Island Fern-bird (*Bowdleria punctata punctata* Quoy and Gaimard).

This species is becoming very rare in Southland; I have not met with it for six or seven years. In the summer of 1913–14, in company with Mr. R. Gibb, I visited Stewart Island, and among the manuka scrub on the Rakiahua Flat we found the bird abundant.

MUSCICAPIDAE.

South Island Tit (*Myiomoira macrocephala macrocephala* Gmelin).

Observations on the habits of the South Island tit point to the conclusion that it mates for life. During the winter a male and female are often to be seen in company, and I have seen the male giving food to the female as early as the first week in August. In the spring much fighting goes on between the cock birds, but the quarrelling is not confined to that season; on several occasions a pair of males were observed fighting in the presence of a female in the late autumn and winter. The tit is certainly holding its own wherever the native forest is still standing. It is equally common in the *Nothofagus* forest at 3,000 ft. and the mixed forest at sea-level.

South Island Robin (*Miro australis australis* Sparrman).

In considering the problem of the diminution in numbers of New Zealand birds the case of the South Island robin offers some peculiar features. While the bird has disappeared from large areas remote from settlement, it is still to be found in several districts in close proximity to farming, mining, and timber-working activities. Though the coastal forest from beyond the Waiau to Preservation Inlet—many hundreds of thousands of acres—does not now apparently contain a single robin, the bird still holds out in certain localities comparatively close to towns. If the stoat and weasel were alone responsible for the scarcity of the robin we should expect to find outlying districts more favourable to its safety; certainly the writer's experience is that the stoat is much more common in the neighbourhood of cultivation. From 1914 to 1917 I visited the Hunter Mountains each year in January, ascending through the Titiroa Forest from Monowai Flat. In 1914 the robin was common in the lower bush; in the following year only a few were about; on the third trip only a single bird was heard; and in 1917 there was no sign of the species at all. I am unable to suggest a reason for such rapid disappearance. On the Monowai Flat rabbits are very plentiful, and cats and stoats are probably not uncommon. The part of the Titiroa Forest in question is attached to Sunnyside Station, and the owner, Mr. H. Cuthbert, informs me that nearer the homestead the robin is still to be found. In Stewart Island in 1913 I found the bird plentiful on Rakiahua and Table Hill, but it is not in evidence near Half-moon Bay and other settled districts.

South Island Grey Warbler (*Maorigerygone igata igata* Quoy and Gaimard).

The grey warbler is a bird which I think will adapt itself to the new conditions attendant upon the settlement of the country. It frequents orchards and plantations, and several instances of its nesting in fruit-trees and macrocarpa hedges have come under my notice.

A point worth investigating is the variation in the song of this bird in different localities. The notes of the Longwoods bird vary a little from those of the Seaward Bush songster, but the song of the Titiroa Forest bird is altogether different. It consists mainly of a beautiful descending trill. Possibly, however, the Titiroa form belongs to the subspecies *sylvestris* Potts.

In the work of nest-building the female warbler does practically all the work. The male may be heard singing near at hand, and occasionally he may visit the site and bring with him a fragment of material, but the bulk of the work is left to his mate. The beautiful domed nest does not, as is popularly imagined, hang suspended from a twig, but is securely stayed in position, one or more stout sprays passing through the thick lower portion. Though occasionally conspicuous, it is usually well concealed, and is not infrequently hidden in quite dense growth. A thin framework of the nest is first put together, much cobweb being used to bind the materials. When this stage is completed the lining-material is thrust through the aperture, and at intervals the hen bird enters the structure and may be seen vigorously moving about, the walls of the nest being pushed out in all directions as she arranges and consolidates the inner layers. In Southland, if the weather is not unfavourable, nest-building commences early in September, and at least two broods are reared during the season.

South Island Fantail (*Rhipidura flabellifera flabellifera* Gmelin).

On reference to my notes I find that more than a dozen instances of the crossing of pied and black fantails have come under my observation during the past ten years. Only a few instances in which both birds were pied, and but one case in which both parents were black, have been noticed during the same period. I entertain no doubt that we have here an interesting case of dimorphism, and that consequently the two forms should be placed under one species. An analysis of ten broods of mixed parentage gives the following results :—

Black.	Pied.	Total.
1	1	2
1	2	3
1	2	3
1	2	3
2	1	3
1	3	4
1	3	4
2	2	4
2	2	4
2	3	5
14	21	35

I was, unfortunately, unable to ascertain the particulars of the brood of which both parents were black, the birds having disappeared during my absence from the locality.

Both parents work industriously at the building of the nest, but I think that the female is the leading spirit. On one occasion I observed the male bring a flake of fuchsia-bark and deposit it in the nest, but on the hen bird's next visit she picked this out and carried it several yards away. In hot weather the nestlings suffer much from the heat, and lie with their heads thrust over the edge of the nest and their beaks wide open. They are also often overrun with hundreds of minute acarids, and the parents seek to abate this annoyance by picking off all they can see on each visit with food. An instance of unusual vigour in nest-building may be worth recording. On the 3rd September, 1917, I found a pair—black and pied—commencing to build a nest. By the 9th they had ceased working at it, and it appeared to be completed, though from the situation I could not make sure of this. On the 16th the pair began another nest about 12 yards away from the first, but work on this was carried on for only about half a day, when another site was selected near it. This third nest was beautifully finished by the 23rd, but the birds never used it, choosing still another site, where they again built, hatching out their eggs on the 22nd October. The nestlings left the nest on the 3rd November, and on the 8th I found the black fan (the hen bird) at work on another nest. This was lower down than any fantail's nest that I have seen, being only about 4 ft. from the ground. Within a yard of it was another nest, nearly completed, and once the bird alighted on this and did a little work at it. The first egg was laid on the 11th, and one on each of the following days till four were deposited. The young birds left the nest on the 12th December, but previous to this the pied parent had disappeared. A young black bird, presumably one of the former brood, began to assist in feeding the brood, and by the 7th January this pair of blacks had built a nest and had young birds hatched out. As mentioned above, I was unable to keep any further watch on this pair.

PARIDAE.

Brown Creeper (*Finschia novaeseelandiae* Gmelin).

Though becoming rather rare in the smaller bush areas, the brown creeper is still common in the larger forests. In the upper portion of Titiroa Forest it is very abundant, and in the Longwood and west-coast blocks it is also plentiful

Yellowhead (*Mohoua ochrocephala* Gmelin).

The yellowhead disappeared from the neighbourhood of Invercargill about ten years ago. West of the Waiau River it is not uncommon in suitable portions of the coastal forest, and it is abundant in Titiroa. I have not met with it on the Longwoods.

MELIPHAGIDAE.

Bell-bird (*Anthornis melanura melanura* Sparrman).

It is gratifying to find that this charming songster, which at one time was thought to be in danger of extinction, is now one of the most common of the indigenous bush-birds. The smallest patch of forest usually supports one or two individuals, and orchards and gardens in the centre of the town are regularly visited. An instance of what appears to have been an individual variation in the song of this bird came under my notice in December, 1917. While camping, in company with Mr. C. C. Fenwick, at the Wairaurahiri River, a bird kept up an incessant short song, consisting of three bell-like notes in a descending scale. It was quite different from anything I had heard in any other locality. On returning to the same spot a year later exactly the same pleasing melody was heard nearly all day long; probably it was the same bird.

Tui (*Prosthemadera novaeseelandiae novaeseelandiae* Gmelin).

The tui is not uncommon in the large forest areas, but appears to favour the lowland mixed type; not many are to be met with in the *Nothofagus* mountain blocks.

ZOSTEROPIDAE.

White-eye (*Zosterops lateralis tasmanica* Mathews).

The white-eye appears to build about the end of October in this district. Apparently partial migration takes place in the winter, as the large flocks which may be seen in the late autumn are represented by only twos and threes in the spring. A great many, however, fall victims to the cat while they are searching the vegetables and small-fruit trees for insects.

MOTACILLIDAE.

South Island Pipit (*Anthus novaeseelandiae novaeseelandiae* Gmelin).

Not uncommon in the open country round Invercargill. It is strange that this bird, which nests and roosts on the ground, does not succumb to the stoat in a district where these animals are so plentiful. On the Hunter Mountains, at an elevation of 3,000 ft. to 4,000 ft., the pipit is common, and I am of opinion that these alpine birds are much lighter in colour than those found on the low country.

ACANTHISITTIDAE.

Rifleman (*Acanthisitta chloris chloris* Sparrman).

Plentiful in all forests, and extending to the bush-level on the mountains. I have never met with one in the open or seen one flying from forest to forest.

ALCEDINIDAE.

Kingfisher (*Sauropatis sanctus forsteri* Mathews and Iredale).

About the middle of September a few kingfishers always visit the outskirts of the bush districts, and may be seen and heard among the scattered trees in the fields. During the winter they either migrate northwards or retire to the coastal areas.

CUCULIDAE.

Shining Cuckoo (*Lamprococcyx lucidus* Gmelin).

The shining cuckoo and the long-tailed cuckoo (*Urodynamis taitensis* Sparrman) are certainly not so common as formerly near settlement, but their rarity is simply the result of the clearing of the forest. In the untouched forest areas both species are abundant in their season. In the hill country the long-tailed species is common at all elevations, but I have not met with the shining cuckoo above 2,000 ft.

BUBONIDAE.

Morepork (*Spiloglaux novaeseelandiae novaeseelandiae* Gmelin).

Throughout the winter months for the past four years a morepork has lived in a small piece of bush within the Invercargill boundary. During the day he could almost always be found perched under some tree-fern fronds. Frequently several kinds of small birds would gather round and mob him, but he took very little notice of them. In the spring and summer the bird was never to be found on the usual perch, which seems to indicate that the morepork pairs for the nesting season only. It is popularly supposed that this owl shelters by day in a hole in a tree, but I have on many occasions surprised the bird by day, and always found it perched under tree-fern fronds or in similarly shaded situations.

Wherever any forest is still standing the morepork is not uncommon. A few years ago I had the good fortune to come upon a brood of young birds which had just left the nest. They were perched on a dead limb, and both parents were busy catching moths and other insects for them. I think it very probable that the old birds largely supplement their own diet with such large insects as they can catch.

NESTORIDAE.

KEA (*Nestor notabilis* Gould).

The kea is common on the Hunter Mountains, where its numbers seem to be on the increase. Contrary to the experience of flock-owners in other localities, Mr. H. Cuthbert, who utilizes Mount Burns and Cleughearn, informs me that the birds have never to his knowledge interfered with his sheep. During several visits to the Hunters in January of each year I paid special attention to the food of the kea. In January, 1917, the mountain-flax (*Phormium Cookianum*) was in flower, and little flocks of keas might daily be found sucking the nectar from the blossoms. On more than one occasion keas were observed breaking off and splitting up the flower-stalks of the celmsias. The soft central portion of the stalk seemed to be the part desired, for, though I examined the refuse in order to ascertain if it was caterpillars or some other form of insect-life that the bird was after, I could find no trace of such. The gizzards, however, of a few which were captured showed that insects formed a large proportion of their food, remains of the larvae of Cicadae being plentiful. Though the kea may often be seen stripping off the lichen and moss from the branches of trees, the bird does not seem to bore into and break up decayed wood as its congener the kaka does; probably *Nothofagus* logs do not contain sufficient insect-life to make it worth while.

During the greater part of the day the keas frequented the open hills, but in the mornings and evenings they were to be found about the upper edge of the forest, and they passed the night in the trees. On sunny days, generally about four in the afternoon, they took what appeared to be pleasure flights. They would circle about in companies, breaking up and re-forming again, swooping down towards the ground and soaring up again, and crossing and recrossing each other's paths with excited cries. The kaka has the same pleasing habit.

Though I have found the kea very inquisitive and given to the investigation of every strange object, I have not met with any instances of that extreme playfulness recorded by some observers.

KAKA (*Nestor meridionalis meridionalis* Gmelin).

Abundant in the coastal forest beyond the Waiau River; it ascends as high as the bush-line, but is most common in the mixed forest near the sea. In the Titiroa Forest it is not plentiful, even in the lower areas. In Stewart Island the back country still yields a refuge, but near the settled areas the bird is scarce. The smaller forests are now practically forsaken by this interesting parrot. In 1913 a very handsome variety was shot in Stewart Island. The specimen, which is now in the Southland Museum, has the forehead dull leaden grey; the crown and nape are scarlet, each feather being tipped with olive-brown; the feathers of the neck and pectoral band are broadly margined with yellow; the back and scapulars are scarlet, with crescentic olive-brown marks; the wings are scarlet mixed with olive, the primaries being olive-grey; the rump and upper tail-coverts are scarlet; the tail-feathers are dark olive, basal half pale scarlet, tips olive-grey; the ear-coverts are faintly yellow; the lores, cheeks, and throat are dark olive, the cheek-feathers being centred with pink; the breast is scarlet mixed with olive, the flanks, abdomen, and under tail-coverts being almost wholly scarlet.

CACATUIDAE.

Parrakeets (*Cyanorhamphus*).

The three species of *Cyanorhamphus* which were once so common in Otago are now seldom seen or heard in any of the smaller forests. *Cyanorhamphus malherbi* Souancé, which was never so abundant as the other two, is in all probability extinct, but the red-fronted and yellow-fronted species still occur far back in the great timbered areas. It is very noticeable that these remaining birds are much more timid than the parrakeets of the early days. They seem to frequent the tall trees only, and are much more often heard than seen. Between thirty and forty years ago the parrakeet fed freely on the low berry-bearing shrubs, and frequently hunted about on the ground for fallen seeds. They were so tame that a boy with a "shanghai" could soon make a fair bag; but now it would be difficult to get within gun range. Possibly this acquired timidity will prove the salvation of the species. Two specimens of *C. malherbi* are in the collection of the Southland Museum, and the yellow varieties of *C. novaezelandiae novaezelandiae* and *C. auriceps auriceps* referred to by Sir Walter Buller (*Trans. N.Z. Inst.*, vol. 29, p. 188) are also still in good condition.

TRERONIDAE.

Wood-pigeon (*Hemiphaga novaeseelandiae novaeseelandiae* Gmelin).

The pigeon is still plentiful except near settlement. Orchards near the Titiroa Forest are visited when the cherries are ripe, and such large birds exact a heavy toll upon the owners of the trees. In the open glades on the Hunter Mountains above 3,000 ft. I found this beautiful bird feeding on the berries of *Coprosma rugosa*. In fine weather they appear to feed in the morning and evening, and to rest in the shade during the hottest part of the day.

RALLIDAE.

Black Weka (*Gallirallus brachypterus* Lafresnaye).

It is pleasant to be able to record the fact that the black weka is undoubtedly becoming more plentiful in the Fiord County forest. While gold-mining operations were being carried on at Preservation Inlet, with the attendant traffic along the Orepuki–Preservation track, the weka naturally became scarce in that locality. Many were killed for food, and many more were destroyed needlessly by the miners' dogs. In 1911, by which time there was little activity at the inlet, I found that the black weka had recovered to a great extent from its persecution, and was to be found in fair numbers from the coast to the western bank of the Wairaurahiri River. On the east side of the river only a few were to be met with. In the summer of 1916–17 the bird was found to be abundant to the west of the Wairaurahiri, and common on the eastern side, occurring, though in diminishing numbers, almost to Bluecliff. By the summer of 1917–18 they were common at Bluecliff and beyond, one or two being heard within a few miles of the settlement of Papatotara. Even at the top of the forest on the Hump Ridge a pair were present—the first seen there by the writer, though the spot had been visited five or six times since 1911.

During the last spring and summer a plague of mice has occupied this western forest. While an odd mouse or two might always be found about the huts on the track, there has never been, in my experience, anything approaching the number present on this occasion. They were everywhere—on the sea-beach and the hill-tops, in the huts, on the track, and in the dense bush. Very probably their numbers accounted in some degree for the spread of the weka; the birds were snapping them up on every opportunity, the victims being swallowed whole, head first. On the beach I saw the wekas picking up many small crustaceans (sand-hoppers); the large stag-beetles (*Lissotes*) also formed part of their diet.

STEWART ISLAND WEKA (*Gallirallus australis scotti* Grant).

In the back country of Stewart Island this species is still fairly common. My experience with this bird leads me to regard it as much less vigorous and enterprising than the black weka. I should imagine that the latter species, if introduced into the same region, would soon exterminate the former.

PUKEKO (*Porphyrio melanonotus stanleyi* Rowley).

The pukeko is one of our birds which is in danger of extinction. Few are to be found now, even in localities remote from settlement.

ARDEIDAE.

WHITE HERON (*Herodias alba maoriana* Mathews and Iredale).

Two very fine specimens, in spring plumage, are in the Southland Museum. These, I learn from Mr. James Hunter, were shot by Mr. J. Fox at Kew, near the mouth of Kingswell's Creek, in the year 1875. As showing that the bird was not then regarded as very rare, it may be mentioned that the museum authorities purchased the skins for 10s. each. In the early "eighties" the writer remembers seeing a white heron near the Waihopai River, where the buildings of Collingwood now stand.

WHITE-FRONTED HERON (*Notophoyx novaehollandiae* Latham).

The white-fronted heron is exceedingly rare, but a specimen was shot near Invercargill during the present spring.

BITTERN (*Botaurus poeciloptilus melanotus* Grey).

About ten or twelve years ago the bittern was not uncommon in swampy localities near Invercargill. The draining and reclamation of these areas has driven the bird farther back, and it is now rarely seen.

HAEMATOPODIDAE.

Redbill (*Haematopus niger unicolor* Forster).

Along the coast, wherever masses of rock are to be found in conjunction with sandy shores, the redbill is not uncommon.

CHARADRIIDAE.

Dotterel (*Pluviorhynchus obscurus* Gmelin).

Seldom seen on the mainland. In Stewart Island it occurs in fair numbers, nesting on the dunes near the sea and visiting the bare tops of the high country.

RECURVIROSTRIDAE.

Pied Stilt (*Himantopus leucocephalus alba* Ellman).

The pied stilt seems to be in no danger of extinction. A flock of about fifty was observed recently on the mud-flats of the New River Estuary, and pairs and small groups may frequently be met with in shingly river-beds and other suitable situations.

SCOLOPACIDAE.

Oriental Whimbrel (*Numenius variegatus* Salvadori).

In the collection of the Southland Museum is an example of this species. It was shot on the New River Estuary in 1907, being in company with a flock of godwits.

LARIDAE.

White-fronted Tern (*Sterna striata striata* Gmelin).

This very common tern breeds at several rocky stations along the coast. In the middle of December I found numerous eggs and a few young birds just hatched. No attempt at a nest is made, the egg being laid on the sandy grit in the hollows of the rocks. The parent bird will not allow any other species to approach the breeding-place; a pair of paradise ducks which were swimming in the sea near the rocks were set upon, and compelled to dive repeatedly in order to escape their tormentors, and on more than one occasion a harrier which had only come within several hundred yards of the nestery found itself vigorously attacked. It was surprising to see the hawk retreat, without the least show of defence, from a bird less than half its size.

Art. XXII.—*Descriptions of New Species of Lepidoptera.*

By Alfred Philpott.

[*Read before the Otago Institute, 10th December, 1918; received by Editor, 27th December, 1918; issued separately, 20th June, 1919.*]

Pyraustidae.

Scoparia illota n. sp.

♂ ♀. 18–20 mm. Head, palpi, and thorax fuscous-brown mixed with grey. Antennae fuscous, ciliations very short. Abdomen grey, anal tuft ochreous. Legs fuscous, posterior pair paler, apex of tarsal joints narrowly whitish. Forewings elongate, triangular, blackish-fuscous, densely irrorated with white: *first line broad, curved, bluntly angled at middle, white:*

second line distinct, sinuate beneath costa, thence almost straight inwardly-oblique to dorsum, white; subterminal broad, widely and deeply indented at middle, white: cilia grey with fuscous median and subapical lines. Hindwings grey, infuscated round termen: cilia as in forewings but paler.

Nearest *S. cyptastis* Meyr., from which it differs in the more strongly curved first line, and in the second line being sinuate, not indented, beneath costa. It may be regarded as the forest representative of *cyptastis*.

I took one specimen at Cromarty (Preservation Inlet) in March, 1911. In December, 1917, Mr. C. E. Clarke and myself found it not uncommon from Blue Cliffs to Knife-and-Steel Boat-harbour. It is therefore probably distributed throughout the coastal forest of Fiord County.

TORTRICIDAE.

Tortrix inusitata n. sp.

♂. 20–21 mm. Head and thorax brownish-ochreous. Palpi rather long, fuscous-grey, tinged with ochreous outwardly. Antennae pale ochreous with dark annulations, ciliations $1\frac{1}{2}$. Abdomen ochreous-grey, bright ochreous beneath, anal tuft blackish. Legs pale ochreous, tarsi broadly annulated with black. Forewings triangular, costa moderately arched, apex obtuse, termen sinuate, hardly oblique, tornal angle broadly rounded, *purplish-fuscous: a narrow basal patch bright ochreous, extending along costa to about* $\frac{1}{3}$; extreme costal edge sometimes ochreous throughout; an outwardly-oblique dark striga obscurely indicated at $\frac{1}{2}$; some undefined dark dots on costa: cilia purplish-fuscous, paler round tornus. Hindwings ochreous-grey with numerous dark strigulae: cilia as in forewings but paler.

Distinguished from *T. excessana* (Walk.), its nearest ally, by the strongly contrasted basal patch.

Mr. C. E. Clarke has taken a few examples at Waitati, Dunedin, in forest, in the months of October and November. I have taken a single specimen near Invercargill in November. Type in coll. C. E. Clarke.

NEPTICULIDAE.

Nepticula lucida n. sp.

♂ ♀. $5\frac{1}{2}$ – $6\frac{1}{2}$ mm. Head greyish-white. Antennae black. Thorax fuscous. Abdomen black. Legs greyish-black. Forewings in ♂ elongate, rather broad basally, apex broadly rounded, in ♀ lanceolate, *shining dark fuscous: a broad outwardly-curved white band at* $\frac{3}{5}$: cilia fuscous. Hindwings and cilia dull fuscous-black.

Differing from any described New Zealand members of the genus in the dark coloration and the striking white band on forewings.

Discovered by Mr. C. E. Clarke. Several beaten from the foliage of *Nothofagus* at Waitati (Dunedin) in November.

Art. XXIII.—*Fauna of the Hampden Beds and Classification of the Oamaru System.*

By P. Marshall, M.A., D.Sc., F.G.S.

[*Read before the Wanganui Philosophical Institute, 7th December, 1918; received by Editor, 30th December, 1918; issued separately, 16th July, 1919.*]

Plates XV–XVII.

Contents.

Descriptions of New Species of Fossil Mollusca found at Hampden.

Circulus inornatus n. sp. (Plate XV, fig. 15.)

Shell minute, round, 2½ mm. in diameter. Spire almost plain, consisting of three whorls only. Whorls increasing rather quickly in size and suture strongly incised. Aperture of a broadly oval form. Surface quite smooth. Umbilicus moderately wide.

A single specimen, in good condition. The entire absence of sculpture distinguishes this from the other New Zealand species.

Type in the Wanganui Museum.

Cerithidea minuta n. sp. (Plate XV, fig. 11.)

Shell minute, 5 mm. by 2 mm. Spire tapering and composed of five whorls which are slightly convex. Aperture oval, extending very slightly over the base, and produced anteriorly into a short canal. Sculpture: About nine low rounded radial ribs on each whorl, which are crossed by four elevated sharp spiral ridges: these are more pronounced on the radial ribs than elsewhere. Suture not deep and without a border. Body-whorl with about twelve spiral ridges, which decrease on the base and extend almost into the aperture.

One specimen only, in good condition. I can find no record of *Cerithidea* being found at a lower horizon than that of the Awamoa beds.

Type in the Wanganui Museum.

Cerithiella tricincta n. sp. (Plate XV, fig. 2.)

Shell small, 10 mm. by 3 mm., with a narrow turreted spire. Spire of ten whorls, each of them distinctly convex, and slowly decreasing in diameter. Suture very deep. Whorls with spiral and radial ornamentation. Three raised spiral rounded ridges on each whorl, the lowest of them the most prominent. They are crossed by seven radial ridges on the half-whorl. At the points of intersection of the radial and spiral lines there are distinct rounded knobs. Body-whorl not preserved. Columella smooth.

Suter remarks that this species is closely related to *C. fidicula* Suter The sculpture of the present species is, however, far coarser, and there are fewer radial lines. The diameter of the whorls also decreases more rapidly.

One specimen only, imperfect, and embedded in the matrix.

Type in the Wanganui Museum.

Turritella rudis n. sp. (Plate XVII, fig. 3.)

Shell small, the largest specimen 15 mm. by 6 mm. Sharply conical. Whorls narrow. In a small specimen 7 mm. long there are eleven whorls. Each whorl with some broad spiral ribs more or less broken into rounded or blunt nodules in large numbers. In the higher whorls there is generally only one of these ribs, nearly median in position, but in the lower whorls there are generally four. The spaces between these ribs have a number of fine spiral lines. There are no axial riblets. Suture deep.

Several specimens, in good condition. The species is closely related to *T. ornata*.

Type in the Wanganui Museum.

Submargarita ? tricincta n. sp. (Plate XV, fig. 14.)

Shell small, turbinate, slightly conic above. Whorls 3½ to 4. Spire very small; protoconch depressed. The last whorl comparatively very large, slightly angulated by the last three spiral riblets. The lower riblet defines the basal area, which is contracted and slopingly convex. Sculpture: On the body-whorl, in addition to the three principal riblets, there are on the base a number of minute threadlets which vanish on approaching the basal margin. Between the basal and middle principal spirals are about five minute threadlets. The space above is narrower and has two or three threadlets. Between the upper principal spiral and the suture is a fairly wide area, sloping, slightly convex, and with four or five threadlets; irregular growth-striae cut the threadlets into minute gemmules. The apex is somewhat eroded, and sculpture, if any, is not determinable. Sutures somewhat impressed. Aperture rounded; outer lip slightly effuse, more marked on the basal area. Columella narrow above, then expanding into a stout freely projecting plate which unites with the basal lip. Parietal wall thinly calloused, minutely perforate. Beneath the outer calcareous layer the shell is somewhat iridescent. Height, 5·25 mm.; breadth, 5 mm.

This species was submitted to the late Mr. Suter, and he suggested its inclusion in *Submargarita*. There is one example only, and it appears to be adult and not the juvenile of *Turbo* or *Astraea*.

Type in the Wanganui Museum.

This description was kindly written by Mr. Murdoch.

Erato antiqua n. sp. (Plate XV, fig. 7.)

Shell small, 4½ mm. by 3½ mm. Broadly oval, but slightly produced anteriorly. Aperture almost linear, but rather wider in the anterior than in the posterior portion. Outer lip much thickened, with numerous denticles. Spire completely covered by the body-whorl and a posterior callosity. Surface quite smooth and polished.

One specimen only, in good condition. The small size and absence of a distinct spire distinguish this species from *E. neozelanica* Suter. This is the only other species of the genus which has been found in New Zealand.

Type in the Wanganui Museum.

Epitonium tenuispiralis n. sp. (Plate XVII, fig. 6.)

Complete shell not available. Four whorls of the spire only, which measure 10 mm. by 5 mm. The whorls taper rather rapidly. Radial ribs slightly rounded, prominent, about fourteen on each whorl. Interstices rather wider than the ribs. Both ribs and interstices are crossed by a large number of exceedingly fine spiral lines.

Although the specimen is extremely fragmentary, the very distinct sculpture justifies its description under a specific name.

Type in the Wanganui Museum.

Turbonilla antiqua n. sp. (Plate XV, fig. 10.)

Shell small, and only the lower four whorls remain in the single specimen which was found. Length, 8 mm.; width, $1\frac{1}{2}$ mm. The whorls taper very gradually, and the entire shell must have a considerable length relative to its breadth. Whorls nearly flat in outline, but suture rather deep. About twenty-two straight transverse ribs on each whorl, but no spiral sculpture. On the body-whorl the transverse ribs do not extend over the base. Columella with a slight umbilicus. Inner lip thickened at its base with a small fold. Outer lip rather thick. The gradual taper of the whorls and the fold on the columella distinguish this species from those that have been described in New Zealand.

Type in the Wanganui Museum.

Dicroloma zelandica n. sp. (Plate XV, fig. 16.)

Shell of moderate size. Length, 28 mm.; breadth, 9 mm. Spire of five convex whorls rapidly decreasing in size. Suture shallow. Beak not complete, but apparently about two-thirds the length of the shell. The whorls with numerous slightly raised spiral threads; there are twelve on the penultimate whorl: these are crossed by numerous low radial lines which are strongly bent backwards in the middle. Body-whorl with spiral striation more distinct, but no radial lines can be distinguished. At the very beginning of the body-whorl a keel starts to develop a little above the crown of the convexity of the whorl. A little farther forward another keel is developed slightly below the crown of the convexity. The two keels are separated by four spiral lines. The two keels rapidly increase in prominence, and where they reach the outer lip they extend into two large wings. The anterior wing is at first directed forward in direct continuation of the keel; 10 mm. distant from the outer lip it bends through a right angle and, extending for 9 mm., it terminates apparently near the end of the beak. The other keel also ends in a wing, which at first proceeds outward in a continuation of the direction of the keel, then bends gradually downward, and ends about 15 mm. from the penultimate whorl.

Several specimens have been found, but none of them show the aperture and wings in a good state of preservation. The first one that was found was small, but was worked out of the matrix in a satisfactory state. Unfortunately, it was completely smashed when it was sent through the post to Mr. Suter. Another specimen (Plate XV, fig. 16), found in 1918, showed the spire fairly complete, but the greater part of the wings is absent, though the impression of them is quite clear in the matrix. The impression has been coloured white in order to show more clearly in the photograph. The beak also was detached, and a small amount of the material has been lost. I think, however, that there is no doubt as to the generic position, and in this Mr. Murdoch agrees with me. The species is probably closely allied to *D. myurus* Desl. (Cossmann, *Essais de Paléoconchologie comparée,* vol. 6, p. 85, pl. 6, fig. 1). The genus *Dicroloma* has not hitherto been definitely recorded from a higher horizon than the Upper Jurassic (Portlandian), though a doubtful species, highly imperfect, is mentioned by Dickerson from the Tejon of California.

Type in the Wanganui Museum.

Fusinus altus n. sp. (Plate XVI, fig. 5.)

Shell of moderate size, narrowly fusiform. Length, 60 mm.; width, 17 mm. Spire of seven whorls, gradually tapering; each whorl strongly convex, adorned with twelve broad transverse ribs which extend to the anterior but not to the posterior suture: they are much stronger on the suture than elsewhere. About twelve strong spiral striae on each whorl, but they are much stronger near the carina than elsewhere. There are often much smaller striae intercalated between the larger ones. Aperture not complete, but moderately wide. Outer lip with well-marked internal ribs. Beak long, with spiral striation similar to that of the rest of the shell.

This species is rather slender, but approaches more closely to *F. kaiparaensis* than to any other. The radial ornamentation, however, is much less pronounced, and the carina is much less marked. The shell is also considerably narrower.

A single specimen, not well preserved.

Type in the Wanganui Museum.

Latirus dubius n. sp. (Plate XVI, fig. 6.)

Shell of moderate size, 33 mm. by 10 mm., narrowly fusiform. Spire of four whorls, each of them strongly convex. Aperture incomplete, but terminating in a short canal which is bent sharply upwards. Inner lip wide, and extending forward beyond the columella for two-thirds of its length. Columella with two well-developed folds. Outer lip wanting. On each whorl a number of radial ribs—generally fourteen: these are moderately high and rounded, and extend from suture to suture. On the upper third of each whorl a number of fine spiral lines. On the lower two-thirds of each whorl there are five strong spiral lines which are much raised where they cross the radial ribs. Between the strong spirals there are a number of fine spirals similar to those in the upper part of the whorl.

One specimen only, rather imperfect. I have some hesitation in following the late Mr. Suter's advice and classing this species in the genus *Latirus*.

Type in the Wanganui Museum.

Belophos incertus n. sp. (Plate XV, fig. 3.)

Shell small, shortly fusiform, 15 mm. by 9 mm. Spire of four whorls, rapidly decreasing. Each whorl with about 22 radial ridges, which are slightly raised and somewhat prominent on the carina. Carina quite prominent, and whorls almost shouldered; suture impressed. About five small threads between the carina and the anterior suture. Body-whorl with radial ridges far less pronounced than those on the spire, and towards the aperture they degenerate into growth-lines. Spiral lines numerous and distinct, especially towards the end of the siphon. Aperture semi-lunar. Outer lip thin but arched. Inner lip without any callosity. Columella slightly bent backwards.

The genus *Belophos* has not previously been recorded from New Zealand, but it has been found in the Eocene of Australia.

A single specimen, in good condition.

Type in the Wanganui Museum.

Volutoderma zelandica n. sp. (Plate XVII, figs. 4, 5.)

Shell small. Length, 12 mm.; width, 5 mm. Spire incomplete; portions of the first and second whorls alone remain. Whorls rather rapidly decreasing. Aperture prolonged anteriorly into a moderately long siphon which is bent backward towards its extremity. Each whorl with a distinct ridge bordering the posterior suture. Six prominent costae on each whorl, which are most pronounced near the keel; they extend forward to the anterior suture, but do not reach the posterior one. Five small spiral ridges on each whorl crossed by numerous growth-lines. On the body-whorl the costae are little more than tubercles on the carina. The growth-lines are numerous and distinct, but spiral lines are visible near the end of the siphon only. Columella with one prominent plait. The growth-lines indicate that there is a moderately deep sinus between the suture and the keel. The aperture is too imperfect in the specimens to show this feature. I am indebted to the late Mr. Suter for provisionally classifying this species.

Two specimens, somewhat imperfect, in the Wanganui Museum.

Marginella aveniformis n. sp. (Plate XV, fig. 8.)

Shell small, 6 mm. by 2½ mm., narrowly oval. Spire of three whorls, rapidly decreasing. Aperture about two-thirds the length of the shell. Spire short; whorls convex in outline, but suture only slightly marked. Surface perfectly smooth and polished. Aperture narrow, with a slight anterior canal. Columella with four narrow folds, the two posterior of which are nearly at right angles to the columella, but the two anterior ones are highly oblique. Outer lip swollen, and furnished with a number of denticles on its inner margin.

A single specimen, in good condition. The spire is longer than that of other New Zealand species.

Type in the Wanganui Museum.

Turris politus n. sp. (Plate XVII, fig. 9.)

Shell small, 10 mm. by 4 mm., with a polished surface. Spire consists of six strongly keeled whorls. Seventeen small rounded tubercles on the carina of each whorl. Growth-lines extend upwards from the tubercles, and where they intersect the raised anterior border of the suture there is another series of much smaller tubercles. There are no spiral markings on the portion of the whorl between the posterior suture and the keel. On the keel there is a small spiral furrow which intersects all the tubercles. There are four other small furrows between the keel and the anterior suture. On the body-whorl the furrows in front of the keel are more numerous. Aperture imperfectly preserved.

Two specimens, in fair condition, but the aperture is imperfect. Suter remarks that this species is closely related to *T. complicatus* Suter. The species, however, is considerably smaller, the tubercles are much less prominent, and the spiral ornamentation in front of the carina is distinct.

Type in the Wanganui Museum.

Turris margaritatus n. sp. (Plate XVII, fig. 2.)

Shell small. Length, 15 mm.; width, 5 mm. Spire consists of six strongly-keeled whorls. Aperture less than half the length of the shell. The keel has eighteen bead-like tubercles on each whorl, but rather flattened in front. The whole whorl is finely striated spirally. Body-whorl with a moderate anterior canal. The growth-lines, which are quite distinct, indicate that the anal notch is rather deep, but the specimens have not the aperture sufficiently well preserved to show it. The portion of the body-whorl in front of the keel has large as well as fine striations.

The number of tubercles on the keel and the number of fine spiral striations distinguish this from the other New Zealand species.

Five specimens, in a fair state of preservation.

Type in the Wanganui Museum.

Turris reticulatus n. sp. (Plate XVII, fig. 8.)

Shell small, 15 mm. by 6 mm., but the greater part of the anterior canal is wanting. Spire of six whorls, strongly keeled. Each whorl with a number of strong spiral lines behind and in front of the keel. On the penultimate whorl there are ten of these lines above and five below the keel: the second from the upper suture and that on the keel are by far the strongest. On the keel there are sixteen well-developed tubercles, which are rather larger radially than longitudinally. Well-marked growth-lines pass through the tubercles and reach the upper suture. Where they cross the second spiral line below the suture they give rise to small tubercles, which are far more prominent on the upper whorls than on the lower. The intersection of the growth-lines and the spirals give rise to an appearance that is almost reticulate. The anterior part of the body-whorl has more marked spiral lines and very numerous growth-lines. Columella smooth, but aperture not fully preserved.

One specimen only, not very well preserved.

Type in the Wanganui Museum.

Surcula gravida n. sp. (Plate XVI, fig. 4.)

Shell large, fusiform, 70 mm. by 28 mm. Spire of moderate length and composed of five whorls. Whorls convex and sharply keeled, but no tubercles on the keel. Aperture about half the length of the shell, but lips imperfectly preserved. Anal sinus deep, not sharp, but well rounded. Ornamentation: A distinct border in front of the suture. A number of rather prominent spiral lines both above and below the suture. On the penultimate whorl there are eleven of these in front of the keel and nine behind it. On the body-whorl the spiral lines in front of the keel are less prominent, and there are no spiral lines on the beak.

This species approaches, though rather distantly, to *S. hamiltoni* (Hutt.). The spiral angle, however, is 40°, in place of 25° in *S. hamiltoni*. The ornamentation is quite different. There are tubercles on the keel of *S. hamiltoni* and no spiral lines above it, and there are no spiral lines on the beak.

A single fairly perfect specimen, though a little compressed.

Type in the Wanganui Museum.

Surcula marginalis n. sp. (Plate XVII, fig. 10.)

An imperfect specimen only. Seven whorls remain on the spire, and there is a protoconch of three whorls. In the first six whorls there are eighteen tubercles on the keel, but the last whorl is smooth. Sutures prominently bordered in front. All portions of the whorl have prominent spiral striations, including the tubercles. As shown by the growth-lines the anal sinus is moderately sharp, but less so than in *S. hamiltoni* Hutt.

This species is closely related to *S. hamiltoni*, but differs from it in having the prominent border of the suture, more numerous tubercles, and a much more abundant spiral ornamentation both above and below the keel.

A single imperfect specimen.

Type in the Wanganui Museum.

Surcula equispiralis n. sp. (Plate XVI, fig. 3.)

Specimen imperfect, not showing the aperture. Length, 20 mm.; width, 7 mm. The remaining part of the spire consists of six whorls, which are slowly tapering, and each one is clearly convex. Each whorl with about twelve nodular elevations on the carina. These are slightly extended transversely, but do not reach either suture. They are inclined forward anteriorly. There are many fine spiral lines developed equally on all parts of the whorl. Suture bordered in front by a raised ridge, which is marked spirally like the rest of the whorl.

Mr. Suter remarks that this species is nearest to *S. pareoraensis* Suter. The nodules, however, are much more prominent, the suture more distinctly bordered, and the spiral ornamentation more prominent than in that species.

A single specimen, imperfect, but showing the sculpture very distinctly.

Type in the Wanganui Museum.

Surcula torticostata n. sp. (Plate XVII, fig. 7.)

Shell small, and the specimens quite imperfect; 13 mm. by 4 mm. Spire long and slender; six convex whorls showing in the best specimen. Suture impressed with a well-marked border anteriorly. Whorls with eighteen radial ridges, which extend from suture to suture and are strongly twisted forward at the anterior end. A series of very fine spiral striae cover all parts of the whorls. Aperture not preserved in any of the specimens, but the fairly distinct growth-lines show that the anal notch was broad and rounded.

Four specimens, which show the ornamentation clearly, but the anterior part of the shell is not preserved.

Type in the Wanganui Museum.

Terebra sulcata n. sp. (Plate XVI, fig. 2.)

Shell of moderate size, 30 mm. by 8 mm. Spire gently tapering, and consisting of six very slightly convex whorls. Sculpture consisting of large sharp transverse ribs, which are slightly bent backwards in the middle. There are twenty of these ribs on the body-whorl, and they are nearly as prominent on the body-whorl as on the higher whorls.

The only specimen is incomplete, though the sculpture is distinct. Mr. Suter says that the species approaches more closely to *T. biplex* than to any other species.

Type in the Wanganui Museum.

Sarepta solenelloides n. sp. (Plate XV, figs. 4, 5, 6.)

Shell of moderate size, 30 mm. high, 15 mm. long, and 10 mm. thick. Shape oval and slightly inequilateral, the anterior end being a little longer and more acute. Dorsal margin sloping slightly downward on both sides of the umbo, which is situated a little behind the middle of the hinge-line and points slightly posteriorly. Ventral margin gently curved, and passes gradually to the posterior margin, which is rounded. Hinge-line not quite straight, with about seventeen teeth on each side of the umbo, below which there is a large alivincular pit. Pallial line simple. Lunule large but narrow. A broad but very shallow groove extends from the umbo to the anterior margin. The sculpture consists of a series of fine concentric grooves with relatively flat and wide ridges between them.

In my previous paper (*Trans. N.Z. Inst.*, vol. 49, p. 464, 1917) this shell is classified as a species of *Malletia*, a genus which it closely resembles in external form. However, it has the hinge of *Yoldia*, the pallial line of *Nucula*, and the external form of *Malletia*—peculiarities that Fischer cites as characteristic of *Sarepta*. Several specimens were obtained, some in good condition.

Type in the Wanganui Museum.

It may be that this is the species recorded by Hutton from these beds under the name *Malletia funiculata*, but his specimens seem to have disappeared, and the name is a *nomen nudum*.

Sarepta tenuis n. sp. (Plate XV, fig. 9.)

Shell very small, but thick for its size. Height, 3 mm.; length, 4 mm. Shape broadly oval. Inequilateral, with a slight anterior extension. Hinge-line a little curved, with seven inclined teeth in front of the umbo and three behind it. Shell somewhat tumid. Umbo prominent. Concentrically striated with shallow grooves leaving low rounded ridges between them.

A single specimen, in good condition. Differs from *S. obolella* in its shape, its small size, and its concentric ornamentation.

Type in the Wangamui Museum.

Limopsis hampdenensis n. sp. (Plate XV, figs. 12, 13.)

Shell small, sub-rhomboidal, inequilateral, somewhat inflated; sculptured with small rounded concentric riblets about the same width as the interspaces and sensibly granular. On the posterior end from a line with the umbo are numerous well-marked radiating riblets giving the area a distinctly cancellated surface. The disc shows several well-marked periods of rest. Umbones nearer to the anterior end and prominent, slightly projecting beyond the almost straight dorsal margin. Anterior end short, slightly convex, the curve almost uniform with that of the basal margin. Posteriorly the dorsal margin almost twice the length of the anterior portion, the end truncated, sharply descending, a little oblique, nearly straight, and forming a curve on uniting with the broad upward-sweeping basal margin. Hinge slightly curved; a narrow triangular pit beneath the apex, and a few small denticles below the teeth, gradually getting larger as they proceed outwards, anteriorly four or five, posteriorly six or seven, and more oblique. Anterior muscle-scar small and immediately below the hinge-margin, the posterior lower and much larger. The interior shows faint radiations, the margin worn but in places slightly crenulate. Height, 3·5 mm.; length, 4 mm.; diameter of a single valve approximately 1·25 mm.

Type in the Wanganui Museum.

The description is derived from two right valves, and the measurements from the larger of the two. It is a minute form compared with others recorded from the New Zealand Tertiaries.

Mr. Murdoch was good enough to write this description.

Trigonia areolata n. sp. (Plate XV, fig. 1; Plate XVII, fig. 1.)

Shell small, ovate, inequilateral, slightly extended posteriorly. One valve 14 mm. high and 15 mm. long; another 17 mm. high and 18 mm. long. Interior of the shell highly nacreous. Beaks rather prominent, distinctly prosogyrous. Dorsal margin descending rapidly in front, and posterior margin evenly rounded; posterior ventral margin nearly circular; anterior margin at first well rounded, then ascending gradually to the umbo. Sculpture a series of broad rounded ribs except over the area. There are fifteen of these ribs, which are distinctly broader than the grooves which separate them. Grooves crossed occasionally by irregular fine lines of growth. Ventral margin slightly crenated. Near the ventral margin on the interior surface the grooves have a few irregular striations in the direction of their length. The posterior "area" constitutes about one-fourth of the surface of the valve. Close to its border it has one rib-like elevation extending from the posterior margin one-third of the distance to the umbo. Another much broader rib near the posterior margin of the area, also extending about two-thirds of the distance to the umbo. A series of fine transverse ridges cross the area. The right valve shows one large cardinal tooth, which, however, shows no trace of striation The posterior part of the hinge has not been preserved.

Two right valves only, both with somewhat incomplete hinge. The nacreous internal surface and the posterior area appear to make it necessary to refer this shell to the genus *Trigonia*. The smooth tooth, however, as well as the prosogyrous character, are most anomalous. Suter suggests that there may be a subgenus of *Trigonia* possessed of this peculiarity, but there is no mention of this in the available literature. Cossmann in his work *Sur l'evolution des Trigonies* does not mention a single species which has these two characters.

Trigonia densicostata n. sp. (Plate XVI, fig. 1.)

Shell rather large, 50 mm. high and 65 mm. long. Interior surface highly nacreous. Umbo indistinct but apparently pointed forward. Dorsal margin nearly straight, but soon descending and sweeping with a rounded curve to the ventral margin, which is not complete but appears to bend round evenly to the posterior margin, which is also incomplete. Sculpture: A large number of fine, rather sharp radiating ridges which are rather narrower than the intervening grooves. The ribs are nearly equal, and they can be distinctly seen on the interior surface of the shell. Hinge-line incomplete, but with one prominent pointed tooth somewhat resembling that in *T. areolata* Marshall, described above.

The generic position of this shell is very doubtful. In my former list it was referred to *Cardium (Papyridina)*, but Suter afterwards referred it with the greatest hesitation to *Pseudomonotis*. It is described here merely in order that it may be possible to refer to it by name, but it will shortly be forwarded to Mr. H. Woods for identification. In the meantime it may be said that the species does not belong to any other genus of Tertiary or Recent mollusca hitherto found in New Zealand.

One specimen only, somewhat imperfect.

Type in the Wanganui Museum.

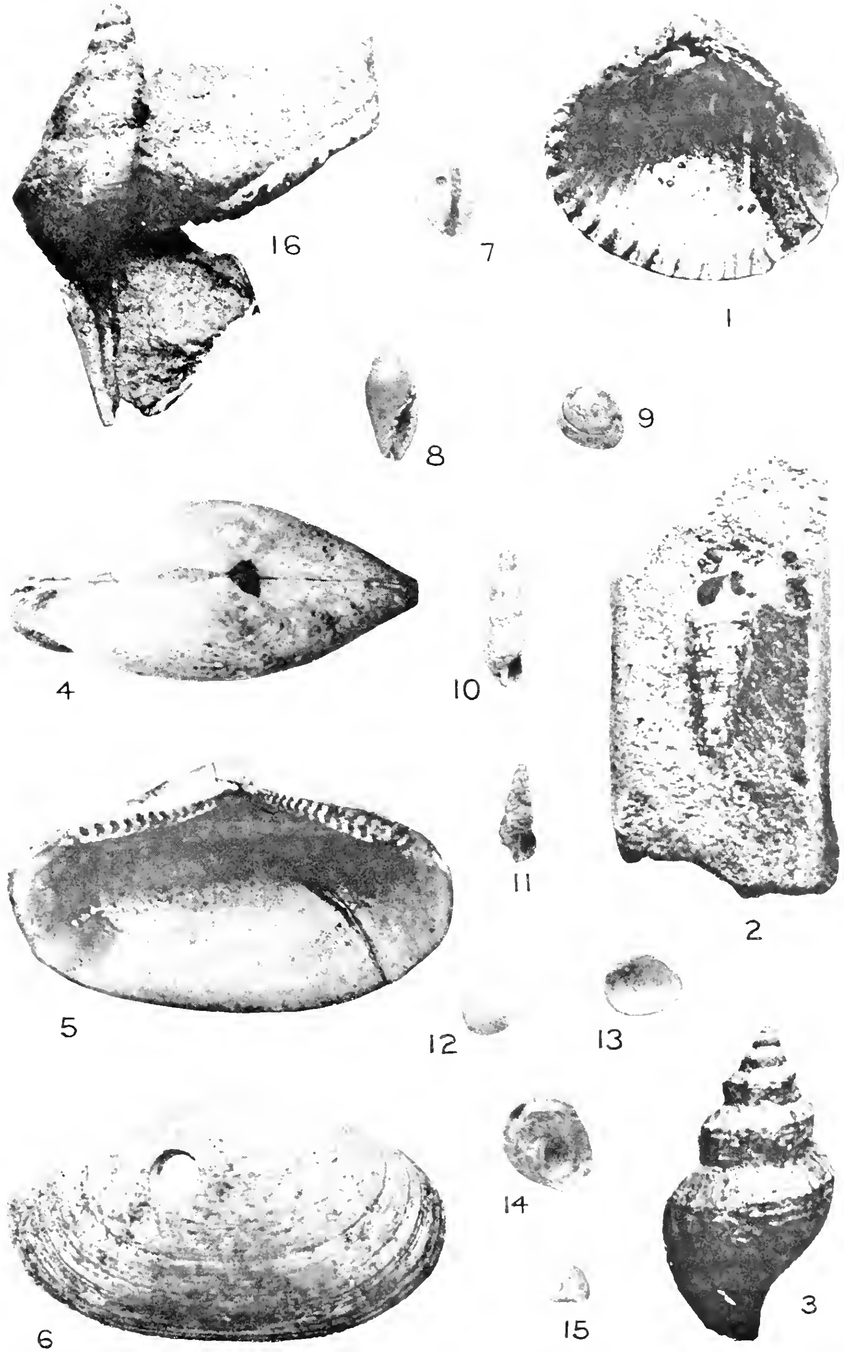
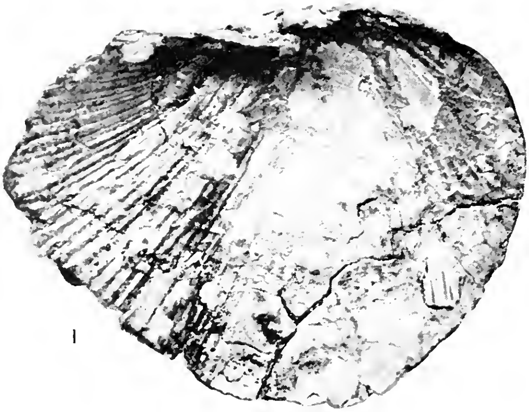


Fig. 1.—*Trigonia areolata* n. sp. × 2½.
Fig. 2.—*Cerithiella tricincta* n. sp. × 2½.
Fig. 3.—*Belophos incertus.* × 2½.
Figs. 4, 5, 6.—*Sarepta solenelloides.* × 2½.
Fig. 7.—*Erato antiqua.* × 2½.
Fig. 8.—*Marginella areniformis.* × 2½.
Fig. 9.—*Sarepta tenuis* n. sp. × 2½.
Fig. 10.—*Turbonilla antiqua* n. sp. × 2½.
Fig. 11.—*Cerithidea minuta* n. sp. × 2½.
Figs. 12, 13.—*Limopsis hampdenensis.* × 2½.
Fig. 14.—*Submargarita tricincta* n. sp. × 2½.
Fig. 15.—*Circulus inornatus* n. sp. × 2½.
Fig. 16.—*Dicroloma zelandica* n. sp. × 2.

Face p. 234.]



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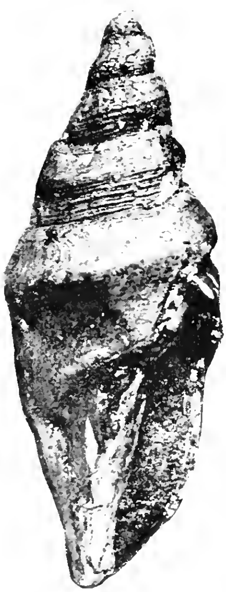

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FIG. 1.—*Trigonia densicostata* n. sp. × 1½.
FIG. 2.—*Terebra sulcata* n. sp. × 1½.
FIG. 3.—*Surcula equispiralis* n. sp. × 1½.
FIG. 4.—*Surcula gravida* n. sp. × 1½.
FIG. 5.—*Fusinus altus* n. sp. × 1½.
FIG. 6.—*Latirus dubius* n. sp. × 1½.

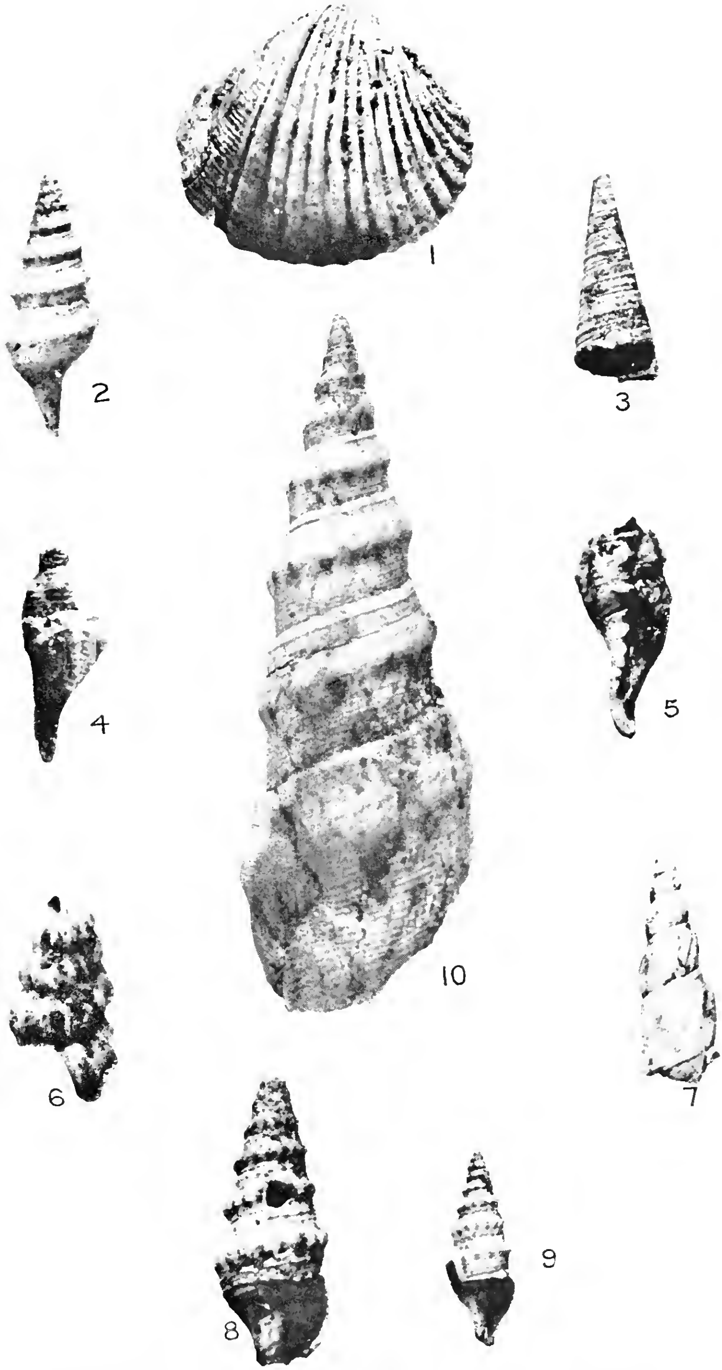

Fig. 1.—*Trigonia areolata* n. sp. × 2½.
Fig. 2.—*Turris margaritatus* n. sp. × 2½.
Fig. 3.—*Turritella rudis* n. sp. × 2½.
Figs. 4, 5.—*Volutoderma zelandica* n. sp. × 2½.
Fig. 6.—*Epitonium tenuispiralis* n. sp. × 2½.
Fig. 7.—*Surcula torticostata* n. sp. × 2½
Fig. 8.—*Turris reticulatus* n. sp. × 2½
Fig. 9.—*Turris politus* n. sp. × 2½.
Fig. 10.—*Surcula marginalis* n. sp. × 2¼.

LIST OF HAMPDEN MOLLUSCA.

The following list contains all the species of Mollusca that have been collected by me at Hampden—*i.e.*, the species that have been described above and a few species that were found during 1918.*

Aturia sp.
Architectonica n. sp.
Clio aff. *urenuiensis* Suter
Circulus inornatus n. sp.
Cerithidea minuta n. sp.
Cerithiella tricincta n. sp.
Turritella symmetrica Hutton
Turritella ornata Hutton
Turritella rudis n. sp.
Struthiolaria cincta Hutton
Struthiolaria minor Marshall
Sinum (Eunaticina) elegans Suter
Submargarita tricincta n. sp.
Ampullina waihaoensis Suter
Ampullina suturalis Hutton
Natica zelandica Q. & G.
Erato antiqua n. sp.
Cymatium minimum Hutton
Galeodea senex Hutton
Epitonium rugulosum lyratum (Zittel)
Epitonium tenuispiralis n. sp.
Turbonilla antiqua n. sp.
Dicroloma zelandica n. sp.
Fusinus solidus Suter
Fusinus altus n. sp.
Exilia waihaoensis Suter
Latirus dubius n. sp.
Siphonalia nodosa Martyn
Siphonalia turrita Suter
Belophos incertus n. sp.
Alectrion sp.
Volutoderma zelandica n. sp.
Cymbiola (Miomelon) corrugata Hutton
Ancilla novae-zelandiae Sowerby
Marginella arenoides n. sp.
Turris duplex Suter
Turris nexilis bicarinatus Suter
Turris complicatus Suter
Turris politus n. sp.
Turris regius Suter
Turris margaritatus n. sp.
Turris reticulatus n. sp.
Surcula hamiltoni Hutton
Surcula gravida n. sp.
Surcula marginalis n. sp.
Surcula equispiralis n. sp.
Surcula torticostata n. sp.
Surcula serotina Suter
Surcula sp.
Bathytoma sulcata Hutton
Terebra costata Hutton
Terebra sulcata n. sp.
Gilbertia tertiaria Marshall
Bullinella enysi Hutton
Dentalium mantelli Zittel
Dentalium pareoraense Suter
Cucullaea alta Sowerby
Sarepta solenelloides n. sp.
Sarepta obolella (Tate)
Sarepta tenuis n. sp.
Arca novae-zelandiae E. A. Smith
Limopsis hampdenensis n. sp.
Limopsis zitteli Ihering
Trigonia areolata n. sp.
Trigonia densicostata n. sp.
Lima angulata Sowerby
Atrina sp.
Ostrea waellerstorfi Zittel
Cardium sp.
Pecten huttoni Park

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* Further collecting at Hampden resulted in obtaining a good specimen of *Dicroloma zelandica* which shows the aperture perfectly, though the distal portions of the wings are wanting. The following additional species were collected:—

Euthriofusus spinosus.
Scila cfr. *bulbosa.*
Epitonium cfr. *gracillimum.*
Surcula, 2 n. sp.
Fusinus n. sp.
Siphonalia n. sp.
Trochus? sp.
Borsonia sp.

None of these specimens seems to have a Recent occurrence, and if that is the case the percentage of Recent species in the formation sinks to 9·1. The number of species in the Hampden fauna is unusually large compared with the number of specimens that can be found. The Recent species are in nearly all cases represented by a single specimen. *Arca novae-zelandiae*, *Turritella symmetrica*, *Sarepta obolella*, *Natica zelandica*, and *Lima angulata* are identified from bad single specimens only. (May, 1919.)

The Age of the Hampden Beds.

The main features of the Hampden beds were described in a former paper, in which a brief reference was made to their geological position* and to the opinions that had been expressed in regard to them by various geologists. Further collecting has been done and a more complete examination of the specimens has been made since then, with the result that eight additional species can now be recorded from these beds. Of these eight species only one is Recent; thus the percentage of Recent species is only slightly affected, and remains at 10·3.

The specimen which was previously classed as *Malletia* sp. is now found on examination of some perfect examples to be a new species of *Sarepta*. It is much larger and has a much thicker shell than any other species of *Sarepta* that has been previously recognized in this country.

One of the additional species is *Struthiolaria minor* Marshall, which has previously been recorded from Wangaloa only. Further examination of *Trigonia* sp. shows that although it has an area with a sculpture quite different from that on the rest of the shell, and is thus in no way related to the Recent or Tertiary species of *Trigonia*, it yet apparently has teeth that are destitute of the striations which are so characteristic of this genus. Mr. Suter advised that it should be sent to England for further comparison and examination.

The specimen previously classed as *Papyridea* sp. is now found to be certainly not a species of that genus, and in fact it is quite clear that it does not belong to any genus that has hitherto been recognized among the Recent or Tertiary species of Mollusca of New Zealand. Mr. Suter considered that it was a Pteriid, and suggested that it might belong to *Pseudomonotis*. The shell has a marked nacreous lustre, while its dentition suggests a relationship to the species classed as *Trigonia areolata* Marshall, and its ornamentation has no marked resemblance to any New Zealand genus. It is here provisionally classed with the genus *Trigonia*. Mr. Suter remarked that it was not possible to do justice to this species in New Zealand, where comparatively little literature was available and few specimens from other parts of the world were available for comparison.

An additional specimen of *Dicroloma* was obtained, but unfortunately it also is incomplete; but in the matrix in which it is embedded there are definite impressions of the wings, and the species is now placed in the genus *Dicroloma* with some confidence. It is most unfortunate that so many of the species that are found in this locality should be in such a poor state of preservation.

The list of species that have been found at Hampden given above shows that altogether some sixty-eight species have been obtained. Of these as many as twenty-nine—a percentage of 42·7—are regarded as new. This very large proportion in itself suggests that the beds belong to an horizon from which little collecting has been done in New Zealand. Since nearly one thousand species of Mollusca have now been recorded from the Tertiary rocks of this country, it is clear that the Hampden beds cannot be one of the ordinary Tertiary horizons, from nearly all of which fairly large collections have now been made.

Of other Hampden species that have also been found in other localities the following are noteworthy. *Gilbertia tertiaria* Marshall is thought by

* P. Marshall, *Trans. N.Z. Inst.*, vol. 49, p. 463, 1917.

Cossmann to be possibly identical with *G. paucisulcata* Marshall from Wangaloa. In addition the following species occur in both of these beds: *Cucullaea alta* Sow., *Turritella symmetrica* Hutton, *Bullinella enysi* Hutton, *Dentalium mantelli* Zitt., *Struthiolaria minor* Marshall.

I have previously stated that in my opinion the Wangaloa beds are the oldest Tertiary horizon that has yet been recognized in this country, and that the occurrence of *Perissolax* and *Pugnellus* shows that there were some Cretaceous Mollusca still in existence. In addition *Gilbertia* and *Heteroterma* suggest an extremely early Eocene or perhaps a Paleocene age as an equivalent. The further fact that the percentage of the Recent species sinks as low as 8 again supports the view as to the antiquity of these beds. This opinion as to their great antiquity is supported by Trechmann* and by Thomson.† The percentage of Recent species in the Hampden beds is about the same as in the collection from Wangaloa, but the Recent species are not the same in the two localities.

In addition the antiquity of the Hampden beds is shown by the presence of the genera *Gilbertia*, *Volutoderma*, *Trigonia*, and *Dicroloma*. These genera, however, with the exception of *Gilbertia*, are not the same as those of high antiquity in the Wangaloa collection. This difference in details may, however, be due to the different lithological nature of the strata, and therefore, in all probability, of the station at which deposition of the strata took place. The Wangaloa beds are quartz sands with a small amount of glauconite. The Hampden beds, on the other hand, are formed of an extremely unctuous mud, in which, however, there is a large amount of glauconite.

I believe that in the present state of our knowledge of the range of genera and species in the older Tertiary rocks both in space and in time it is unreasonable to insist on the occurrence of considerable numbers of identical genera and species of fossils for the correlation of horizons, for we cannot at present make proper allowance for the differences that are due to station. On the other hand, the outcrops of these older Tertiary rocks are so isolated from one another that in view of the generally accepted belief in the great overlap in their stratigraphical relations it is very undesirable—if, indeed, possible—to classify all the Tertiary rocks on a basis of purely stratigraphical considerations, as has lately been attempted by Thomson.

For these reasons it is in the opinion of the author far better to base the classification of these rocks on the general affinities of the fossil fauna contained in them. This may be most conveniently effected by comparing the faunas in such a way as to show the percentage of species that are common to the various strata, and in particular by paying special attention to the percentage of Recent species that occur in the various collections that have been made. The Recent fauna is particularly suitable for this comparison, since it contains species that have littoral occurrence as well as those which occur in water of moderate depth. This comparison may, however, tend to suggest rather too great an age for those strata which were deposited in deep water, because the molluscan fauna of our deep-water areas is still most imperfectly known.

Thomson, indeed, now suggests that the geographical separation of the outcrops of our Tertiary formations is due to minor diastrophic

* C. T. TRECHMANN, *Geol. Mag.*, dec. 6, vol. 4, p. 296, 1917.
† J. A. THOMSON, *Trans. N.Z. Inst.*, vol 49, p. 402, 1917.

movements instead of overlap. Of this there is at present no proof whatever. Certainly the continuity of the Tertiary strata between the Waihao and Shag Point gives no suggestion of such a series of movements as would be required to account for the different age of the lowest strata of the series of younger rocks (Oamaru system) in different parts of that district.

A further comparison of the Hampden fauna with that of other horizons in the Oamaru district is also of interest. This comparison should begin with those strata that are oldest. In my opinion the oldest from which collection has been made (with the exception of the Hampden and of the Shag Point beds) is the Bortonian of Park. That is also the opinion of Park, who says, "The Bortonian is the lowest marine fauna of the Oamaruian in North Otago, if not in New Zealand."* The list of Mollusca, however, which he gives is relatively small, for it contains only forty-three species. In another respect also it is rather strikingly different from all the other collections that have been made in North Otago, as it contains twenty species—nearly half of the total—of lamellibranchs. This may be due to a shallower-water station or to the imperfect preservation of the smaller species of gasteropods.

The beds from which this collection was made are composed of a quartz sandstone which must have been deposited under conditions quite different from those under which the Hampden beds were deposited. Under these circumstances it would not be expected that the faunas from these two localities would show very great resemblance even if they were of the same age. In actual fact but little resemblance can be discovered. It is, however, noticeable that *Sinum elegans* Suter and *Surcula serotina* Suter occur in both formations, and that these species have been found in the lower formations of the Oamaru district only.

The horizon that appears to me to be next in the order of age in the Oamaru district is that of the greensand of Waihao. Collections from this horizon were listed in 1914,† but the collections were very small. Out of thirty-three species some 12 per cent. were found to be Recent. Six of these species, however, have been found in the Hampden and Waihao beds only up to the present time. These are—*Ampullina waihaoensis* Suter, *Exilia waihaoensis* Suter, *Turris duplex* Suter, *Turris regius* Suter, *Turris complicatus* Suter, and *Surcula serotina* Suter. The last of these has been found in the Bortonian also.

The occurrence of these species in the two beds is of special importance when it is realized that all of them are absent from the Awamoa and Target Gully localities, in which large collections have been made, numbering 87 and 212 species respectively. These two localities topographically lie directly between the Hampden and Waihao greensand deposits. The Waihao greensands lie stratigraphically between the quartz sands with coal—probably the Bortonian beds of Park—and the Oamaru or Ototara limestone horizon. Another stratum which occupies the same local stratigraphical position and has the same lithological nature is the Wharekuri bed; but this lies farther to the west, and on the assumption of the correctness of the theory of continuous overlap the Wharekuri beds, which lie farther to the west, would be of greater age than the Waihao greensands, which are situated twenty miles farther to the east and in a region, therefore,

* J. Park, *N.Z. Geol. Surv. Bull. No. 20*, p. 34, 1918.
† P. Marshall, *Trans. N.Z. Inst.*, vol. 47, p. 385, 1915.

submerged at an earlier date as the sea margin gradually advanced westwards. Actually the Wharekuri beds contain 18·7 per cent. of the species that are found in the Hampden beds, and this is a larger percentage than is found in any other of the beds in the Oamaru district.

CLASSIFICATION OF THE OAMARU SYSTEM.

These comparisons between the Hampden fauna and that of other localities within the Oamaru area is of special interest in view of criticisms that have lately been made by Thomson,* and of classifications that have been proposed by Park,† and of statements which have been made by Morgan.‡

In various publications I have insisted that the series of rocks that rest on the Hokonui formation, or on rocks that are older than these, belong to one period of continuous deposition. The upper limit of this formation has been placed by me as certainly not below the base of the Wanganui rocks, and perhaps as high as the upper limit of this formation. This whole system of rocks I have called the Oamaru system.

This suggestion to classify all the younger rocks in a single system has been constantly opposed by Park, who has written, "To the young geologist there is always something attractive and alluring about a Cretaceo-Eocene succession." Since 1904 he has been pointing to one horizon after another as obviously the plane of division between the Cretaceous and the Tertiary, but in each case he has been forced to withdraw from his position. His latest statement, after being forced to retreat from his position of 1912, is: "A settlement can only be reached by a detailed geological survey of the middle Waipara and Weka Pass districts."§ This is the result after fifteen years of effort to find a plane of disjunction in a small area where continuous sections are remarkably clear in stream-valleys running generally at right angles to the strike.

Morgan, in discussing this proposal to classify all these younger rocks in one system, writes: "This proposal has not been fruitful in any respect save in the promotion of discussion and in the temporary thickening of the cloud of confusion involving an admittedly difficult problem." It is only necessary to add that it has stimulated research in such a way that it is now definitely known that the planes that were previously thought to be breaks between different geological formations are merely stratigraphical planes in a series of continuous deposition.

Thomson, on the other hand, agrees with the proposal to regard all the sediments above the Hokonui system up to and including the Wanganui system as a single formation "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."

Thomson objects to the use of the name "Oamaru" for this rock-system. He lays stress on the fact that the name had been previously used for a rock-system in New Zealand, and he says also that the strata are not

* J. A. THOMSON, *Trans. N.Z. Inst.*, vol. 48, pp. 28–40, 1916; also vol. 49, pp. 397–413, 1917.

† J. PARK, *N.Z. Geol. Surv. Bull. No. 20*, 1918.

‡ P. G. MORGAN, *10th Ann. Rep. N.Z. Geol. Surv.*, Parl. Paper C.–2B, p. 28, 1916.

§ J. PARK, *Trans. N.Z. Inst.*, vol. 49, p. 393, 1917.

fully developed in the Oamaru district. My reasons for wishing to retain the name "Oamaru" for this system are as follows:—

(1.) Historical: (*a*) The locality is the one from which the first collection of fossils in New Zealand was made; and (*b*) Hutton's Oamaru system included nearly all the strata in the district, and his Oamaru system includes the majority of the rocks classed in the Oamaru system by me. The retention of the name will serve to keep alive the memory of the man who did so much spade-work in the palaeontology and stratigraphy of New Zealand.

(2.) Palaeontological: The fossils in the Oamaru area have been far more fully collected, studied, and classified than in any other region where the system of rocks is well developed.

(3.) In the Oamaru district there is a fuller development of the various strata of a fossil-bearing nature than elsewhere. Between Shag Point, Wharekuri, and the Waihao River the strata are continuous, and so far as known they are not disturbed by any minor diastrophic movements. A nearly complete series of fossiliferous strata is now known:—

Awamoa	36·8	per cent.	Recent species.
Target Gully	34	,,	,,
Otiake	24	,,	,,
Wharekuri	23	,,	,,
Waihao Valley greensands ..	10–15	,,	,,
Bortonian	18	,,	,,
Hampden (early Tertiary) ..	10·3	,,	,,
Shag Point (Senonian).			

At Mount Harris there are beds which are stratigraphically still higher, but satisfactory collections have not yet been made from them. In no other district where the strata have such a full development have so many fossils been collected from such a variety of horizons. Confusion with Hutton's Oamaru system is easily avoided, for it has already fallen into disuse.

Thomson* has lately proposed to call my Oamaru system the Notocene system. This appears to me to be a very unfortunate suggestion. The suffix "cene" has a definite and satisfactory meaning when used in the ordinary names of the divisions of the Tertiary era. This meaning of "recent" ceases to have any point when used in the word Notocene. The word "noto" should mean either that this is the farthest southern point where such rocks have been found or that the formation is common to southern latitudes. Neither of these is the case, for younger rocks and their contents have been fully described from Seymour Island. There are also well-known and wide occurrences of young rocks in South America and in Australia, and these cannot be included under the same name as the New Zealand formations. The name Notocene would thus be scientifically misleading, and it is at once pretentious and inexact. If it is desired to use a name that has no special locality origin, and if hybridism is not an offence, I would suggest "Maoricene"; or if a name with a special and exact meaning is required "Notonesinene" might be used, as this might well be taken to mean "The young rocks of southern islands."

However, as I have already said, the retention of the name "Oamaru" is desirable for the reasons—(1) it is historical; (2) it helps to emphasize

* J. A. Thomson, *Trans. N.Z. Inst.*, vol. 49, p. 398–413, 1917.

the memory of the pioneer in the Tertiary palaeontology of New Zealand; (3) Oamaru is the district where nearly the whole system is developed; (4) the rocks are there more richly fossiliferous in the various horizons than elsewhere, and fuller collections have been made from them.

My classification of the divisions of the Oamaru system has also been criticized because it is based on the percentage of Recent species contained in the faunas of the different beds. It appears to me that any classification of the divisions of the strata must be based on at least one of the following considerations: (1) The occurrence of easily recognizable and widely extended lithological horizons, or on a similar succession of strata in different localities; (2) the occurrence of genera or species of fossils that have a relatively short range in time and are also widely distributed areally; (3) the general features and relationship of the faunas in the different strata.

The first of these considerations appears to me to be incapable of general application to the Oamaru system. The rocks of the system have probably a great overlap, and consequently deposits that are strikingly different from one another lithologically may be strictly contemporaneous.

In Thomson's opinion the areas of deposition have been affected by local diastrophic movements.* I can reasonably hold that no proof has been given of these supposed local distrophic movements in New Zealand, and I can quote the Oamaru district, at least, as one in which the Tertiary strata are continuous over a large district without any indication of being affected by local diastrophic action.

Thomson's divisions of his Notocene appear to be based entirely on the lithological characters of certain beds near Oamaru itself. The descriptions that he gives of them are as follows:—

Awamoan (uppermost stage)—Blue clay of All Day Bay.
Hutchinsonian—Hutchinson Quarry beds and concretionary band.
Ototaran—Limestone.
Waiarekan—Waiareka tuffs and Enfield-Windsor greensands = Ngapara greensands.
Ngaparan—Coal-measures, sands, conglomerates, and coal-seams.†

These purely stratigraphical divisions are poorly enough defined from a lithological standpoint, and no mention whatever is made of any palaeontological characters that they may have. It appears almost impossible to correlate any other beds with them. Endless confusion would be caused, too, by attempts to place the various beds at Oamaru in them. Actually, so far as lithological characters are concerned, this classification is almost the same as that proposed by myself and colleagues in 1911, but this lithological classification was then stated to be proposed merely because the palaeontological researches up to that time did not, in our opinion, provide satisfactory material for the classification of the strata, and for that reason we refrained from giving stage names for the strata. Now, however, there is, in my opinion, sufficient material to allow me to frame a classification that is based on palaeontological research.

In making use of our present knowledge of palaeontology the first point that requires notice is that the fossil Mollusca that have been found in each of these divisions of a lithological nature extend in large numbers—25 to

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* J. A. THOMSON, *Trans. N.Z. Inst.*, vol. 49, pp. 400–1, 1917.
† J. A. THOMSON, *Trans. N.Z. Inst.*, vol. 48, pp. 34, 35, 1916.

50 per cent.—into the divisions above and below. It is therefore necessary to exercise the greatest care in selecting those species which are to be regarded as the distinctive species of any one horizon. Even yet our knowledge is probably not quite sufficient to allow us to do so in all cases with great confidence. But even where this is so it does not justify us in neglecting the large amount of palaeontological knowledge we now have, as is actually done by Thomson.

As stated before, endless confusion would be caused by attempts to place the various beds near Oamaru in the stages as defined by Thomson. What, for instance, is the position of the Wharekuri beds? There is no Ototara limestone near them, and there is no Waiareka tuff, and there are no beds that in any way resemble the blue clays of the Awamoa stage. In our old classification of 1911 they had already a definite place, though it was regarded as provisional only. Park without any hesitation classes them in the Hutchinsonian because, he says, they lie below his Waitaki stone and above his lignitic beds.* This is at best a guess, and Thomson, with all other geologists except Park, refuses to recognize any difference between the Ototara and Waitaki limestones. Palaeontological results, however, can here be utilized with advantage, for seventy-five species of Mollusca have been found in the Wharekuri beds. If the general relationship of this fauna and the percentage of Recent species can be taken as a guide it can be clearly shown that the horizon is lower than that of the Ototara limestone and higher than the Bortonian of Park.

The reason for all of this is that Thomson maintains that the fauna of each locality is still imperfectly known, and he will not accept any fauna as characteristic until repeated visits to a locality fail to result in the collection of additional species. He states that he has examined ten thousand specimens of brachiopods from all parts of New Zealand, and says that until a similar investigation has been made of the Mollusca no rock grouping can rightly be based upon them. Actually I have examined far more than ten thousand specimens of Mollusca at Target Gully alone, and many times this number of specimens in other parts of New Zealand. More than eight hundred species of Tertiary Mollusca that occur in New Zealand have now been described, and the number of species recorded from several localities is now more than sixty. Surely our knowledge is now sufficient to allow us to adopt a palaeontological basis for our grouping of the rocks of the Oamaru system.

The basis of classification that has been found satisfactory in all parts of the world is dependent upon the occurrence of genera or species which have a restricted range in time. Unless a clear sequence of fossiliferous strata is found in any locality, or unless some rough grouping of the rocks is first obtained, the range of species is in general rather hard to determine. There will, however, always be some species that have a restricted range in any one fossiliferous locality, and by comparing those species that have a short life in different localities a classification can soon be arranged.

Attempts which have been made to do this in New Zealand have not up to the present time proved very successful. The more accurate identification of fossils and the more extensive collecting of recent years have, however, now made it possible. Some of our genera in particular are specially suited for this. *Struthiolaria* appears to me to be one of the best.

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* J. Park, *Bull. N.Z. Geol. Surv. No. 20*, p. 84, 1918.

The species are numerous, and their ornamentation distinct and varied, and many of the species appear to have a short range.

There can now be no doubt that the genus *Struthiolaria* is derived from *Pugnellus* Conrad, or from that modification that has been called *Conchothyra* by McCoy. *Conchothyra parasitica* McCoy occurs at the Selwyn Rapids and other places in rocks of Senonian age, and at the Waipara in rocks probably of the same age it is represented by *Pugnellus waiparaensis* Trechmann, a closely related species, while at Wangaloa, in rocks that are of very early Tertiary age, *Pugnellus australis* Marshall occurs, a species quite closely related to *P. waiparaensis*. At Hampden and Wangaloa there is *Struthiolaria minor* Marshall, a species that has a callosity extending over the greater part of the spire. *Pugnellus australis* Marshall is thought by Cossmann to be quite probably a *Struthiolaria*. *S. calcar*, *S. spinosa*, and *S. tuberculata* have a restricted range in the middle part of the Oamaru system, while *S. canaliculata* occurs in the portion that is commonly compared with the Upper Miocene, and *S. frazeri* is found in beds that are possibly the equivalent of the Lower Pliocene, and two species extend up to the Recent period.

Fusinus is another genus that can probably be used in the same way, for *F. solidus* is found in the Hampden beds, and in other rather higher but still old Tertiary beds. At Wharekuri *F. pulcher* occurs. *F. carinatus* occurs in beds that are rather low in the system in Canterbury, while *F. climacotus* is found at Enfield and Target Gully. In the north *F. morgani* and *F. kaiparaensis* are also species that appear to have a restricted range. *F. spiralis* occurs in Wanganui and Recent beds.

Exilia is a genus that is said by Cossmann to be characteristic of the Eocene period. In New Zealand *E. waihaoensis* is found in the Hampden beds and at Waihao, *E. dalli* extends to the top of the Oamaru limestone, and a third species is found in beds of a low horizon at Enfield.

Surcula is a genus that is well represented, and many of the species have a restricted range. Thus *Surcula hamiltoni* is found at Hampden, Wharekuri, and Kakahu. *Surcula serotina* is confined to the beds of low horizon at Hampden and Waihao and at Borton's. Many of the other species have a sufficiently restricted range to allow them to be used as index fossils.

There are many other genera, such as *Pecten*, *Cardium*, *Venericardia*, *Natica*, *Crassatellites*, and *Siphonalia*, that have species which by reason of their common occurrence, distinctness, and short range in time are eminently suitable for indicating the age of certain horizons.

The relation of various faunas to the Recent fauna and to one another gives another basis for correlation that may be used with the greatest advantage in studying the divisions of the Oamaru system. Thomson compares it with Lyell's original basis for the classification of the European Tertiaries, and says that the great geologist adopted this method because the European fossiliferous Tertiary beds were discontinuous. Surely that is also so in New Zealand, for otherwise we should not still at the present day be worrying about the stratification succession in them after forty years of effort. The fact that Lyell included the Brachiopoda in his comparisons does not affect the question. In New Zealand the brachiopods occur so sporadically and in such a small number of species compared with the Mollusca, and the species are so hard to identify with certainty, that they are far less satisfactory for purposes of correlation. Nobody would slavishly follow Lyell to the extent of requiring in New Zealand the same percentages for the different divisions of the Tertiary sediments as those that were used by him. It would be inadvisable to include the Brachiopoda in any New Zealand comparisons, because it so often happens that no brachiopods are to be found in the beds that contain molluscan fossils.

A further objection to this method is based on the possibility of the migration of faunas to New Zealand at different times. Our knowledge of the fauna is probably sufficient now to enable us to express a definite opinion on this subject, and it can be stated with some confidence that we have every reason for thinking that at no time has an introduction of a considerable number of species to our Tertiary molluscan fauna taken place. It is certainly a fact that a statement of the number of Recent species in the different fossil faunas will more speedily discover whether there has been such a migration than any other method of research.

It is now generally admitted that there is no stratigraphical break in the series of Tertiary rocks, and also that there is none in the faunal succession that is represented in them, for, as I have previously quoted, Thomson and Morgan state "Each Tertiary fauna seems to merge gradually into the succeeding one"*; and the late Mr. Suter has written the following in a letter to me: "There is no doubt that our molluscan fauna has gradually decreased, and also that the Tertiary forms gradually merge into one another." If this is the case it will certainly be extremely hard, if not impossible, even when our Tertiary fauna is completely known and the range of species definitely recorded, to find a horizon at which any important number of species disappear simultaneously. It is distinctly better under these circumstances to characterize the beds as containing certain percentages of Recent species.

This statement of the proportion of Recent species will, however, not provide a secure basis for comparison with European horizons. The small size of New Zealand and the fact that the more recent researches and the number of autochthonous species in its fauna and flora all show that the land has been isolated from other countries since, at the latest, the late Cretaceous, except possibly in the post-Tertiary, suggest that the organic changes must have been relatively slow. This belief is further supported by the knowledge that there has been no great variation of climatic conditions: that is, though the climate has been warmer and colder, it has not been tropical at any time, nor has there been anything that has approached the arctic cold of the Great Ice Age of Europe.

Again, it must be emphasized that our strata were deposited under the most different conditions of depth of water and of proximity to the shoreline, so that it is almost certain that in different parts of the area conglomerates, greensands, and limestones were contemporaneous formations. Such different lithological horizons would necessarily have also very different palaeontological facies, and a very great deal of work must be undertaken before we can be reasonably certain of their contemporaneity if we rely upon the occurrence or absence of index fossils. On the other hand, the Recent fauna contains species that live under all these different conditions, and it therefore affords a basis for comparison with the fauna of every lithological facies of the Tertiary strata.

It follows that if there is in New Zealand a continuous succession of our Tertiary molluscan species and an unbroken series of Cainozoic strata, and if the contemporaneous strata have a great variety of lithological facies,

* Preface to *Palaeontological Bulletin No. 5*, 1917.

then this country is a typical one in which a calculation of the percentage of Recent species in representative collections from different strata affords the most satisfactory means of gauging the relative age.

It is not reasonable to refuse to use the percentage criterion because the present collections have not exhausted the fauna of any locality. In most cases sixty or seventy species are sufficiently representative of a fauna, and it is usually found that the percentage of Recent species in a collection of forty species in New Zealand strata remains practically the same even when large additions are subsequently made to it. At Target Gully, Oamaru, when the collection was 69 species the percentage of Recent species was 32·8; when 126 species, 36·3 per cent.; when 155 species, 33 per cent.; and when 212 species, 33·4 per cent. In calculating these percentages allowance has been made for erroneous identifications which were made in the earlier lists when they were first published.

Of course, it must be realized that the personal equation in the identification of species may cause a considerable variation in the percentage of Recent species when the identification is made by different authorities. Probably by the time that this has had much effect we shall be able to substitute definite species as indicating a special horizon in place of these percentages. At present it must be noted that in the Target Gully fossils Cossmann cannot agree that the species identified by Suter as *Chione mesodesma* and *C. oblonga* are actually the same as these Recent species. It is noticeable also that the relatively large *Natica zelandica* which is found Recent and in the Wanganui beds differs greatly in size from the consistently small form which is found in the Target Gully and Wharekuri beds and in other beds of that series near Oamaru. Again, the *Malletia australis* of Wharekuri is notably different from the Recent and Wanganui specimens, while specimens from Awamoa have characters intermediate in many respects. Mr. Murdoch, too, assures me that in his opinion the *Crassatellites obesus* from Target Gully is quite a different species from that which is still living.

In summarizing the above I should say that the following facts appear to me to justify the use of the percentage method in the present state of our knowledge in classifying the strata of the Oamaru system in New Zealand: (1) There is a continuous succession of strata belonging to this system, which extends from perhaps the equivalent of the European Senonian to the Pliocene; (2) the faunas of the various Tertiary horizons gradually merge into one another; (3) contemporaneous strata differ so greatly lithologically and have been deposited under such very different bathymetric conditions that comparisons of species are in the light of our present knowledge unsatisfactory; and (4) the actual range of species is not yet sufficiently well known to allow of definite index fossils being stated as distinctive of different horizons.*

The table below, which has been prepared with great care, shows the faunal relations between the various beds near Oamaru. It also shows some comparisons between the Oamaru strata and those of the Trelissick beds of Canterbury, and also those of the Pakaurangi Point, Kaipara Harbour, North Auckland. It is difficult to frame a table that will give

* In reference to the use of the percentage of Recent species for defining the age of the Tertiary periods the most comprehensive of lately published text-books of geology says, "A wider knowledge of the marine Tertiary molluscs has shown that this classification has permanent value." (L. V. Pirsson and C. Schuchert, *Text-book of Geology*, p. 914.)

the actual faunal relationships between the different strata in a distinct manner when the collections which have been made in the different localities vary much in the number of species. For instance, when a comparison is made between the Otiake and the Target Gully faunas one is comparing a collection of 61 species with one of 212 species. One would naturally expect that a high percentage of the former would be found in the latter. On the other hand, only 28 per cent. of the Target Gully species could occur in the Otiake collection. On the whole it appears to be the best plan to take each collection separately and calculate what percentage of the species that occur in each of the other localities is found among the species that occur in the stratum which is being considered. A comparison is also made with the fauna of the Recent beds and of the fauna that has been recorded from the Wanganui beds. In the latter some 200 species are recorded by Hutton, but the collection that he describes has been made from a large number of horizons, though all of them are younger than the strata at Oamaru and younger than those of the Trelissick Basin. It appears to me probable that no single horizon at Wanganui will yield more than 150 species of fossil Mollusca, even when fully collected. Of the Recent Mollusca it seems that no more than 400 of the recorded species could be expected to occur under the conditions of depth of water in which the Oamaru deposits were laid down. This, at any rate, is the assumption that is made, and in all of the percentage calculations it is assumed that the Recent fauna consists of 400 species only.

The various beds from which collections have been made may be described as follows:—

(1.) Hampden: On the coast about three miles north of the township of Hampden, or about fifteen miles south of Oamaru. The beds are unctuous green marls with a good deal of glauconite. Perhaps some 1,000 ft. above the base of the Oamaru system in that locality.

(2.) Wharekuri: Typical glauconite sands. Exposed on the left bank of the Waitaki River six miles from Kurow, about thirty miles north-west of Oamaru.

(3.) Otiake: Close to the right bank of the Waitaki River, four miles south-east of Kurow, or twenty-five miles north-west of Oamaru. The rocks are gritty polyzoan limestones which are higher in the series than the Wharekuri beds and probably rest directly on them. It is very generally admitted that this is the horizon of the Oamaru or Ototara limestone.

(4.) Target Gully: These are about half a mile from the Oamaru Railway-station, close to the Eden Street bridge. The beds are greyish sands with a little glauconite. The beds rest some 30 ft. above the Oamaru or Ototara limestone.

(5.) Awamoa: Near the coast about four miles south of Oamaru. The beds are a blue mudstone, which is admitted to be a higher horizon than the Target Gully beds.

In addition some comparisons are made with the Bortonian beds of Park* and also with the fauna of two beds in the Trelissick Basin, which have lately been fully listed by Speight,† and with the Pakaurangi fauna of North Auckland.

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* J. Park, *N.Z. Geol. Surv. Bull. No. 20*, p. 34, 1918.
† R. Speight, *Trans. N.Z. Inst.*, vol. 49, pp. 346, 348, 1917.

	Hampden, 68 Species.	Wharekuri, 75 Species.	Otiake, 61 Species.	Target Gully, 212 Species.	Wanganui, 200 Species.	Recent, 400 Species.	
Hampden, 68 species	..	14	8	16	7	7	Number of species found also in Hampden fauna.
	..	18·7	13·3	7·5	3·5	1·7	Percentage of species found also in Hampden fauna.
Wharekuri, 75 species	14	..	31	41	18	16	Number of species found also in Wharekuri fauna.
	20·6	..	50·2	19·3	9	4	Percentage of species found also in Wharekuri fauna.
Otiake, 61 species	8	31	..	43	19	15	Number of species found also in Otiake fauna.
	11·8	41·3	..	19·7	9·5	3·8	Percentage of species found also in Otiake fauna.
Target Gully, 212 species	16	41	43	..	71	71	Number of species found also in Target Gully fauna.
	23·5	54	67	..	35	18	Percentage of species found also in Target Gully fauna.
Awamoa, 87 species	11	30	25	59	35	34	Number of species found also in Awamoa fauna.
	16	40	41	28	17·5	9	Percentage of species found also in Awamoa fauna.
Trelissick (1), 87 species	4	13	13	27	27	33	Number of species found also in Trelissick (1) fauna.
	5·9	17·3	21·3	12·7	13·6	8·2	Percentage of species found also in Trelissick (1) fauna.
Trelissick (2), 66 species	6	10	11	31	17	21	Number of species found also in Trelissick (2) fauna.
	8·8	13·3	18	15·1	8·5	5·2	Percentage of species found also in Trelissick (2) fauna.
Pakaurangi, 113 species	11	21	18	48	24	23	Number of species found also in Pakaurangi fauna.
	16·2	28	29·5	22·6	12·0	6	Percentage of species found also in Pakaurangi fauna.
Bortonian, 43 species	5	12	5	17	11	8	Number of species found also in Bortonian fauna.
	7·3	16	8·2	7·5	5·5	2	Percentage of species found also in Bortonian fauna.

	Number of Lamellibranchs.	Total Number of Species.	Percentage of Lamellibranchs.
Hampden	14	68	20
Wharekuri	30	75	40
Otiake	19	61	31
Target Gully	60	212	28
Awamoa	24	87	28
Trelissick (1)	57	87	66
Trelissick (2)	40	66	60
Pakaurangi	39	113	34
Bortonian	18	43	42

The relations of the different faunas as shown by this table must give a very definite idea of the relative ages of the strata. The conclusion to which it leads is in perfect accord with that at which I had previously arrived by employing the criteria of stratigraphy and of the percentage of Recent species.

The percentage of the species of the Hampden fauna which occurs in each of the other strata is relatively low, and clearly points to the considerable antiquity of the Hampden fauna. So far as the other localities are concerned, the percentage of the Hampden species gradually decreases from the Wharekuri to the Recent. On the other hand, the percentage of the Target Gully and of the Awamoa species gradually decreases from the Wharekuri to the Recent. However, these beds are more closely related to the Otiake beds below them than to the Wanganui beds above them. This obviously points to the probability or certainty that there are intervening beds of an intermediate age which will show a complete faunal gradation. In fact, the upper and lower strata in the Wanganui district are very different in age, as is clearly shown by the fact that the higher beds at Castlecliff contain about 90 per cent. of Recent species, while the beds at Waipipi, near Waverley, contain little more than 65 per cent. This, however, is a matter that will be worked out more fully subsequently.

The Bortonian, Trelissick, and Pakaurangi faunas are also tabulated in order that they may be more definitely compared with that of the beds near Oamaru. The Bortonian is clearly seen to approach most nearly to the Wharekuri strata, and this fact in itself shows quite clearly that the basal beds at Borton's are much younger than the basal beds in the Shag Point – Hampden portion of the Oamaru basin.

The Trelissick formations do not enter so readily into a comparison with the strata near Oamaru. The character of the fauna is somewhat different, as is clearly shown by the fact that there is a high percentage of lamellibranchs in it. At the same time the upper bed shows a closer approach to the Otiake stratum than to any other in the Oamaru district. This is significant, for the lower Trelissick bed is the middle of the limestone horizon in the Canterbury area, while the Otiake bed has the same position in the local series of Oamaru. The upper Trelissick bed, which rests directly on the surface of the limestone, is shown by the table to be much more closely related to the fauna of the Target Gully beds, which also have the corresponding position with reference to the Oamaru limestone that the Trelissick (2) beds have to the limestone (Amuri limestone) in that locality.

The fauna of the Pakaurangi beds is also shown to be more closely related to that of the Target Gully beds than to any other beds of the local Oamaru area, though there is a fairly close affinity with the fauna of Otiake—the Oamaru limestone horizon. This again agrees closely with the stratigraphical position that I have assigned to them. As stated elsewhere, the Pakaurangi beds, in my opinion, rest conformably on the hydraulic limestone, which I have correlated with the Oamaru limestone* (Otiake beds), and are therefore the local equivalent of the Target Gully beds. In applying the table to this matter it must be realized that only 53 per cent. of the Target Gully fauna could occur in the Pakaurangi beds, as is shown by the actual numbers of the species that have been collected. On the other hand, 100 per cent. of the Otiake fossils could occur in it.

The considerations that have been stated in this paper seem to me to justify the proposal to use the palaeontology of the strata near Oamaru as a basis for the correlation of the Oamaru system of rocks, and I would

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* Thomson (*Trans. N.Z. Inst.*, vol. 48, p. 49, 1916) objects to the correlation of the hydraulic limestone of North Auckland with the Amuri limestone. It is a fact, however, that the hydraulic limestone rests on strata which contains a Senonian fauna and is covered by strata which contains a Tertiary fauna – the criterion given by Thomson for the stratigraphical position of the Amuri limestone.

now suggest the following divisions of the system in amplification of that proposed by me in a former paper*:—

OAMARU SYSTEM.

Probable European equivalent, Senonian to Pliocene.

Castlecliff Series (80–90 per cent. of Recent species).

Characteristic fossils: *Bezanconia huttoni, Calliostoma ponderosum, Actaeon ovalis.*

Until full collections have been made from these beds it is a little difficult to fix the boundary-line between them. At present it seems to me to be best placed at the horizon of the Moa bed, one mile south of the Nukumaru Beach.

The beds of the whole system certainly show a complete faunal gradation throughout, and it is therefore impossible to select fossil species that are entirely absent from the series above and below. In several cases the species that have been cited are found also in other series. It is thought, however, that they are more characteristic of the series under which they are mentioned than of the others.

Nukumaru Series (70–80 per cent. of Recent species).

Characteristic fossils: *Melina zealandica, Lutraria solida, Lucinida levifoliata, Ataxocerithium perplexum, Struthiolaria frazeri.*

A full list of species from this series has not yet been published, but it is hoped that this will be done next year. This series probably includes the Matapiro and Petane beds.

Waipipi Series (60–70 per cent. of Recent species).

Characteristic fossils: *Ostrea ingens, Pecten triphooki, Cardium spatiosum, Lima waipipiensis, Diplodon ampla.*

Collections from this locality are not yet completed. It is probable that localities near Hawera and in the higher portions of the Wanganui River contain a fauna that will fill in the gap between the Waipipi and the Target Gully series. The probability of this is shown by the collection made by Park from the Paparoa, on the Upper Wanganui River.†

The Greta and the Awatere beds and those at Castle Point may occupy a position intermediate between the Target Gully and the lower beds of the Wanganui coast-line—the Waipipi series. The collections that have been made up to the present are not sufficiently extensive to settle this matter definitely.

Target Gully Series (30–40 per cent. of Recent species).

Characteristic fossils: *Venericardia pseutes, Terebra orycta, Vexillum rutilidomum, Murex octogonus, Calyptraea maccoyi, Turbonilla oamarutica, Murex angasi, Chama huttoni, Fusinus climacotus.*

Nearly all species, however, are found in higher or in lower strata as well as in the Target Gully beds. In addition to species previously recorded from these beds I wish now to record *Venericardia bollonsi, Ficus subtransennus, Loripes concinna, Drillia laevis, Nucula sagittata, Leda semiteres.*

* P. MARSHALL, *Trans. N.Z. Inst.*, vol. 48, p. 119, 1916.
† J. PARK, *Reports Geol. Explorations during 1886–87*, p. 173, 1887.

The strata called elsewhere in this paper "Trelissick (2)," the Pakaurangi beds, and the sandy beds of the lower Waipara Gorge should probably be placed here.

Ototara Series (25–30 per cent. of Recent species).

Characteristic fossils: *Pecten athleta*, *P. hochstetteri*, *P. williamsoni*, *Ostrea nelsoniana*, *Lima laevigata*.

This series is more definitely marked lithologically than palaeontologically, for it consists mainly of the limestone stratum which has such a general occurrence throughout New Zealand and but seldom contains molluscan fossils. Nearly all the fossils that have been found in this limestone have been found in higher and in lower horizons as well.

Wharekuri Series (20–25 per cent. of Recent species of Mollusca).

Characteristic fossils: *Surcula serotina*, *Borsonia mitromorphoides*, *Fusinus maorianus*, *Erilia dalli*, *Crassatellites subobesus*, *Niso neozelanica*, *Polinices huttoni*, *Turritella ambulacrum*.

Since my previous publication on the Whharekuri beds the following additional species of Mollusca have been collected: *Turris subaltus* n. sp., *Cucullaea australis*, *Terebra orycta*, *Terebra sulcata* Marshall, *Crassatellites subobesus* n. sp., *Panope orbita*, *Divaricella cumingi*, *Argobuccinum?* sp., *Cardium waitakiense*, *Marginella harrisi*, *Typhis maccoyi*, *Borsonia mitromorphoides*, *Chione* sp., *Siphonalia subnodosa*, *Zenatia acinaces*, *Fusinus maorianus*.

The Waihao greensands are probably to be placed in this series.

Wangaloa Series (0–20 per cent. of Recent Species of Mollusca).

Characteristic fossils: *Gilbertia*, *Perissolax*, *Heteroterma*, *Dicroloma*, *Volutoderma*, *Struthiolaria minor*, *Pugnellus australis*.

Waipara Series (Senonian).

Characteristic fossils: *Trigonia hanetiana*, *Inoceramus australis*, *Conchothyra parasitica*, *Belemnites lindsayi*, *Kossmaticeras*, *Baculites*, *Mosasaurus*.

Art. XXIV.—*Occurrence of Fossil Moa-bones in the Lower Wanganui Strata.*

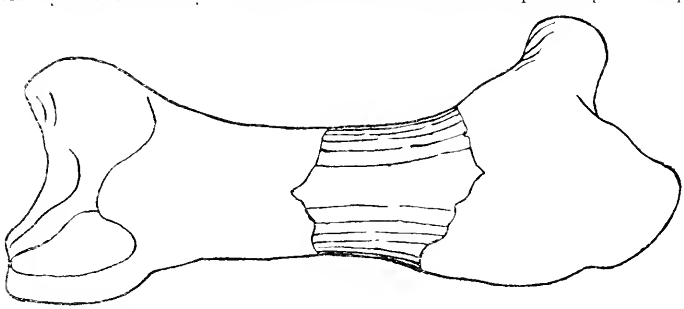
By P. Marshall, M.A., D.Sc., F.G.S.

[*Read before the Wanganui Philosophical Society, 7th December, 1918; received by Editor, 30th December, 1918; issued separately, 16th July, 1919.*]

Plate XVIII.

No occurrence of fossil remains of the larger species of moa has yet been recorded. Such records as there are of fossil moa-remains were collected by Hutton (*Trans. N.Z. Inst.*, vol. 24, p. 141, 1891). Since the publication of that paper no further record has been made. If it be true, as I have often advocated, that the area of New Zealand has practically been isolated since the Upper Cretaceous period, the development of the numerous species of moa must have taken place within the limits of this country. Since there is a great mass of Tertiary rocks in New Zealand, and they are often of a shallow-water origin, it was reasonable to expect that at some time or other remains of the moa would be found in them. It was therefore with some satisfaction that last summer a few bones were discovered embedded in the papa rock forming the cliffs near the Nukumaru Beach. The greater number of the bones were in a poorly preserved condition, but a portion of one femur (Plate XVIII) was in a sufficiently good condition to be identified. It was sent to Professor W. B. Benham, of Otago University, who was good enough to compare it with the large collection of moa-bones in the Otago Museum. My thanks are due to him for the following report on the specimen:—

"The curious trellis of bone lining the medullary cavity is quite similar to what occurs in the long bones of the moas. From our extensive stock of moa-bones I selected for comparison those of *Dinornis robustus*, and find a very close resemblance to the femur of that species, both in size, details of surface-marking, and thickness of outer wall as seen in transverse section. One small feature that seems characteristic is the small size of the vascular foramen on the posterior face, which is not only relatively smaller in proportion to the size of the femur in this species but absolutely smaller than in other species. Taking this as a starting-point, comparison of the ridges and prominences on this surface agrees quite closely, though not absolutely, with those on *D. robustus*, where they are more prominent and rather differently formed. This no doubt is explicable by wear and by variation in individuals, or possibly it is specific.



Femur of *Dinornis robustus*, showing position of fragment found at Nukumaru.

"I send an outline tracing of the right femur of *D. robustus* with the fragment shown in position. [See text-figure.] It will be seen, therefore, that the fossil is a portion of the shaft just below the great trochanter. . . .

"Whether the species is *D. robustus* or an allied species it would be difficult to decide, but the bird must have been of the same size as that. . . ."

The actual locality where the specimen was found is about three-quarters of a mile south of the Nukumaru Beach. The stratum is composed of a fine pebbly material with much unctuous blue clay. The pebbles are not composed of local material, but seem to be derived from the rocks of north-west Nelson. I have previously drawn attention to the probability of the micaceous sand of Wanganui having its origin in the granite rocks of Nelson. The stratum is regularly interbedded with the other strata of which the cliff is formed, and, like them, it dips south-west 5°. A preliminary estimate shows that this stratum lies about 1,000 ft. below the highest beds at Castlecliff.

Some species of Mollusca were found in the bed from which the moa-bones were obtained. These were somewhat rolled, but some of them could be identified. The following is a list of the species that have been identified:—

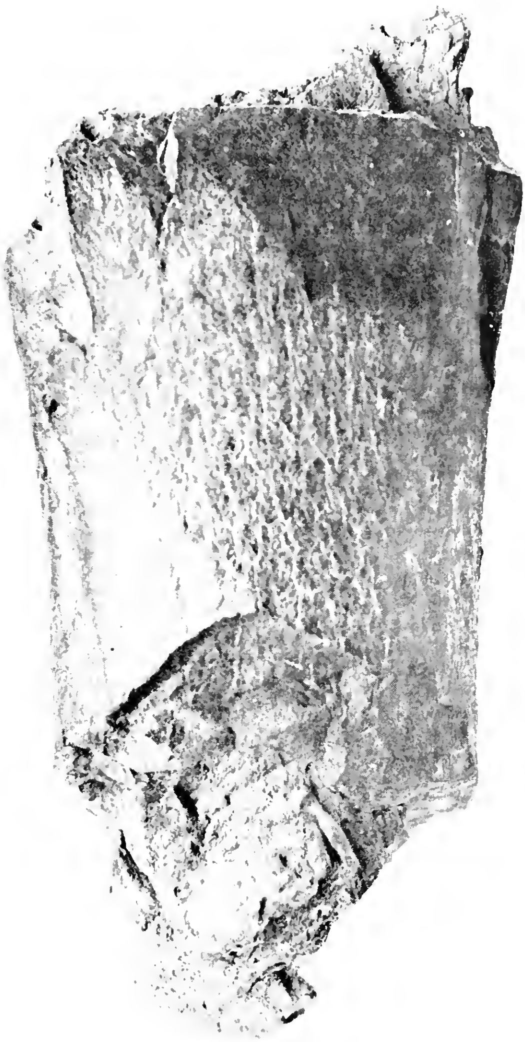
Ancilla novae-zelandiae (Sowerby)
—— *depressa* (Sowerby)
Ataxocerithium perplexus Marshall and Murdoch
Barnea similis (Gray)
Chione crassa Q. and G.
—— *stutchburyi* (Gray)
Cominella maculosa (Martyn)
Crepidula gregaria Sowerby
Cytherea oblonga (Hanley)
Ethalia zelandica (H. & J.)
Lucinida levifoliata Marshall and Murdoch
Lutraria solida Hutton
Mactra discors Gray
Mesodesma australe (Gmelin)
—— *subtriangulatum* (Gray)
Ostrea angasi Sowerby
Psammobia lineolata Gray
Turritella rosea Q. & G.
Venericardia zelandica (Deshayes)
—— *australis* Lamarck

This list contains twenty-two species, of which five are extinct. The occurrence of *Mesodesma australe* confirms the impression of deposition in shallow water made by the pebbly nature of the stratum and by the rolled condition of many of the Mollusca. This species is said by Suter in the *Manual of the New Zealand Mollusca* to have its habitat between tide-marks.

Another stratum about 40 ft. lower in the series and bearing a larger number of fossils crops out at the beach-level nearly 500 yards farther north. The following species of Mollusca were found in this stratum:—

Anachis pisaniopsis (Hutton)
Ancilla novae-zelandiae (Sowerby)
—— *lata* Hutton
Anomia huttoni Suter
Calliostoma hodgei (Hutton)
—— *selectum* (Chemnitz)
—— *ponderosum* (Hutton)
Calyptraea alta (Hutton)
—— *maculata* (Q. & G.)
—— *scutum* Lesson
Cantharidus purpuratus (Martyn)
Chione spissa (Deshayes)
—— *disjecta* Perry.
—— *stutchburyi* (Gray)
Cominella virgata A. Ad.
Crepidula crepidula Linn.
—— *gregaria* Sowerby
Divaricella cumingi (Ad. & Ang.)
Dosinia subrosea (Gray)
Epitonium zelebori (Dunker)
Ethalia zelandica (H. & J.)
Euthria striata (Hutton)
—— *drewi* (Hutton)
Fulgoraria arabica (Martyn)
Lucinida concinna Hutton
—— *levifoliata* Marshall and Murdoch
Lutraria solida Hutton
Mangilia protensa (Hutton)
Melina zealandiae Suter.
Mytilus magellanicus Lamarck
Paphia intermedia (Q. & G.)
Pecten zelandiae Gray
Seila chathamensis Suter
Siphonalia subnodosa (Hutton)
Struthiolaria frazeri Hutton
Trochus tiaratus Q. & G.
Trophon ambiguus (Philippi)
—— *cheesemani* (Hutton)
Turbonilla zealandica (Hutton)
Turritella rosea Q. & G.
—— *symmetrica* Hutton

An interesting feature of this fossil-bed is the large size of many of the shells: for instance, *Lutraria solida*, 140 mm. (Hutton's type, 110 mm.); *Chione disjecta*, 65 mm. (*Manual*, 58 mm.); *Dosinia subrosea*, 75 mm. (*Manual*, 48 mm.); *Struthiolaria frazeri*, 110 mm (Hutton, 75 mm.); *Paphia intermedia*, 65 mm. (*Manual*, 57 mm.). *Lucinida levifoliata* is far larger than other Recent or fossil species of that genus in New Zealand.



Part of femur of a species of moa found in the lower Wanganui strata near Nukumaru Beach. Natural size.

It is interesting to have definite evidence that the large species of *Dinornis* existed when so many extinct species and genera of Mollusca were still living in New Zealand waters.

It is perhaps worth noting that *Lutraria solida* has not yet been found in any beds on the coast-line higher than that containing the moa-bones. Of other well-known extinct species of Mollusca the following information has now been gained so far as occurrence in the strata on the coast-line is concerned: *Melina zelandica*, *Struthiolaria frazeri*, and *Crepidula gregaria* first occur in the bed that has been mentioned 40 ft. below the moa-bed, and *Cardium spatiosum* and *Ostrea ingens* are first found at Wilkie's Bluff, close to the south of the Waitotara mouth. *Glycymeris subglobosa* first occurs two miles north of the Waitotara. At Mokoia, close to Hawera, a shell of *Dosinia magna* was obtained.

From the collections that have been made at present it seems that about 90 per cent. of the Mollusca in the Castlecliff beds are of Recent occurrence. In the moa-bed there are about 80 per cent. of Recent species. At the Waipipi Beach, five miles north of the Waitotara mouth, the percentage falls perhaps as low as 65.

I hope to publish a fuller statement of this matter, with lists of the species, next year.

ART. XXV.—*Some New Fossil Species of Mollusca.*

By P. MARSHALL, M.A., D.Sc., F.G.S., and R. MURDOCH.

[*Read before the Wanganui Philosophical Society, 20th December, 1918; received by Editor, 31st December, 1918; issued separately, 16th July, 1919.*]

Plates XIX–XXI.

THE species of fossil Mollusca which are described in the following pages have been collected from Tertiary beds in several different localities. Some of the specimens were submitted to the late Mr. Suter, but he had no time to describe them.

The following species were found at Wharekuri, on the Waitaki River, a few miles above Kurow: *Fusinus maorium*, *Leucosyrinx subaltus*, and *Crassatellites subobesus*. The material from which they were taken is argillaceous greensand, which in this locality rests upon quartz sands, which contain coal-seams. Altogether seventy-five species of Mollusca have been found in these beds, and 24 per cent. of these are Recent species. We regard this bed as a stratigraphical series in the Oamaru system, lying below the Ototara limestone.

Ficus imperfectus was found at Target Gully, as well as *Venericardia bollonsi* Suter and *Drillia laevis* (Hutton), two species which have not previously been recorded from that locality. These species raise the total number collected at Target Gully to 223. Some 34 per cent. of these are Recent. The horizon is 40 ft. above that of the Ototara stone. It has been placed by Marshall in the Awamoa series of the Oamaru system.

Lima waipipiensis was found at the Waipipi Beach, five miles from Waverley. The horizon is probably some 1,500–2,500 ft. below the highest part of the Castlecliff beds at Wanganui. Such well-known fossil species as *Lutraria solida*, *Cardium spatiosum*, *Ostrea ingens*, and *Pecten triphooki* have been found in the same bed. In a collection which is quite incomplete some 70 per cent. of the species are Recent. I propose to call this bed, from which more complete collections will shortly be made, the Waipipi series, in the upper part of the Oamaru system.

Lucinida levifoliata occurs in the same bed, and also at Nukumaru, where it is associated with *Melina zealandica*, *Lutraria solida*, and *Struthiolaria frazeri*. The whole molluscan fauna so far collected at Nukumaru contains about 80 per cent. of Recent species. This horizon also offers good material for collecting, and will be called the Nukumaru series of the upper part of the Oamaru system. The series is perhaps 500 ft. above the Waipipi series.

The two remaining species, *Thracia vegrandis* and *Surcula castlecliffensis*, came from the Castlecliff Beach, near Wanganui. The percentage of Recent species in this fauna approximates to 90. It is the highest described series of the Wanganui system. A list of the Mollusca found in it will shortly be published.

Ataxocerithium perplexum n. sp. (Plate XX, figs. 5, 6.)

Material, two examples, much rolled and having the sculpture almost erased except on a small area near to the aperture, which is spirally ribbed: interspaces and ribs about equal, the latter cut into small gemmules by the varying development of the growth-striae. Shell elongated, turreted, body-whorl exceeding one-third of the total length, base rounded and with an ill-defined spiral ridge, anterior to which it is rather more abruptly contracted. Sutures well marked, apparently not channelled. Apex imperfect. Aperture ovate, produced in a very short open canal: outer lip more or less channelled above; body-wall with a well-marked callus which unites with the columella and forms a distinct ridge: the columella is slightly arched and twisted to the left at the anterior end.

Length, 34 mm.; breadth, 11 mm.; length of aperture with canal, 10 mm.

Locality, Nukumaru, in blue sandy clay. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The examples are much worn, the only area with sculpture being near to the outer lip. Sculpture on approaching the aperture in many genera is more or less suppressed: we may therefore reasonably expect a bolder sculpture on the spire-whorls of better-preserved examples.

Fusinus maorium n. sp. (Plate XXI, figs. 1, 2.)

Material, two fragments: the larger consists of the penultimate and body whorls, with a small part of the canal; the other, the complete canal and greater part of body-whorl. Shell fairly large, fusiform, penultimate whorl subangular at the periphery, body-whorl rounded or slightly angular, rather abruptly contracted at the base; longitudinally and spirally ribbed; canal long, slender, and almost straight; sutures deeply impressed, slightly undulating, margined above and below by a small riblet. The longitudinal ribs are broad and flexuous, about fourteen on a whorl, most prominent on the periphery, obsolete on the lower portion of the base as it unites with the canal: interspaces narrower than the ribs, crossed by undulating spiral cords. On the penultimate whorl there are seven of these, excluding the small marginals at the sutures; they are widely spaced, much narrower than the interspaces, strengthening on the periphery and forming angular nodules; on the body-whorl there are ten or eleven spirals similar to the whorl above except that the basal are less nodular, thence more closely spaced, smaller and approximating the spirals on the canal, of which there are eighteen or more; in addition there are in the interspaces a few minute spiral lineations. Strong, irregular growth-lines cut the spirals and nodules into minute secondary sculpture. Aperture ovate, narrowed into a long canal; outer lip sharp, slightly crenulated by the sculpture; inner lip with a narrow callus continuous with the margin of the canal.

Dimensions (largest fragment): Length, 38 mm.; breadth, 24 mm.; aperture, greatest length (excluding canal), 18 mm. The smaller example has a length of aperture and canal of 30 mm.; breadth of body-whorl, 19 mm. The largest fragment is somewhat compressed and distorted.

Locality, Wharekuri, in brown sand. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The species is perhaps nearest to *F. solidus* Suter, recorded from South Canterbury and North Otago.

Ficus imperfectus n. sp. (Plate XXI, fig. 4.)

The material comprises a single example only, of which a considerable portion of the outer lip is broken away, also some small part of the columella. The example gives the impression that it is not adult. Shell small, fragile, pyriform, spire slightly elevated, last whorl rounded, the area between the suture and a line with the outer lip very slightly convex, and giving it a slightly shouldered appearance; canal fairly long, anteriorly somewhat curved and twisted to the left. Whorls about four, those of the spire sloping-convex; protoconch small, slightly rounded; the first two volutions smooth, thence minute irregular growth-striae, followed by delicate but well-marked transverse riblets, which as the whorl progresses assume a slightly backward slope; fine spiral threadlets make their appearance. The shell is slightly rubbed, and it is quite probable that the sculpture may extend to all the whorls. On the last whorl the sculpture is more strongly developed, the longitudinals somewhat irregularly disposed, narrower than the interspaces, slightly flexuous on the shoulder, and becoming obsolete on the canal; a secondary sculpture of minute threadlets adorns both riblets and interspaces; spirals on the area between suture and shoulder minute, on the shoulder and anteriorly strengthening and forming small nodules on the axial sculpture, the interspaces wider than the cords and with one or more minute threadlets; on the canal the spirals smaller and more closely spaced. Sutures narrow and slightly impressed. Columella smooth, slightly curved, and thinly calloused. Aperture imperfect.

Length, 10 mm.; breadth, 5·5 mm.

Locality, Target Gully. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The species is perhaps nearest to *F. parvus* Suter, from which it may be distinguished by the axial riblets and the small but well-marked nodules on the last whorl.

Surcula castlecliffensis n. sp. (Plate XXI, fig. 3.)

Shell small, fusiform, spire turreted, aperture and canal about equal to half the total length. Whorls seven; protoconch about one and a half volutions, smooth and with an angular ridge; succeeding whorls strongly angled slightly below the middle; the angle or keel with oblique longitudinal short nodular ribs, directed backwards, about eighteen on the penultimate whorl; as the whorls progress there are one, two, and three fine undulating spiral grooves which cut the axial ribs into fine gemmules; the shoulder slightly concave, with two or three fine spiral lines; below the angle straight or slightly concave, and with two ill-defined low spirals on the penultimate whorl. Body-whorl below the angular shoulder slightly contracted, more pronounced on approaching the canal; the latter long, tapering, and somewhat twisted to the left; below the nodular area there are three or four rather widely spaced small grooves and a number of very minute threadlets on the canal. Sutures well margined above by a small rounded riblet; aperture ovate, narrowed below into a fairly long open canal; columella and inner lip with a thin callus; outer lip with a fairly deep rounded sinus situate between the angle and suture, its position on the lower whorls marked by the growth-lines.

Length, 12 mm.; breadth, 4·5 mm.

Locality, Castlecliff, in blue sandy clay. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The species is perhaps nearest to *S. obliquecostata* Suter, from which it may be distinguished by the position of the sutural rib.

Leucosyrinx subaltus n. sp. (Plate XX, fig. 7.)

Shell elongate-fusiform; spire-whorls with a strong acute keel a little below the middle, absent on the protoconch; the apical whorl is lost, but the adjoining portion is smooth and rounded; body-whorl strongly and sharply keeled, a second low blunt angulation below it, the area between them slightly concave; the spire-whorls above the keel sloping and slightly concave, below sharply contracted and somewhat concave. Sculpture (except the protoconch): All whorls with closely spaced small spiral riblets, which the irregular growth-striae cut into minute gemmules. Whorls about eight, regularly increasing, the last (with the canal) exceeds the spire in length. Sutures linear. Aperture: The outer lip imperfect, certainly strongly angular above, contracted anteriorly, and terminates in a fairly long canal; columella nearly straight. Sinus between the keel and suture not well marked.

Length, 30 mm.; breadth, 11 mm.

Locality, Wharekuri. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The species is perhaps nearest to *L. alta* (Harris) var. *transenna* Suter, from which it may be distinguished by the uniform spiral sculpture on all whorls except the protoconch, and by its more robust form.

Lima waipipiensis n. sp. (Plate XIX, fig. 1.)

Shell large, irregularly ovate, inequilateral, sculptured with fourteen strong radiating ribs, narrower than the interspaces; these are crossed by irregularly developed growth-striae, which form frequent but irregularly disposed hollow scales on the ribs. Beak curved forward, "imperfect." Ears anterior very small, irregularly ribbed; posterior larger, obtusely angular, sculptured with a few small riblets and numerous growth-striae. The anterior end short, the margin descending abruptly and distinctly concave in the dorsal third, thence straight, inclining outwards until coalescing in the basal curve; submargin straight and forming a slight angle on meeting the lower curve of the valve; the submarginal area bent inwards, long, narrow, and concave above, sculptured with rough irregular lines of growth; the posterior margin forms a broad uniform curve from the ear to the centre of base, thence the curve gradually becomes steeper. Interior with shallow radiating grooves corresponding with the external ribs; adductor impression large, indistinct; hinge broken; margin of the valve sharp and undulating.

Dimensions (right valve): Height, 76 mm.; length, 60 mm.; diameter, 13 mm.

Locality, Waipipi, in a fine bluish-grey sand. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The description is derived from a right valve. The species belongs to the *L. lima* group, and may be distinguished from other of our fossil forms by being shorter comparative to its height, and by the fewer and more distinct ribs.

Crassatellites subobesus n. sp. (Plate XIX, figs. 2, 3.)

Shell elongately ovate, inequilateral; anterior area short and convex: posterior attenuated, the end obliquely truncated; continuous with the curve of the umbo, and extending to the lower margin of the truncation is a broadly rounded ridge, the area above being flattened or slightly concave towards the posterior end, giving the dorsal area a winged appearance. Beaks less than one-third from the anterior end, incurved, and directed forward. Lunule deeply impressed, oval; escutcheon long, narrow, and concave. Sculpture consists of small, rounded, concentric riblets, rather less than two per millimetre, and about the same width as the interspaces, on the posterior dorsal area irregular, mostly coarse striations; towards the base the ribs are more or less irregularly developed and spaced, with a number of growth-striae in the interspaces. Marginal contour: The anterior end from the beak steeply declining, straight, thence broadly rounded; the base a wide sweeping curve, becoming flattened as it approaches the posterior end; posterior dorsal margin sloping downwards, straight or slightly concave, the end obliquely truncated. Interior of left valve-margin smooth; adductor impressions and pallial lines impressed. Hinge with three diverging cardinals, united above, the posterior slender, the lower limbs of the two anterior narrowly separate; posterior lateral forms a long rounded rib with a deep groove above; anterior area a broad shallow groove, above which is a stout rib ending abruptly at the anterior end of the umbonal margin.

Dimensions: Height, 32 mm.; length, 54 mm.; diameter of perfect specimen, 20 mm.

Locality, Wharekuri. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The species is perhaps nearest to *C. obesus* (A. Adams) = *trailli* Hutton; the latter is distinctly triangular, and has a less winged appearance posterio-dorsally.

The material consists of one perfect specimen and a left valve; the former is filled with matrix, and it appears too risky to attempt to separate the valves.

Lucinida levifoliata n. sp. (Plate XX, figs. 1, 2, 3, 4.)

Shell orbicular, subglobose, nearly equilateral, juvenile examples more lenticular; beaks contiguous, directed forward, sharply incurved, and terminating in a small point; the lunule deeply impressed, ovate. Sculpture consists of irregularly spaced, small, sharp concentric lamellations with fine growth-striae in the interspaces, the lamellae as a rule become more irregular as the base is approached, usually crowded in places marking periods of rest; radiate sculpture is very minute, almost absent in some examples. On the posterior area of the shell is a feeble radiating flexure; the anterior dorsal area is defined by a distinct flexure, excavate above, and the margin expanded. Marginal contour: The posterior dorsal margin declining, slightly curved, distinctly angular on meeting the broad almost uniform curve which extends around the base and terminates at the anterior flexure; anterior dorsal margin immediately in front of the umbo distinctly concave, thence a well-marked rounded projection followed by a shallow concavity. Interior of valves with distinct radiations; anterior adductor-scar elongated; the posterior irregularly ovate. Hinge: Right valve with two cardinals, the posterior strongest, usually bifid and a distinct pit on either side; anterior lateral, a stout rib with a small tubercule towards the end; posterior lateral simple: left valve with two diverging cardinals, the anterior usually bifid; anterior lateral distant, the posterior long and well developed.

Dimensions: Height, 20 mm.; length, 22 mm.; diameter, 13 mm.

Locality, Nukumaru, in blue sandy clay (type); also Waipipi, near Waverley. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The Waipipi example is imperfect: its dimensions (approximate)—height, 24 mm.; length, 25 mm. A smaller but perfect example from Nukumaru is chosen as type.

Thracia vegrandis n. sp. (Plate XXI, figs. 5, 6, 7.)

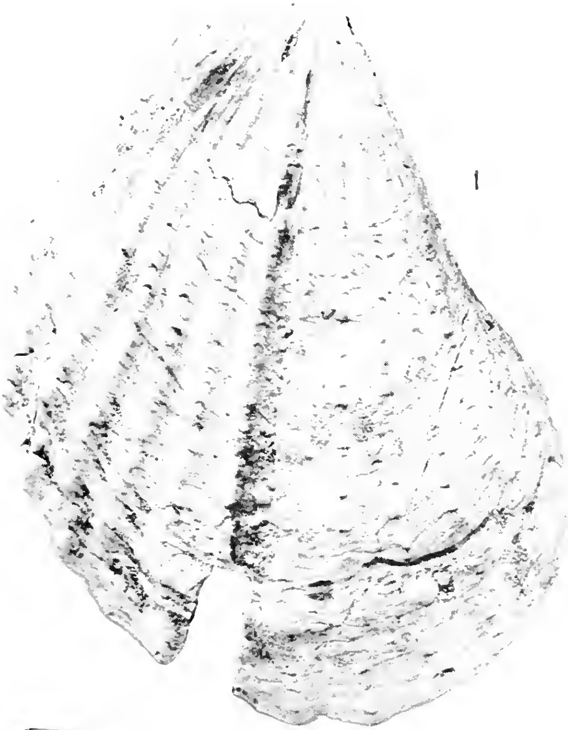
Shell small, fragile, oblong, inequilateral, equivalve, truncated posteriorly. Beaks within the posterior third slightly curving backwards, not prominent. A blunt angular ridge extends from the beak to the basal margin of the truncation; in some examples there is a very small ridge which unites with the dorsal margin of the truncation, the area thus defined is flattened and somewhat excavate. Contour: Anterior dorsal margin long with a slightly downward slope, almost straight, the end rounded, the curve rather narrower above; base slightly curved, almost straight, posterior dorsal margin short, slightly excavate below the beak, declining more rapidly than the anterior margin; the end truncated and slightly oblique. Sculpture consists of very fine concentric growth-striae, with usually a few feebly marked rest-periods. The valves are slightly rubbed, and there is no indication of radiate sculpture. Interior margins smooth, adductor-scars and pallial line indistinct, the anterior scar the smaller, the pallial sinus apparently not large. Hinge without teeth, deeply cleft under the apex, a comparatively strong oblique and inward-projecting lithodesma posterior to the beak.

Dimensions: Height, 8 mm.; length, 14 mm.; diameter (single valve), 2·5 mm.

Locality, Castlecliff, blue sandy clay. Collector, P. Marshall.

Type to be presented to the Wanganui Museum.

The material consists of several valves. It is distinguished from *T. vitrea* (Hutton) by its smaller size, more oblong form, the truncation comparatively broader, and the less curved basal margin.



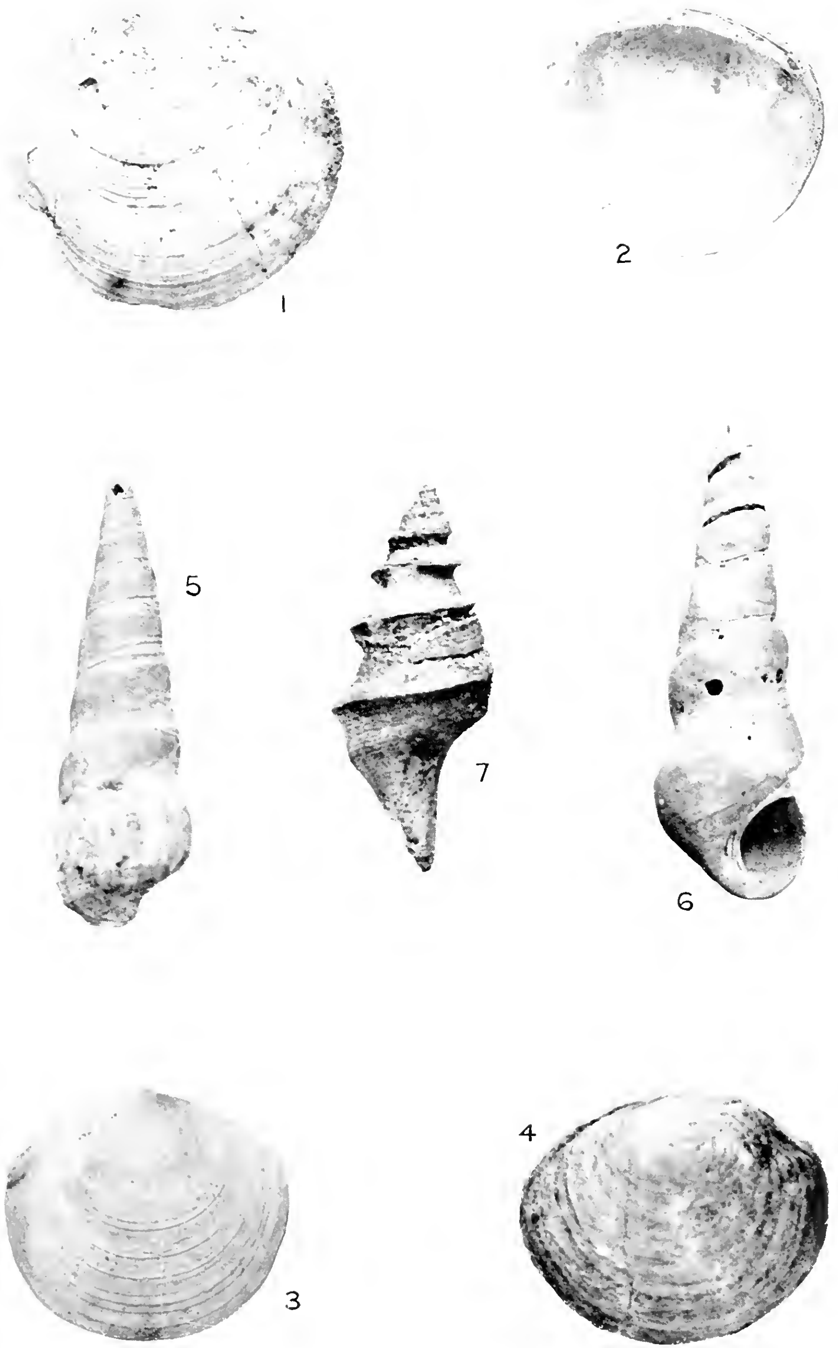
1

2

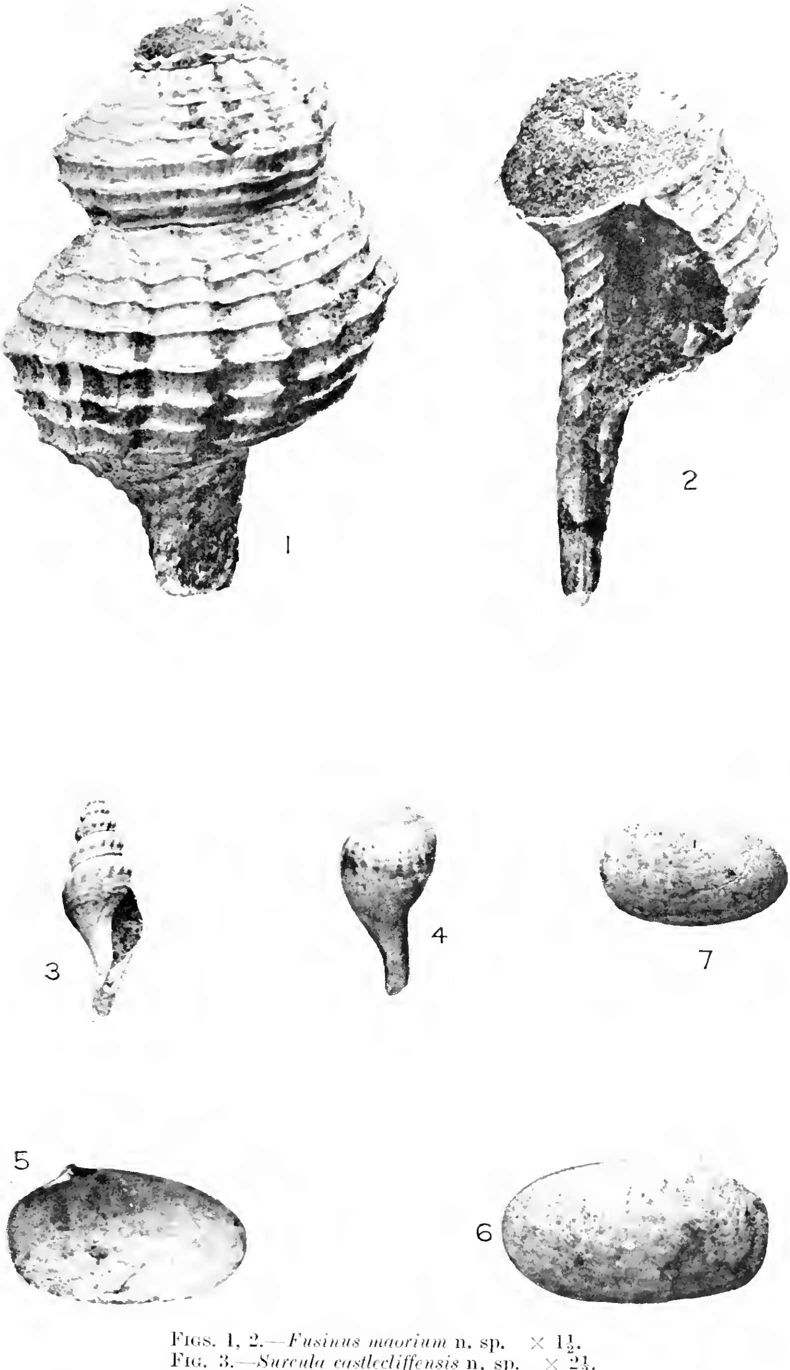
3

FIG. 1.—*Lima waipipiensis* n. sp. Natural size.
FIGS. 2, 3.—*Crassatellites subobesus* n. sp. Natural size.

Face p. 258.]



Figs. 1, 2, 3, 4.—*Lucinida levifoliata* n. sp. × 1½.
Figs. 5, 6.—*Ataxocerithium perplexum* n. sp. × 1½.
Fig. 7.—*Leucosyrinx subaltus* n. sp. × 1½.



Figs. 1, 2.—*Fusinus maorium* n. sp. × 1½.
Fig. 3.—*Surcula castlecliffensis* n. sp. × 2½.
Fig. 4.—*Ficus imperfectus* n. sp. × 2½.
Figs. 5, 6, 7.—*Th cia vegrandis* n. sp. × 2½.

ART. XXVI.—*The Edible Fish, &c., of Taupo-nui-a-Tia.*

By the Rev. H. J. FLETCHER, Taupo.

[*Read before the Wellington Philosophical Society, 18th December, 1918; received by Editor, 31st December, 1918; issued separately, 16th July, 1919.*]

FOR the purposes of this paper we use the name Taupo-nui-a-Tia as describing Lake Taupo and its watershed. It includes the lake and all the streams running into it, the Poutu Stream, Roto-a-Ira and the streams running into it. The area is a very large one. It extends from the water-shed between the Rangitikei and Whangaehu Rivers, which flow towards the west coast of the North Island, and the sources of the Waikato River, which flow into the Taupo Lake, on to some distance beyond the northern end of the lake, a distance from north to south of over sixty miles. From east to west it extends from the summits of the Kaimanawa Ranges to Hauhungaroa and Hurakia Ranges, a distance of about fifty miles. Its area would be reckoned at about 2,000 square miles.

Throughout the whole of this large area the eel, that great source of valuable food to Maoris in other more favoured districts, was practically unknown. There are stories of large eels having been caught in Roto-a-Ira in days gone by, but none for many years past. Some women are supposed to have seen an eel in the Toka-anu Stream quite recently, but it was not caught. Eels are caught in the small streams running in to the Whanga-nui River which have their source on the slopes of Tongariro. They are plentiful on the side towards Whanganui, but there are none on the side towards Roto-a-Ira. The eels known to have been caught in Roto-a-Ira would be a few enterprising explorers from the Whanganui streams. I have been told of eels having been caught in other rivers and carried alive to Taupo and liberated with the idea of stocking the lake. It is said that some members of the Armed Constabulary caught some eels in a tributary of the Mohaka and liberated them in Roto-ngaio, a small lake that empties itself into Taupo. Of course, all such attempts ended in failure.

The fish, &c., caught in various ways and used as food are known under five general names. Some of these may have slight local variations, but the general names are common to the whole of New Zealand. The largest and most important is the *kokopu* (*Galaxias fasciatus*). The others are: *inanga* (*Galaxias attenuatus*), *kakahi* (*Diplodon lutulentus*), *koura* (*Paranephrops planifrons*), and *koaro*.

KOKOPU.

The *kokopu* was caught in several ways, the most important of these being by means of a *pouraka*. This was a kind of basket net formed by first bending a piece of wood to make a hoop about 1 ft. in diameter. A net of fine mesh was then worked on to the hoop until a bag of at least 18 in. was made for the bottom portion of the trap. The top was made in a similar manner. The net was of flax (*Phormium tenax*). The entrance of the *pouraka* was at the top. The bottom portion was made so that it could be gathered in and tied fast. It could be untied for the purpose of emptying the net. On the inside of the net some *koura* were carefully fastened as bait. As the *pouraka* was for use in deep water, a flax line of three-ply plait was made 30 fathoms long. A piece of wood (*totara*) was used in a most ingenious way to serve the double purpose of reel and float. This float was about 2 ft. long, the mid-section roughly an oval, the major diameter being 6 in. and the minor 3 in. For about one-third of its length at each end a portion was cut away, leaving two long horns. A section of a Nottingham fishing-reel would exactly show the shape in miniature. Its local name is *poito*. Two stone sinkers were fastened to the inside of the *pouraka*, the bait carefully tied in place, the line wound on the *poito*, and then the fisherman went off in his canoe to the selected spot to try his luck. The time selected for placing the nets was at evening. The fisherman was guided to the best places by marks on shore, and at each place known to the fisherman a *pouraka* would be let down until all would be set. The *poito* would serve as a float, a hitch round one of the horns making it stand upright in the water. In the morning the nets were visited and lifted to see what had been caught. The *poito* was first placed on the canoe and then the rope carefully pulled up. If the *pouraka* was full the fisherman would know by the agitation of the water in it as soon as it came in sight. It was lifted on board, the bottom of the net untied, and the *kokopu* emptied into the bottom of the canoe. Fresh bait was then attached and the *pouraka* lowered again at the same spot. All the *pouraka* were visited in succession; if any of them were found empty they were taken on to some other spot. The *kokopu* caught in this way were about the length of a man's hand, and they were very fat. The time of fishing was from November to March.

Another method of catching *kokopu* was by means of a *tau*. In February or March, when the new fern (*Pteris esculenta*) was fully grown, men cut large bundles of it and left them to dry. While the fern was drying they prepared a long and strong rope, plaiting it of flax. The length of the rope would be from 40 to 50 fathoms. A number of shorter lengths of light three-ply plaited flax ropes were prepared. When all the material was ready it was taken to a suitable spot. A strong stake was driven in on the edge of the shore and the thick rope firmly attached. The lighter ropes were fastened at suitable intervals along the whole length of the main rope to within a short distance of the end farthest out from the shore. To this end a heavy stone was attached to serve as an anchor.

Large bundles of the prepared fern were firmly tied to the free ends of the lighter ropes, and when all was ready the bundles of fern were lowered into the water. A *poito* was fastened to the large rope near the junction of the first short line. Sometimes as many as thirty bundles of fern would be fastened to the main line.

The bundles would be lifted during the daytime, and very great care was taken to pull the bundles up one at a time in such a way that no sudden jar was given to them. The bundles were either shaken into the canoe, or a net called a *karapa* was passed under the bundle to catch the *kokopu* as they fell from the fern. This method of catching *kokopu* was practised from the month of April to the end of September.

There was a method of taking a large variety of *kokopu*, known as *kokopu-para*, in the rivers by the use of a bob. This is the common instrument in use for catching eels in other places. A number of worms were threaded on some dressed flax and tied in a bunch to the end of a short, thin rod. The fish would bite the worms and be suddenly jerked into a canoe, or, if the fishing was from the shore, upon the dry land.

Kokopu when eaten fresh were, without any preparation, steamed in a Maori oven and eaten as a relish with fern-root, *kumara*, or, in more modern times, with potatoes. They were sometimes dried in the sun by first threading them on fine strips of flax and hanging them up in the wind and sun to dry. When sufficiently dry they were placed in the storehouses for future use.

The following story tells how a place famous for its *kokopu* was discovered in Taupo Moana over three hundred years ago. A man named Kopeke was living at Tu-tete, on the eastern side of Taupo and north of the Hine-maiai River. One morning in early summer he noticed a number of shags going away out on the lake seeking food for their young. They went away out beyond any shallow known to the Maoris, and Kopeke knew there must be some spot out there where it was not too deep for the shags to get fish. One calm morning Kopeke and his men went out to see if they could find the spot where the shags had been fishing. They came at last to a shallow spot which they called Popoia-nga-oheohe. It is otherwise known as "The roof of the house of Horo-matangi." A net was tried, and in a very short time they got a very large haul of *kokopu*. The right to fish on that reef was retained by Kopeke and his descendants right up to the present time. The right is given in the proverb, "The fish in calm water are for everybody; the fish in the current are for Kopeke."

After heavy winds *kokopu* were cast up on the beaches in large numbers and gathered and used for food. The larger varieties were afflicted by a small parasite in the shape of a thread-worm about 1½ in. long.

INANGA.

Inanga were caught in two different ways. One way was by means of a *hinaki*. *Hinaki* for this purpose were not very large, nor were they made so strong as the *hinaki-tuna*. The general shape was the same, but the material used was a strong species of rush that grows among *manuka* (*Leptospermum*) in dry situations.

When using a *hinaki* a suitable place was chosen on the edge of a stream. Experience and judgment were shown in selecting a suitable spot on the river-bank, for unless a good spot was chosen no fish would be caught. A trap was made at the place selected by driving in a few pieces of *manuka* or other suitable stakes at a slight angle out into the stream. Any light material was interlaced between the stakes to form a barrier that the fish could not pass. At the narrow place the *hinaki* was securely fastened with the mouth in the narrow gap. The young fish ascending the river would crowd into the place prepared for them and pass on into the *hinaki*; their further progress was blocked, and there was no return. The wily fisherman would examine his trap at frequent intervals and enjoy the fruits of his cunning. This method of catching *inanga* was practised from the beginning of September to the end of January. The young of the *kokopu* would be caught with the *inanga* and would be reckoned under the general term *inanga*.

In *Dominion Museum Bulletin No. 2*, page 56, there is a plate showing "a small fish-trap (set), Tongariro River." On page 67 we are informed that the trap is for eels and small fish. For "eels and small fish" read "*inanga*."

The other method of catching *inanga* was by means of a net. This net was known as a *kupenga*, and it was used in almost the same way as the seine or large drag-net of European use. The length of the *inanga* net varied from 50 to 100 yards, and its depth from 6 ft. to 8 ft. The diagram given on page 72 of the *Bulletin* quoted above gives a fair idea of an *inanga* net. It was made of very thin strips of flax worked into a small mesh; this, the central part of the net itself, was called a *kaka*. The rope along the top was called *kaharunga*, the bottom rope *kahararo*, the floats *poito*, and the sinkers *karihi*. My informant was unable to give me the name of the *manuka* spreaders. Page 65 of the *Bulletin* illustrates a bunch of floats. There were two methods of using the net—one from a canoe tied by the middle thwart to a pole firmly fixed in a shallow spot, the other from the shore. When used from a canoe, another canoe started out from the bow of the anchored canoe with from 200 to 500 yards of rope. When this was all out the net was put overboard, roughly at right angles to the line, and when all the net was out the canoe returned to the stern of the anchored canoe with another long length of line. The net was then pulled steadily in towards the anchored canoe. The same process was used from the shore, but in the case of the canoe the lines were coiled up in the bow and stern, leaving the centre free for the *inanga* to be emptied out of the net. Some of the shallow spots on the eastern side of the lake where the anchored-canoe method was used were the places named Te Rimu, Nga-Parenga-rua, Te Hohonu, Karanga-wairua, Te Tii, Te Purakau, and others.

There is an ancient story that seems to illustrate the method of fishing from the shore. The date of the story is at least 250 years ago. On one occasion Uru-taraia was using a net in the lake for the purpose of catching *inanga*. Tutetawha went on board the canoe that was carrying the net and paddled to the place where it was to be used. The net was cast into the water some distance from the shore and then dragged ashore, bringing the fish in front of it. As the ends of the net were brought close to the shore, so the *inanga* came too, and the stretchers stirred up the fish to the top of the water. Uru-taraia jumped into the water to press down the bottom line of the net, at the same time peering into the water. Tutetawha picked up some stones and threw them into the water to drive the fish back into the net. One of them fell just where Uru-taraia's eyes were fixed. The splashing of the water wet the whole of his face. He uttered a curse which led to bloodshed at no distant date.

In addition to the places named above, there were many other places where *inanga* were caught, the ownership of such places and the right to catch fish in them being carefully conserved. The time of fishing was from September to March. The fish so caught were eaten as a relish with pounded fern-root or *kumara*, and in modern times with potatoes. They were also dried in the sun and stored for future use.

A net such as described has not been used in Taupo for many years. The writer has seen a length of scrim used as a substitute.

Koura.

On page 73 of the *Bulletin* already mentioned there is a good illustration of a *rou koura* of the kind used in the olden days at Taupo. The frame of the mouth was made of *manuka*, the straight piece at the bottom being of much heavier timber than the curved portion. The net portion was made of fine strips of undressed flax. An old Maori recently drew the outline of one of these obsolete nets, and from his sketch, which was full size, traced on the road, we could see that the bottom rod was from 6 ft. to 8 ft. long. The length of the net was from 8 ft. to 9 ft., tapering from the mouth towards the back to about 3 ft. from the end. This last 3 ft. was straight, and about 1 ft. in diameter. The sinkers were attached exactly as shown in the illustration referred to.

When the net was used it was taken out a long distance from the shore and lowered overboard, care being taken that it was the right way up. It was then hauled ashore. Very large catches were sometimes made in this way. *Koura* were also caught by means of bunches of fern, as described under the heading of "*Kokopu*." The writer has seen as many *koura* as *kokopu* shaken out of the bunch of fern into the bilge of a canoe.

Of late years it has been a common practice for Maori women to grope for *koura* among the weeds in the lake and rivers, and also under rocks and stones along the edge of the lake.

There is a photograph reproduced on page 55 of the *Bulletin* already quoted, and it is called, "Nets for *koura*, Lake Taupo." It is an exact illustration of a *pouraka* with line and reel attached ready for use. We cannot say that *koura* were not caught in them, but their chief use was for catching *kokopu*, as described above.

KAKAHI.

Kakahi is the Maori name of a fresh-water shell-fish which is fairly common over the greater part of New Zealand. It is common in Taupo Lake and Roto-a-Ira, and in the streams running into the lakes. Its average length is $2\frac{1}{4}$ in. In the clear water of Lake Taupo it can be seen pursuing its course over the clear sandy bottom, and leaving its characteristic furrow on the sand. It was never very plentiful, nor was it sought after so eagerly as *kokopu*, *inanga*, and *koura*. Where it was possible to reach it in shallow water by hand it was simply picked up and placed in a kit. In deeper water the method of obtaining it was called *rou kakahi*. In *Museum Bulletin No. 1*, pages 62 and 63, are three illustrations of these dredges. Fig. 1*a* was the type in use at Taupo. The ordinary method of using the implement was carried out by two men. One man, with the dredge attached to a long pole, would put off from shore in a canoe as far as he could touch bottom, while the other man stood on shore with the bow-line of the canoe. The man in the canoe would lightly press the teeth of the dredge into the sand or mud, and the one on shore would haul the canoe ashore. Where the water was shallow for a long distance out the implement was used with the net attached, as shown in the illustration referred to. For a short distance the dredge was used without the net. The flesh was taken out of the shells and dried in the sun after being strung on strips of flax. It then assumed the appearance of small, hard, dark objects, only suited to the digestion of a Maori or a moa.

KOARO.

Koaro is the Maori name of a small fish obtained under peculiar conditions from Roto-a-Ira and the streams running into the lake. It seems to have been ignored by ichthyologists, for as far as we are aware it has not been classified. It has been known to Europeans from the accounts of the earliest visitors. Bidwill says, "The natives said that there were no fish in the lake except what I saw, and which were not more than an inch long. The natives had vast quantities of these dried in baskets, which they cook by making them into a kind of soup, but which did not smell sufficiently nice to tempt me to taste."*

The Rev. R. Taylor in his *Maori Dictionary* mentions the *koaro* as a small fish, about 3 in. long, found in Roto-a-Ira.

There is an ancient lullaby composed by Te Ao-tarewa which speaks of Nga-toro-i-rangi sowing the seed of the *koaro*.† There is an old Taupo

* *Rambles in New Zealand*, p. 54. † *Polynesian Journal*, vol. 14, p. 135.

proverb which reads, "*E noho kai ika, kia haere kai rau*" (Fish-eaters remain, net-eaters are going). It refers to an incident during some fighting which took place just to the south of Roto-a-Ira about two hundred years ago.

The information given in the last edition of Williams's *Maori Dictionary* is no further advanced than Bidwill's—viz., "*Koaro*, a small fresh-water fish like *inanga*."

The fish are caught in *hinaki* with a special arrangement, called a *poha*, attached to the mouth of the *hinaki*. The *hinaki* was made of rushes and the *poha* of flax. *Museum Bulletin No. 2*, page 58, has illustrations of two *hinaki* with *poha* attached. The second and fourth are those used for *koaro*. There are three streams running into Roto-a-Ira which take their rise from springs gushing up out of the earth—the Mapouriki and Ngapuna from Tongariro, and the Waione from Kakaramea. These three were the best for *koaro*. The *hinaki* were pegged down, some with their mouths up-stream quite close to the source, and others alongside of them with their mouths down-stream. The fish caught as they came out of the springs from the underground source were light-coloured, and spotted on the back; those caught ascending the stream were dark. The best month of the year for taking the fish was March. When caught they were spread out on stones in the sun to dry, and then stored in kits for future use.

These brief notes are written in the past tense, for the old methods of catching fish are practically extinct. It is only some of the old men who can explain the use of their old implements.

The introduction of trout to the Taupo Lake and streams put an end to the native fish and methods of catching them. A *koura* 5 in. long from the tip of the claws to the tail was taken recently from the stomach of a trout.

Art. XXVII.—*To what Extent is Earth-rotation the Cause of the Ocean Currents?*

By A. W. Burrell.

Communicated by Mr. J. T. Ward.

[*Read before the Wanganui Philosophical Society, 17th June, 1918; received by Editor, 20th July, 1918; issued separately, 16th July, 1919.*]

Plate XXII.

Those who have given the currents of the ocean their serious consideration must certainly have been struck by the fact that the main currents are circling in a contrary direction to that in which the earth is rotating—that is to say, they are moving in a clockwise direction in the Northern Hemisphere and anti-clockwise in the Southern. This fact seems to me to point to a cause governing the movements of the water in both hemispheres, the cause being earth-rotation.

Given a rotating sphere with its surface interspersed with great land and water areas, in what way will the water behave when acted upon by the attractive power of external bodies in or near the same plane of rotation? It appears to me that currents will undoubtedly be set running in a contrary direction to that in which the sphere is rotating, more especially if the land areas extend in a north-and-south direction to fairly high latitudes, and for this reason: That there exists an affinity, or clinging tendency, between external bodies and the water is proved by the sun and moon lifting and drawing the tides westward; and, as the tides are always lagging behind these bodies, they must have a strong tendency to draw the water in a circle towards the Equator on all west coasts, westward near the Equator, and from the Equator on all east coasts, thus causing a stream to flow continually in that direction; but in reality the sun and moon (and, I suppose, the planets to a small extent) tend to hold the water, and the earth in turning eastward makes the water appear to lag behind; or, in other words, the water is *retarded* by these bodies while the earth rotates eastward.

This does not necessarily imply that the water would flow at the same rate as the tide, but that the water will have a tendency to be drawn in that direction as if it were slightly downhill.

This retarding action is continually in operation, and in the same direction. We have the lunar and anti-lunar, solar and anti-solar tides, all tending to induce the water by earth-rotation to move in a circle between the land-masses and the Equator, for the Equator is a boundary when viewed from the centre of rotation, and naturally the water will tend to return eastward in higher latitudes to replace that which is being drawn northward. These latitudes offer less resistance owing to their being nearer to the neutral line between the opposing tides, and also to the fact that the gravitational pull of the sun and moon, acting as it does obliquely to the surface of the water in these latitudes, has a much weaker effect, area for area, than it has on or near the Equator, where the pull, being mostly perpendicular to the surface, must consequently have a greater retarding action on the water while the earth moves on, thus giving the current a westerly trend relative to the land: or, to put it more briefly, the difference in the gravitational pull on these two positions causes the water to circle clockwise in the Northern Hemisphere and anti-clockwise in the Southern.

These conclusions were arrived at many years ago, but how to embody the conditions in a working model perplexed me for a long time, for I could not divest myself of the idea that it must be done on a globe; but at last I began to see a way out of the difficulty.

If one takes an imaginary bird's-eye view of a hemisphere—say, for instance, the Southern—from a great height above the South Pole, that hemisphere will appear as a rotating disc: in fact, water will behave in the same way on a rotating disc or tray, providing gravity is acting perpendicularly to its surface, and this is easily accomplished by having the tray to rotate on a vertical axis, and if necessary we can give it a uniform speed by using a controller.

So far, then, things are quite simple. All we have to do to represent the Southern Hemisphere is to provide a shallow circular tray mounted on a vertical shaft, with the different land-masses—South Africa, South America, Australia, Antarctica, and a few of the larger islands—modelled in wood, placed in the tray and fastened in their relative positions and almost submerged in water, and then to rotate the tray at a uniform speed. But by doing this we are confronted by another difficulty, for if we give the tray a uniform speed how are we to give the water the very necessary retardation without in any way interfering with its free movement?

To overcome this difficulty, instead of giving the tray a uniform movement for a long period, I gave it an accelerating movement for a short period by means of a falling weight just sufficient to put it in motion. I wish the point to be thoroughly understood, that accelerating the land is equivalent to retarding the water. By this means I obtained the necessary retardation of the water *in relation to the land* without giving it a bias in any direction with the exception of that impressed upon it by the rotation of the land around it. The currents can be observed from the moment the tray begins to move until the cord is unwound, which is about two minutes and a quarter, by which time the tray is beginning to move too fast to observe them, and the water is by centrifugal action beginning to bank up against the wall representing the Equator; but there is ample time to observe that a system of currents is set up generally similar to the existing currents of the Southern Hemisphere.

There is one exception, which I think can be satisfactorily accounted for—the one marked on the maps as the "Cape Horn current," flowing eastward, due, it seems to me, to the fact of the South Atlantic equatorial current impinging on that portion of the coast north of Cape San Roque. This coast-line, running obliquely across the Equator, diverts a great portion of this current towards the Gulf of Mexico, thereby strengthening the Gulf Stream at the expense of the southerly current along the east side of South America, and so allowing part of the current in the South Pacific Ocean to overpower it and flow eastward by Cape Horn. The water in the model, however, being necessarily confined by a wall representing the Equator, does not allow any of the current generated in the South Atlantic to escape northward, and so, flowing with its full strength down the east coast of South America, overpowers the one flowing eastward by Cape Horn, thereby causing this current to flow westward.

The wall representing the Equator, and the shallowness of the water, is a hindrance to the model, for the undue friction gives the tray a tendency to drag the water with it. It nevertheless shows the currents quite strongly. The diminutiveness of the model prevents it showing the smaller currents, which no doubt are mostly in-draughts caused by the larger.

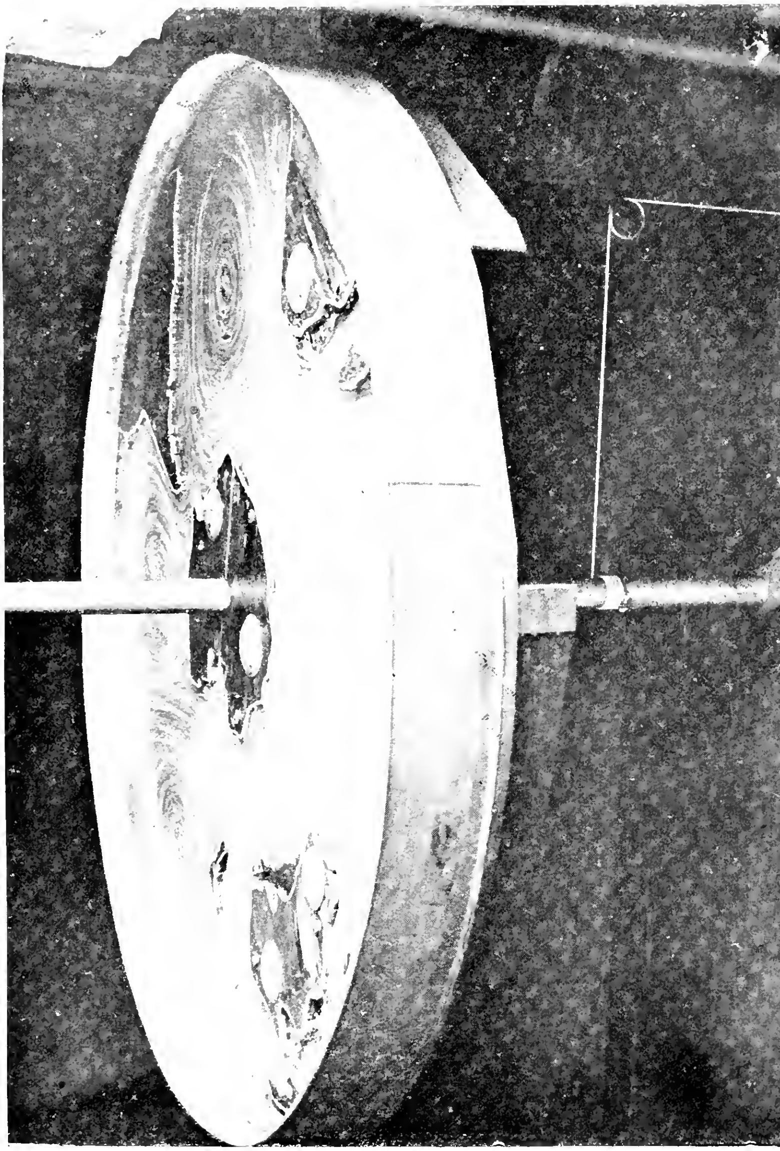
On finding the Southern Hemisphere so satisfactory I modelled the principal land-masses of the Northern Hemisphere in the same way, and on giving the tray an anti-clockwise motion the results were equally satisfactory, with the exception of the Gulf Stream, which shows slightly weaker through not receiving so much of the South Atlantic equatorial current as it does in nature.

Specification of the Working Model. (Plate XXII.)

The model consists of a galvanized-iron tray 5 ft. in diameter and 5 in. deep. The perpendicular wall representing the Equator has a wire edge to stiffen it. In the centre of the tray a hole 2 in. in diameter is cut and a tube 5 in. long is soldered in; this is done so as to allow of a 2 in. shaft passing through without danger of leakage.

The tray is supported by a wooden table of the same diameter firmly bolted to the shaft at about 40 in. from the floor, so as to be at a comfortable height for observation. The shaft is 4 ft. long, and runs on ball bearings top and bottom. About half-way from the table to the floor a stud is screwed in the shaft, to which is fastened the cord; the cord is then carried over a pulley, and a weight of about $3\frac{1}{2}$ lb. attached thereto, the weight having a fall of about 7 ft.

The land-masses are built up of three thicknesses of $\frac{7}{8}$ in. board, the bottom layer being splayed off, so as to be more in keeping with the shores. These are fastened to a false bottom in their relative positions with regard to latitude and longitude, placed in the tray, and almost submerged by



The working model, showing currents produced by rotation and retardation

Face p. 266

water, on which is sprinkled some fine sawdust in order to show up the currents more distinctly.

The cord is wound around the shaft so as to give a clockwise motion to the tray, this being the direction of the earth's rotation when viewed from the South Pole. This is, of course, for a model of the Southern Hemisphere, for the Northern the cord being wound the opposite way so as to give an anti-clockwise rotation. The weight is then attached to the cord, whereupon the tray slowly begins to move, and, while it is slowly accelerating, all the phenomena of the main oceanic currents in the Southern Hemisphere can be observed in miniature.

Art. XXVIII.—*Some Maori Fish-hooks from Otago.*

By H. D. Skinner.

[*Read before the Otago Institute, 10th December, 1918; received by Editor, 27th December, 1918; issued separately, 16th July, 1919.*]

Plate XXIII.

Students of the material culture of the Maoris have long been familiar with the great collections of stone and bone objects obtained from the beaches of Otago. The beaches between Blueskin Bay and Hooper's Inlet, which are not more than nine miles apart in a direct line, have contributed by far the greater part of these collections, though Shag Point and Waikouaiti to the north, and the beaches and islands of Foveaux Strait to the south, have also yielded a share. At the beginning of the last century Otago Peninsula and the coast immediately to the north-west of it were very thickly populated. Indeed, one of the earliest European accounts of this district speaks of " the town of Otago " as being the largest Maori village in New Zealand. But early in the century the South Island was swept by an epidemic which left only a few hundred native inhabitants south of Cook Strait. The coast of Otago had long been frequented by sealers and whalers, and when regular settlement on a large scale began the remnants of the Maori tribes were rapidly Europeanized. For this reason very little detailed information relating to material culture in the south has been preserved, and conjecture is the sole guide in assigning uses to many of the articles in public and private collections. There is no difficulty in diagnosing a large section of the bone objects as the points of composite fish-hooks, the wooden shanks and flax bindings of which have long since decayed away. But, taken as a whole, these bone points, barbed and unbarbed, differ so much from those used in the North Island that students can only conjecture the types of hook to which they originally belonged. No information can be given by the Maoris themselves.

For these reasons the small group of hooks shown in the plate, several of which have lost nothing more than the cord attaching them to the rod or line or spread, is of unusual interest. They formed a part of the large collection of ethnographic material recently presented to the Otago University Museum by Mr. A. Moritzson. Unfortunately, they have no history. When first received they were in a small box together with a number of bone objects of types usually found on Otago beaches, and it was assumed that all had been found in some cave, forming perhaps the complete outfit of some neolithic fisherman. A closer examination showed that while nearly all the loose bone objects had been dug from sand discoloured by charcoal, which still adhered, all but three of the hooks (Plate XXIII, figs. 4, 5, 6) had blue estuary-mud still adhering, and were stained the same deep brown as is timber waterlogged in estuaries and harbours. The flax cord also showed signs of estuary-mud. On the back of one of the hooks (Plate XXIII, fig. 7) was a fragment of plaited flax, the plait being that commonly used by the Maoris in making kits. A close examination yields evidence that they were found together in estuary-mud, and that some former European owner has carefully scrubbed three of them (Plate XXIII, figs. 4, 5, 6) to which neither mud nor sand of any kind remains adhering.

When the collection was received the serrated bone point of No. 5 was inserted in the shank as shown, but, as it was not secured with small wooden wedges like the points of Nos. 7, 8, 9, it may possibly have been discovered elsewhere and inserted by the owner who scrubbed the three hooks already mentioned. This may also have been the case with the bone points of Nos. 2 and 6, but a careful examination of each will, I think, convince any one that points and shanks all actually "belong."

Several pieces of evidence indicate that the estuary in which the hooks were found was probably in the neighbourhood of Dunedin. In the Otago University Museum collection is a wooden shank from a cave near Otago Heads almost identical with that of No. 5, but lacking the bone point. This type of shank is not known to occur elsewhere in New Zealand. If the bone point be accepted as evidence it is confirmatory, for it belongs to a type common in Otago but not recorded elsewhere. Much stronger is the evidence of hooks Nos. 7, 8, 9, for hooks of identical shape but having a nail in place of a bone point are still used in barracouta-fishing by European fishermen on the Otago coast. The timber now used for the shank is red-cedar, the colour attracting the fish without any need of bait. Frank Bullen has left an interesting account of the Maori method of using this type of hook as practised by the Maoris at Port William, Stewart Island, in the "seventies": "The Maoris have quite an original way of catching barracouta. They prepare a piece of rimu (red-pine) about three inches long by an inch broad and a quarter of an inch thick. Through one end of this they drive an inch nail bent upwards, and filed to a sharp point. The other end is fastened to about a fathom of stout fishing-line, which is in turn secured to the end of a stout five-foot pole. Seated in a boat with sail set, they slip along until a school of barracouta is happened upon. Then the peak of the sail is dropped, so as to deaden the boat's way, while the fishermen ply their poles with a sidelong sweep that threshes the bit of shining red through the water, making it irresistibly attractive to a struggling horde of ravenous fish. One by one, as swiftly as the rod can be wielded, the lithe forms drop off the barbless hook into the boat, till the vigorous arm can no longer respond to the will of the fisherman, or the vessel will hold no more."*

The large hook (Plate XXIII, fig. 2) is made of manuka wood, and was probably used in shark-fishing. At the bottom of the curve, on the outer side, is a small knob which appears to have been carved to represent a human face. This type of hook, to which Nos. 3 and 4 also belong, is common to the whole of New Zealand. The size of the remaining hook, No. 1, indicates that it was used for catching smaller kinds of fish.

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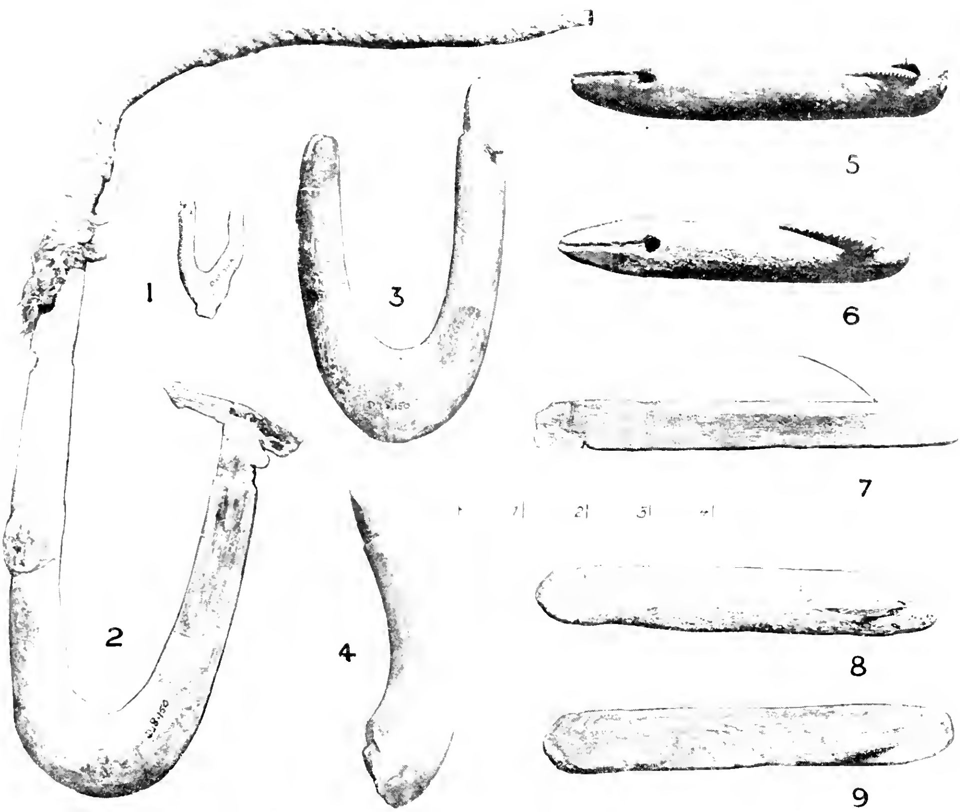
* *The Cruise of the "Cachalot,"* Chapter xxv. For this reference I have to thank Dr. W. N. Benson.



Maori fish-hooks from Otago. (The scale is in inches.)

ART. XXIX.—*The Older Gravels of North Canterbury.*

By R. SPEIGHT, M.Sc., F.G.S., Curator, Canterbury Museum.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 24th February, 1919; issued separately, 16th July, 1919.*]

CONTENTS.

INTRODUCTORY.

WIDELY distributed along the base of the Southern Alps lies a series of unfossiliferous sedimentary beds, consisting for the most part of well-stratified gravels, sands, and clays, with occasional lignite, whose position has hitherto been somewhat doubtful. Haast (1879, p. 316, and map, p. 370) included them in his Pareora formation, and mentioned the occurrence of lignite-beds (p. 318) in the "Moeraki" Downs, at the mouth of the Waipara River, and in the Broken River basin, but hardly mentions the locality where they attain their maximum development—viz., the Mount Grey Downs and the vicinity of the two branches of the Kowai River. Hutton (1885, p. 211) considered them as equivalent to the Wanganui system of the North Island, but remarked that they were difficult to distinguish from the upper gravels of the Pareora system. Park (1910, p. 252) considered them older fluvio-glacial drifts. Thomson (1917, p. 411) refers to them more fully, but is extremely doubtful whether they shall be assigned to his Notocene or Notopleistocene set of deposits.

Owing to the practical absence of fossils it is difficult to determine their position accurately, but they nevertheless represent an interesting series, and the following account is intended to bring out their chief features. In addition to the difficulty noted by Hutton, there is the additional one that in their lithological content as well as to some extent the conditions under which they were laid down they resemble the beds that overlie them, and this makes it at times impossible to separate them from subsequent gravel and sandy beds.

GENERAL DESCRIPTION OF THE DISTRICT WHERE THE BEDS ARE BEST DEVELOPED.

The chief area where they are developed lies to the south-east and south of Mount Grey, between the Waipara and Okuku Rivers, but they attain their greatest development in the basins of the Southern Kowai and the Grey Rivers. Important outliers also occur to the west of the Okuku, on the lower slopes of Mount Thomas, and south of the Ashley River, where they form the Mairaki Downs (= Moeraki Downs of Haast). The beds form a kind of frontal apron to the higher greywacke hills, such as Mount Grey and Mount Karetu; but still they rise in places to well over 1,000 ft. above sea-level. The downs country has been dissected to some extent, and on the front facing south-east consequent streams have cut deep narrow channels, with high precipitous banks, whereas in the north-eastern portion the tributaries forming the Northern Kowai tend to develop valleys along the strike. The same is also true of the east branch of the Grey. The character of the drainage points to recent and rapid uplift, perhaps in agreement with that of which there is distinct evidence on the coast farther north (McKay, 1877, p. 177; Hutton, 1877, p. 55; Speight, 1918, p. 99). On the sides of the steep banks, especially those running with the dip, numerous good sections are exposed; and it will be best at this stage to give a more detailed description of typical sections, preferably those illustrating the relationship between the underlying Tertiary beds and the overlying gravels. Although the beds are typically developed in the basin of the Kowai River, and I have selected the name of that locality as the one most appropriate to designate the series, yet the most instructive sections are to be seen in the basin of the Grey River, and these will therefore be taken first.

Descriptions of Typical Localities.

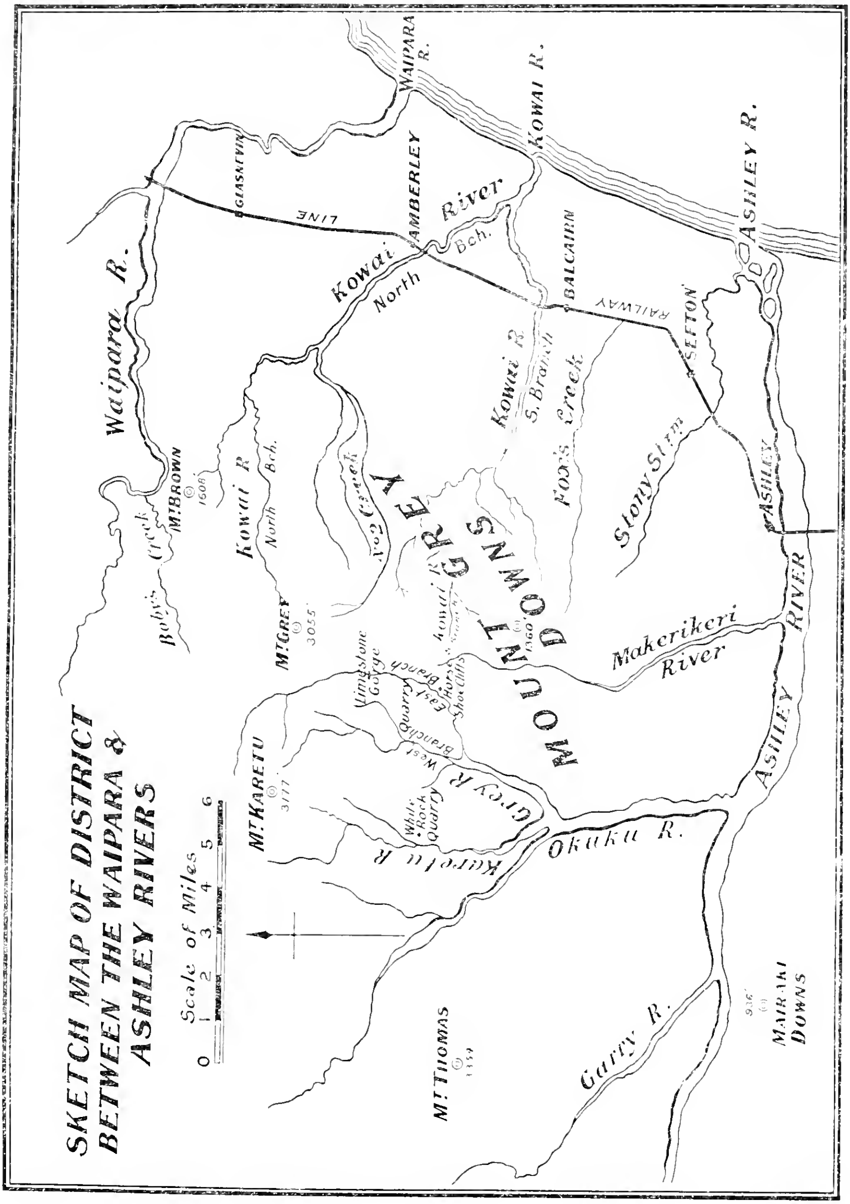
Grey River, East Branch.

The eastern or chief branch of the Grey River rises in the country between Mounts Grey and Karetu, flows south therefrom in a deep wooded gorge, and then gradually turns to the south-west and follows along the north-western edge of the Mount Grey Downs till it enters on the plains and joins the Okuku River in the neighbourhood of White Rock Station. The first part of its course has been cut in greywacke, but on leaving the higher country it crosses the marginal fringe of Tertiary sedimentaries at an angle of about 45° with their strike, so that when the stream runs in the direction of the dip the cross-section of its channel is narrow and trench-like, but when it runs along the strike the valley opens out somewhat, with dip slopes bordering the stream on its north-western side and steep scarp slopes on its south-eastern side. The latter are in places very bold and precipitous, and show clear-cut sections. Especially is this the case at the Horseshoe Cliff, about a mile below the gorge, where the north-western slope of the downs has been scored by a deep washout, and the strata are clearly exposed for 500 ft.

In the lower part of the river-gorge there is a most interesting occurrence of the lower members of the Cretaceo-Tertiary series, analogous to that seen in the Waipara and Weka Pass sections. These beds when followed along the strike run in the direction of the greywacke mass of Mount Grey; and unless they turn round on approaching it, as they do on the north-east slope of the mountain, the junction between the two sets of beds will in all probability be a fault contact. To the west of the gorge, however, the junction between the two sets of beds is a normal unconformity.

The following is a description of the beds here exposed, the sequence being in ascending order:—

1. *Greyish sands and sandy shales*, glauconitic, concretionary in places, and stained with sulphur; succeeded by light-coloured argillaceous and slightly glauconitic sands—all striking north-east and dipping south-east at 45°.


SKETCH MAP OF DISTRICT BETWEEN THE WAIPARA & ASHLEY RIVERS
Scale of Miles
0 1 2 3 4 5 6
Waipara R.
WAIPARA R.
Kowai R.
Kowai North River
North Bch.
AMBERLEY
BALCAIRN
SEFTON
ASHLEY
ASHLEY R.
RAILWAY
LINE
Kowai R. S. Branch
Foo's Creek
Stony Strm
M^t BROWN
1508
M^t GREY
3055
M^t KARETU
3177
M^t THOMAS
MOUNT GREY DOWNS
Makerikeri River
Ashley River
Okuku R.
Karetu R.
Grey R.
Garry R.
MAIRAKI DOWNS
Limestone Gorge
East Branch
West Branch
Quarry
White Rock Quarry
Horse Shoe Cliffs
Boby's Creek

2. *Greenish glauconitic sand* passing up into glauconitic limestone, the glauconitic material being disposed in irregular patches and lenses, giving the rock a somewhat streaky appearance; it is also full of worm-borings filled with glauconitic material. This passes up into
3. *Amuri limestone*, 25 ft. thick, with less glauconite than 2. The passage beds between this and the lower bed consist of fragments of Amuri limestone in a greensand matrix, the limestone finally taking on the facies of the typical Amuri stone, being white and jointed into quadrangular blocks. The strike is as before, but the dip is less, being about 30°.
4. *Glauconitic limestone*, 20 ft. thick, comparable with the Weka Pass stone as it approaches a shore-line (Speight and Wild, 1918, p. 77), but passing up into a more sandy facies.
5. *Marl*, slightly sandy, with concretionary layers and rounded concretions. This is the stratigraphical equivalent of the "grey marl" in the Weka Pass district. It has the same strike and dip as the limestone, and its thickness is about 70 ft.

Thus far the sequence is quite clear and conformable, but for a time the exposures are obscured and the relations to the underlying beds are not plain.

Just below the gorge there is a well-marked bed, striking north-north-east, with slightly flatter dip than the limestone, and containing numerous specimens of *Ostrea ingens*. Farther down-stream, but higher in the series, is a sandy conglomerate followed by sands with broken shells. These pass up into sands with a layer of oyster and other shell fragments, and then follow the beds of the Kowai series.

These are first exposed at the mouth of the gorge, just above the site of the old sawmill. They consist of sands and sandy gravels containing shell-fragments and showing intraformational unconformities, but no clear evidence, given by sections, of an unconformity between the Kowai series and the lower Tertiaries. Almost everywhere in the case of gravels resting on sands or other finer detrital beds the upper surface of the latter has suffered some erosion, but in no case in this branch of the Grey does this, in my opinion, amount to sufficient to be considered a major unconformity.

On the next bluff down-stream, and higher in the sequence, the beds exposed consist of greenish-grey sands (weathering light-brown) and sandy gravels, with sandy carbonaceous shales and impure lignite. These are capped unconformably by terrace-gravels belonging to the early history of the Grey River. This sequence is repeated on the next bluff, but the gravel beds of the Kowai series become more important, one very heavy band of gravel near the top of the cliff being divided into two parts by a layer of carbonaceous shale. In the bed of the river, at the base of this cliff, is a section which shows an unconformable junction between a greenish sand and an overlying bed of gravel. After a careful consideration of the circumstances of this case I have come to the conclusion that it must be considered only as an intraformational unconformity, due to the erosion of the bed of sand by marine currents in the interval between its deposition and that of the succeeding layer of gravel.

These beds strike north-east, and dip south-east at an angle of 20°.

As the sections are followed down-stream their character does not change except that the gravels become increasingly important, a feature that is well exemplified at the Horseshoe Cliff, on the face of which gravels greatly predominate, some layers being from 50 ft. to 70 ft. in thickness. Well-defined sandy layers also occur. The regular stratification of the beds towards the base of the cliff points to their having been deposited in shallow water in close proximity to a shore-line, and not on a land-surface; but at the higher levels the stratification becomes more indistinct and the pebbles become coarser and more subangular in shape, so it is almost certain that the closing beds of the series were laid down on a land-surface. The presence of lignite in the lower beds clearly indicates estuarine or deltaic conditions.

It should be noted that on the high banks of the Grey River there is a still more recent series of gravels belonging to the history of the stream. They are similar in lithological features to the gravels of the Kowai series, but they are neither so well stratified nor so well cemented. They are undoubtedly river and not sea deposits. Where contacts can be seen they are easily differentiated, but elsewhere, especially on the lower slopes of the downs, it is difficult to separate them from the upper members of the lower set of beds, which were also laid down on a land-surface.

Grey River, West Branch.

The general stratigraphy of the beds in the basin of the western branch of the Grey River is similar to that in the eastern. The following is a general description of the strata exposed above the greywacke as disclosed on the sides of the gorge of the stream:—

1. *Sands* and *greensands.*
2. *Limestone*, full of bryozoan remains, but only a few feet thick in the gorge of the stream, thickening, however, to the east and to the west. There is a marked difference in the features of this limestone as compared with that in the eastern branch, and as they are in apparent continuity it might be assumed that the stone in the western branch represents a shallower-water facies. I am by no means certain that this is the true explanation, and the question of the identity as regards their stratigraphical position must be reserved for further investigation.
3. *Marls*, greenish in colour, with rounded concretions and concretionary bands, passing up into greyish sands with fragmentary fossil shells.

In the river these beds strike E. 25° S. and dip south at an angle of 30°, but they have suffered some deformation, and the strike changes to north-east on the ridge between the two branches of the Grey, and also as the beds are traced round to White Rock and the Okuku River. The upper surface of the sands was distinctly eroded before the next bed was laid down. This consists of a heavy band of cemented gravel. The following beds are then encountered, in ascending order:—

4. *Gravel bed* just referred to.
5. *Sandy clays* and *gravels.*
6. *Sandy clay* and *carbonaceous shale*, repeatedly alternating. One bed of shale is from 12 in. to 18 in. thick.
7. *Sandy gravel*, well cemented with iron oxide.
8. *Greenish-grey sands, sandy shales*, and *gravels*, rapidly alternating, totalling over 200 ft. in thickness, the strike gradually becoming east-north-east, and the dip flattening out from 30° to 10°.
9. *Gravels*, sandy and with occasional thin layers of sandy clay, lying flat or with slight dip to the south-east. These are at least 500 ft. thick, and are well exposed on the ridge between the western Grey and the stream near the White Rock Station.

The section in this river thus shows that there is a distinct series in which gravels are the dominant beds lying unconformably on marine Tertiaries. It should be noted that in the western branch there are no gravel beds below the unconformity. Either they have never been deposited or they have been removed by erosion. There is a strong suggestion from the eastern branch that gravel beds are present among the higher members of the underlying marine series, so that their presence cannot be taken as decided evidence that beds containing gravels in this locality necessarily belong to the Kowai series.

Okuku River and Mairaki Downs.

Similar gravels occur on the banks of the Okuku, especially on the western side, where they form low hills fringing the base of Mount Thomas, and stretching westward towards the Garry River and Glentui. Towards the Ashley they are masked by more-recent gravels, but they reappear on the south bank of the river, forming the Mairaki Downs. The strata here consist of thick sandy gravels, sandy clays, and occasional layers of carbonaceous shale. Opposite the mouth of the Garry they strike north-east and dip north-west at an angle of 20°, forming the south-eastern wing of a syncline which is developed farther west, while farther east, towards Rangiora, the structure is anticlinal. The country directly between the Mairaki and Mount Grey Downs is probably a syncline, but the surface is completely masked by recent gravels and clays belonging to the Ashley and Okuku Rivers and to the lower course of the Grey and Makerikeri Rivers, the latter draining a considerable area on the south-western flank of the Mount Grey Downs.

Kowai River, North Branch.

An excellent idea of the structure and general features of the northern part of the downs area can be obtained by examination of the high banks of the North Kowai, and especially of a tributary which rises in Mount Brown itself and flows in a south-easterly direction across the strike of the beds, thus exposing all the members of the series present in this locality. The following is a general description of the beds encountered, starting with the Mount Brown beds and following up to the highest members of the series :—

At the contact with the upper members of the Mount Brown series the latter consist of sands, and marine gravels with shells, striking north-east and dipping south-east at an angle of 10°. The Mount Brown beds are here capped unconformably with sandy gravels containing rounded and sub-angular greywacke pebbles, and belonging in all probability to the high-level terrace-gravels of the present Kowai River. Lower down sands, sandy clays, and sandy gravels dipping south-east at very low angles are exposed on the banks of the stream and in the deep gullies on the northern side. There is certainly a disagreement in dip between these beds and the underlying Mount Brown beds, suggesting an unconformity, but nowhere could I see an actual contact in order to determine this point precisely. The slight escarpment of the downs which faces Mount Brown at this point is determined by the presence of the gravel beds which occur at this horizon. It is noteworthy that there is an entire absence of the gravel beds with broken-shell layers which cover the Mount Brown beds in the vicinity of Weka Pass, a point which increases the probability that the beds forming the downs rest on the Mount Brown beds unconformably.

Farther down-stream the beds lie almost flat, with an east-south-east strike and a dip to the north-north-east at very low angles (less than 5°). On a high bluff a series of well-stratified sands and sandy gravels is exposed. Near the base of the cliff, under a sandy bed cemented in its lower part with iron oxide, lies a narrow band of sandy carbonaceous shale, 6 in. to 8 in. thick, containing pieces of lignified wood, and passing down into sandy clay with interstratified irregular lenses of lignite. Under these lie sands and sandy gravels, and then bluish-green and brown sands. A little below this the strike swings round to north-north-east, with an easterly dip, and in a narrow gully on the south side of the stream an interesting section is exposed. Here both the bluish-green sands and the sandy gravels have been eroded, and on the eroded surface have been deposited sands and sandy gravels containing fragments of the lower beds. A similar occurrence is to be observed on the face of a cliff in the main stream, the lower beds dipping 10° and the upper lying flat across them. A thin layer of broken-shell fragments was observed high up on the face of the cliff in an inaccessible position.

Higher in the series are rapidly alternating sands and fine sandy gravels, in layers down to 1 in. in thickness, and these are succeeded by sands, sandy-gravel beds, and bluish-grey and brown sands, the former with broken-shell layers. In the gravels are numerous fragments of limestone, which must have been derived from a surface of the Amuri limestone exposed to decided erosion. The fragments are generally less than 2 in. in length, but are sometimes longer, and are usually flattened like beach shingle. There is no doubt as to the interstratification of these beds in the series under consideration, as the same feature was observed in a deep gully to the north of the stream in its proper stratigraphical position. The presence of these fragments is positive proof of the presence of an unconformity between these beds and the Amuri limestone, and supports the stratigraphical evidence from the Grey River. In the bluish-green sands there are occasional shell-fragments.

For some distance below this spot there are no clear sections, but sand is probably the major constituent of the beds. At the junction with the Kowai River, however, there are high cliffs on the northern side, where the strata are clearly visible for half a mile. The lowest beds exposed in this locality are sands with interstratified gravels, in which limestone-fragments form a most important constituent. The beds with the limestone-fragments are at least 50 ft. thick, and may be thicker. Higher up the limestone constituent gets less and less, and the pebbles are entirely of greywacke. No other included material, such as fragments of Mount Brown limestone, was noted at this spot, which might indicate the date of the break between the Amuri limestone beds and those under consideration. It is possible that these gravel beds are unconformable to the greenish marine sands, since for some distance no exposures are visible which enable their relations to be precisely determined, and there is evidence from other parts of the area that these upper gravels are unconformable to greenish sands—*e.g.*, in the Grey River (see p. 272) and also in No. 2 Creek (see p. 276). These gravel beds are fairly well stratified, with occasional beds of sandy clay and thin carbonaceous shales, their total thickness being about 1,000 ft., and the whole thickness of the series from the junction of the Mount Brown beds upward being about 1,500 ft., though this may include two series—viz., the Motunau and the Kowai series.

The course of the main stream above its junction with the tributary follows almost along the strike of the beds, so that the structure is not so well displayed. The beds exposed consist of marine sands, which are remarkably current-bedded, and loose and cemented sandy gravels with numerous fossils similar to the beds exposed in the Lower Waipara Gorge. The highest bed of this series exposed in the valley of the stream consists of greenish sandy clay, which weathers a light brown, and contains fossil shells. Its upper surface has been distinctly eroded, and on it rests a heavy layer of cemented gravel, and following this are sandy clays and gravel beds dipping south-east at angles of 10°. These beds pass upward into the gravel beds exposed on the cliffs of the river below the junction with the tributary. In the tributary mentioned above I could find no indication of an eroded surface analogous to that in the main stream, and so it may be an unconformity of local character similar to those recorded elsewhere, but it may indicate a decided unconformity between the Motunau and the Kowai series.

It is owing to the typical development of these gravels and the beds associated with them in the Kowai River, not only in this locality but in the south branch as well, that I have called them the Kowai series. It is possible, however, that the lower part of this group of beds may be equivalent to the upper part of the Motunau series, and subsequent investigation may show the term to be unnecessary.

In No. 2 Creek, a southern tributary of the North Kowai, there is a very important section. Just below the high bluff on the north side, about four miles above the junction, the stream has exposed the following beds :—

1. *Greenish sands*, becoming more clayey in the upper portions and passing up into sandy shale.
2. *Lignite*, very impure, 10 in. thick, striking east-north-east and dipping north-north-west at 5°.
3. *Argillaceous sands*, decidedly clayey above the coal but becoming more sandy and greenish in colour higher up. The thickness exposed is about 6 ft., but it is eroded, and sandy gravels rest on it unconformably. An eroded surface appears just below this in the bed of the stream, with an angular mass of green sandy clay embedded in the gravel.

In close proximity to the erosion surface there is another section showing the same features, but with only 3 ft. of bed 3 interposed between the coal and the gravels.

Just over the dividing-ridge between this and the South Kowai River there are high cliffs, facing south, composed of similar beds, with gravels more strongly developed in the higher levels, and dipping south at angles about 5°. Thus an anticlinal axis runs east-north-east along the ridge in close proximity to the road which runs along the crest.

Just at the point where the stream turns after leaving the steeper slopes of Mount Grey, and assumes a north-easterly course, coal and associated beds are exposed in its actual channel and in the bank of a small gully on the southern side. They consist of—

1. *Greenish sands*, passing up into sandy clays.
2. *Impure lignite.*
3. *Clays* succeeded by greenish sandy clays.
4. *Gravels*, mixed with sand, cemented with iron oxide.
5. *Greenish sandy clays.*
6. *Cemented gravels.*

These beds strike north-east, and dip north-west at an angle of 5°.

When followed up-stream there is an alternation of sands and gravels, apparently conformable to the beds just enumerated, exposed in the slips on the river-banks; but the dip becomes steeper till, on the face of a high bluff below the bush, it reaches 20°. Here are alternating sandy clays and gravels, the former greenish-yellow in colour, which are capped unconformably by somewhat irregular sands and gravels, lying almost horizontally across the denuded edges of the lower set. The upper series evidently forms the distinct ridge which leads down-stream past the point where the undoubted unconformity described above was observed.

Similar beds are observed in places on the banks of the stream higher up, but the covering of bush and soil is too complete to attempt a correlation with those lower down. Owing to this covering it is likewise impossible to say whether the junction between the greywackes of Mount Grey is a simple unconformity or a fault contact.

Kowai River, South Branch.

The high banks of this river rise in places to a height of 500 ft. above its bed, frequently with precipitous faces, and thus excellent sections are exposed. The strata are also folded into gentle anticlines and synclines, so that in the cores of the former the lower beds are exposed. They consist of the following in ascending order:—

1. *Sands* with concretionary layers, with broken-shell beds in the lower part, at least 80 ft. thick.
2. *Green sandy clays and gravel beds*, the latter finer in grain and thicker in the lower part, and cemented with iron oxide.
3. At higher levels there are rapidly alternating *gravel* and *sandy beds*, the former composed of subangular pebbles, which point to deposit either on a land-surface or on a shore-line in close proximity to the source of supply. No limestone pebbles were seen in these beds. In places they exhibit intraformational unconformities, such as one would expect when rapid changes in the conditions of deposit take place, especially when the change is from a sand to a gravel, and *vice versa*. The gravel beds frequently form steep cliffs; and their hard bands determine the dividing-ridges between the tributary streams running into the main river, especially on the south side, and they also determine an important reach of the river itself, although its direction is primarily across the strike, and therefore of consequent character.

A specially good section is to be seen where the river makes a right-angle turn, and changes from the subsequent to the consequent direction. The beds are here bent up into a rather sharp anticline with a north-east strike and a dip to the north-west at an angle of 50°. On the seaward side of the anticlinal axis the dip is much less, the angle being about 10°, the succession being similar. But farther down-stream the strike swings round till it is north-north-east, then north-north-west, and finally north-west, following for a time the direction of the main river. This allows the lower members of the series to be exposed again in the bed and banks of the river. They consist here of sands and sandy clays, greenish-blue in colour and weathering brown, containing fossils, some of the sands with concretionary layers and associated with thin gravel beds. The shells consist of *Siphonalia*, *Glycymeris*, and *Ostrea*, but in a fragmentary condition.

Farther down-stream the greenish-blue beds are still exposed, but the strike gradually becomes north-east with a dip to the south-east, and gravel beds form the greater part of the high bluffs which face the river on the north above the Mount Grey Station.

Opposite the right-angle turn of the river referred to above, and immediately to the west of the axis of the anticline, there is distinct evidence of the presence of an unconformity between the gravels just referred to and a higher series. The beds here consist of sands and sandy gravels which are lithologically indistinguishable from the higher members of the lower series. On a bluff facing the river the beds in contact with the gravels of the lower series are exposed lying across their denuded edges at low angles, and immediately to the north-west they show a reversal of dip and are inclined to the south-east at angles of from 5° to 7°. This dip is in agreement with that which can be observed in sections in the upper basin of the Southern Kowai, and notably to the south of the anticline which runs to the south-east of No. 2 Creek and parallel with it. Thus there is evidence of an unconformity in the Southern Kowai in close proximity to that in the No. 2 Creek in the drainage area of the Northern Kowai.

It will be noted that the lowest members of the series present in the two branches of the Kowai consist of sandy beds with marine fossils, whereas these do not appear with certainty in the Grey River. The gravel beds are, however, equally developed in each area. This difference is perhaps of no special stratigraphical importance, since the gravel beds in both areas are undoubtedly marine, and in the Grey area conditions may not have been favourable for the preservation of fossil remains. As far as I can see at present, there is no evidence of a major unconformity between the gravel beds and the lower marine beds, although minor, intraformational unconformities undoubtedly exist. There is, however, distinct evidence of a discordance at a higher level in the Kowai series between beds of similar lithological character both above and below the unconformity, but not such a discordance as necessitates the higher beds being placed in another distinct series. The whole area and its vicinity no doubt experienced a fairly rapid elevation, probably of a differential character, so that erosion went on in one part of the area while deposition was continuous in an adjacent part. If subsequent deposition over the denuded area then ensued this special stratigraphical feature can be satisfactorily explained.

Fox's Creek.

In Fox's Creek, the next stream south of the Kowai, there is an excellent section of the gravels forming the great mass of the downs area. This stream rises in the centre of the area and flows east, being bounded on the north for the middle part of its course by precipitous banks, in places up to 500 ft. in height above the stream. The beds here exposed consist of sandy gravels, sands, and sandy clays, with occasional thin, discontinuous layers of sandy carbonaceous shale. The sands are frequently blue-green in colour, and without fossils as far as I could see. In this part of the course of the stream the beds lie flat, with a slight dip to the north, but on the eastern margin of the downs the dip increases to 10° and its direction becomes south-east. In the adjacent valleys to the north and south there are similar beds with similar dip.

Lower Waipara Gorge.

Just where the river crosses the western end of the Limestone Range, beds of the Motunau series are exposed, consisting of marine sands, sandy clays, and sandy gravels frequently cemented with calcareous material and containing numerous fossil shells (Speight, 1912 and 1914). They are involved in anticlines and synclines, and sometimes dip at steep angles—as high as 55° to 60°. They do not contain, as far as my observation goes, any limestone-fragments such as might have been shed from the Weka Pass or Amuri limestone beds, and this suggests that they are not unconformable to the beds containing those limestones, a conclusion which is supported by general stratigraphical evidence. These Motunau beds are capped unconformably by gravels containing numerous fragments of limestone, and from their lack of distinct stratification it may be concluded that they are high-level terrace-gravels of more recent date. Similar gravels occur on the downs just east of the Amberley–Waipara Railway, covering a considerable extent of country, as they are occasionally exposed in the sides of deep washouts and cap the cliffs cut by the river in making its gorge.

Along the north bank of the river below the Teviotdale Bridge there is also a series of Motunau beds, consisting of sands, sandy clays, and gravels, some of which are very fine and smooth and are evidently of marine origin. These beds contain fossil shells at various levels, which point to the age being Mio-Pliocene or Pliocene (Speight, 1914). On the south bank of the river the beds are much obscured by slip-material and vegetation, so that in no place is the contact clearly displayed. On the terrace near the mouth of the river the following section is exposed :—

1. *Yellowish sands*, exposed at river-level and for 6 ft. upwards.
2. *Sandy lignite*, with well-marked woody structure and containing crystals of gypsum in stellate and columnar groups, 4 ft. in thickness.
3. *Sandy clay* (fireclay ?), with occasional pieces of bituminized wood.
4. *Lignite*, full of bituminized wood, 6–8 in.
5. *Sand and sandy clay*, with pieces of wood, 4 ft.
6. *Gravel*, 6 ft.
7. *Sandy clay*.
8. *Gravel*.

Farther up-stream the lignite-beds are exposed in similar stratigraphical position, succeeded by yellowish clays and sandy gravels, and at one place there is an exposure under the lignite of well-stratified and rounded marine shingle.

These beds all strike east-south-east and dip west-south-west at very flat angles, and it is impossible to tell on stratigraphical grounds whether the gravels overlying the lignites are conformable or not, or whether they belong to the Kowai series or to recent terrace-gravels. The locality furnishes evidence of the ease with which conformity may be simulated under certain circumstances. If level beds are planed by the sea, and no irregularity left on their being depressed and covered with a veneer of sediments, apparent conformity may occur over considerable distances, and especially will this be the case if the beds in contact are of a sandy or gravelly nature. A suggestion of unconformity is given in this case by the presence in the lowest layer of gravel of large pebbles, up to 8 in. in diameter, and more or less subangular, indicating strong currents on a land-surface or on a sea-bottom in close proximity to land, and that the beds were deposited under conditions entirely dissimilar from those obtaining when the better-rounded gravels were laid down.

Other Canterbury Localities.

There are other localities in this part of the South Island where similar gravels occur, among which may be cited the Isolated Hills in the Culverden

Basin; the cliffs at Gore Bay, where well-cemented gravels are involved in a syncline; the western side of the Trelissick Basin, specially in the Hog's Back Creek; between the Pudding Stone and the North Ashburton River; and in South Canterbury between the Tengawai and Pareora Rivers. It is probable, too, that the deeper gravels encountered in the bore at Chertsey belong to this series, the indications of petroleum coming from plant-remains which elsewhere have formed lignite.* Just below the Rakaia Gorge, where great thickness of gravels has been exposed, there is an underlying set of beds which are more strongly oxidized than the covering strata, and they may perhaps be assigned to a series older than the prevailing shingle beds of the plains. Although this criterion is perhaps an unsatisfactory one on which to base a determination of relative age, yet it has been applied in Switzerland in order to differentiate the gravels of the older glacial series of that region.

General Conclusions as to the Origin and Age of the Beds, and Relation to the Gravels of the Canterbury Plains.

The materials of which these gravels are composed have been derived almost entirely from original greywackes. No limestone was noted among them except in the case of the beds in the North Kowai. Occasional pebbles of basalt also occur, such as might have been derived from areas where such rocks are known to exist. A siliceous sandstone, white in colour and forming rounded masses, which could not be traced to its source, also occurs freely in the gravels of the Mount Grey district. These are perhaps masses of sandstone which have been loosely cemented by processes analogous to those which have formed the sarsen stones, or "Chinamen," as they are called by miners, of the schist areas of Central Otago.

The subangular nature of the pebbles shows that the greywacke land must have been in close proximity to the area of deposit. The absence of large pebbles suggests that it was of moderate relief, though it might have been the outlying portion of a more elevated tract. The gravels contain, however, no suggestion of a glacial or fluvio-glacial origin; they are just such gravels as might have been brought down by the present Ashley or Waipara Rivers, which have no connection with glaciers. The origin of the limestone constituent can be traced exactly, as exposures of limestone of similar nature occur within a short distance of the area where they have been deposited; but these limestone pebbles occur low down in the series and disappear at higher levels, so that the uppermost beds must have been derived from areas where limestone does not exist. Although the lower members of the series are undoubtedly marine, the upper members were in all probability deposited under estuarine conditions or actually on a land-surface.

The determination of the age of the Kowai series is a matter of some difficulty. The unconformity in the Grey River shows that it is certainly post-Miocene, and in the Lower Waipara Gorge beds occur under the gravels with a fossil content which shows them to be upper Pliocene (Speight, 1914, p. 300)—that is, beds which form the upper part of the Motunau series. Therefore we may reasonably infer that the Kowai series is either upper Pliocene, if no unconformity exists between two sets of beds, or Pleistocene, if an unconformity is demonstrable. The Pliocene beds of the lower Waipara are perhaps the uppermost beds of a conformable Cretaceo-Tertiary series.

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* Pieces of carbonized bark have recently been obtained from a depth of 1,900 ft. in this bore.

Therefore if an unconformity can be proved between the Kowai series and any member of the lower series it will be unconformable to all. As the presence of included fragments of limestone in the gravel beds of the Kowai demonstrates the existence of a clear unconformity between the gravels and the limestones, and the undoubted erosion-surface in the Grey River demonstrates the presence of one at a higher level still, we may therefore infer that the gravels of the Kowai series must be of Pleistocene age. If, however, the Cretaceo-Tertiary series is broken up eventually into subordinate unconformable elements, then this argument fails, and the matter will depend on the relation of the Kowai series to the fossiliferous marine beds of the lower Waipara and the Northern Kowai, as being the highest beds on which the Kowai series undoubtedly rests. The relation of the two sets of beds is somewhat obscure, though, judging from the evidence in the latter locality, probably unconformable. Therefore all that can be definitely stated is that the Kowai series overlies undoubted upper Pliocene beds and must be of a later age, and is most probably Pleistocene.

This must be earlier than the gravels forming the Canterbury Plains, for these have suffered no deformation by folding movements, whereas the gravels of the Kowai series are at times folded somewhat acutely. They would therefore antedate the last period of glaciation to which the region had been subjected.

A point which bears on the conformity of the Tertiary sequence should be noted—viz., that in neither of the two branches of the Grey River are the typical Mount Brown beds developed, thus suggesting an unconformity between the Motunau series, or the Kowai series, and the Mount Brown beds in case the absence is due to erosion, or between the Mount Brown beds and the "grey marls" in case the overlying beds, together with the Mount Brown beds, are part of a conformable series. As there appears to be no evidence of unconformity between the Mount Brown beds and the "grey marls" in the typical locality, whereas there is some evidence of an unconformity between the Motunau series and the Mount Brown beds, it seems more likely that the absence of the Mount Brown facies in the Grey River is due to erosion of these beds after deposition. This, however, is a point which requires further investigation.

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Art. XXX.—*Rough Ridge, Otago, and its Splintered Fault-scarp.*

By C. A. Cotton.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 11th February, 1919; issued separately, 16th July, 1919.*]

Introduction.

In another publication* I have referred to Rough Ridge as one of the upland blocks of the Central Otago system of block mountains and associated depressions. It is there described as follows:—

"Its crest is very even for many miles with a height of about 3,200 ft. above the sea. On its north-western and north-eastern sides this block is similar to the Raggedy–Blackstone block. Farther south, however, it is complex and relatively wide, two broad splinters descending towards the north-east and forming offsets on the lowland level between the north-east-trending fault-scarp portions of the boundary-line between the Rough Ridge block and the next depression to the east."†

The map and diagram, figs. 11 and 13 of the paper referred to, show the relation of the Rough Ridge block to the structure and relief of the district as a whole, and fig. 3 is a sketch of its back slope.

This block is of interest both on account of its remarkably even and little-dissected back slope (a fossil plain) on the north-western side, and on account of the faults *en échelon* bounding it on the eastern side, between which two well-defined splinters descend from the upland to the level of the adjacent depression (see fig. 1).

Splintered Fault-scarps.

So far as I am aware, the term "splinter" was first used in a similar connection by Davis, who figured a "rock-splinter on the Hurricane fault" and referred to it in these words: "The view northward showed at a distance of ten or fifteen miles a curious offset in the fault whereby a splinter of upper Aubrey at the edge of the Uinkaret bends down and descends southward to the Shivwits level."‡

In New Zealand another splintered fault-scarp, in the Waitaki Valley, has been described and figured.§

A splintered fault differs from a distributed fault and from a branching fault in that, while the displacement on the whole fault-system remains constant throughout its length or varies constantly in one direction or the other (as might the displacement on a single simple fault), dwindling displacement on one line (such as *AB*, fig. 2) is compensated by the development parallel to it of another line of fault (such as *CD*) with increasing displacement, and this may occur more than once (*EF*); so that discontinuous faults *en échelon* separating successive splinters form the complex boundary between adjacent high- and low-lying blocks. It is as though faulting had followed pre-existing lines of weakness — lines of least resistance — running diagonally across the boundary between the tectonic blocks.

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* C. A. Cotton, Block Mountains in New Zealand, *Am. Journ. Sci.*, vol. 44, pp. 249–93, 1917.

† *Loc. cit.*, pp. 274–75.

‡ W. M. Davis, An Excursion to the Plateau Province of Utah and Arizona, *Bull. Mus. Comp. Zool. Harvard*, vol. 42, pp. 1–50 (see p. 30 and fig. 9), 1903.

§ C. A. Cotton, The Fossil Plains of North Otago, *Trans. N.Z. Inst.*, vol. 42, pp. 429–32 (see p. 432 and pl. xxx, fig. 2), 1917.

ROUGH RIDGE.

The back slope of Rough Ridge is probably the most perfectly preserved inclined fossil plain in Otago. The surface, as shown in fig. 3 of the paper referred to above, is in the stage of erosion when the overmass has been stripped off and the ancient planed floor is undergoing dissection by numerous parallel consequent streams none of which is master. While a few feet of rock have been removed from the stripped floor since the removal of the cover, as is shown by the presence of abundant residual tors of schist, the form of the ancient eroded plain, now tilted with an inclination

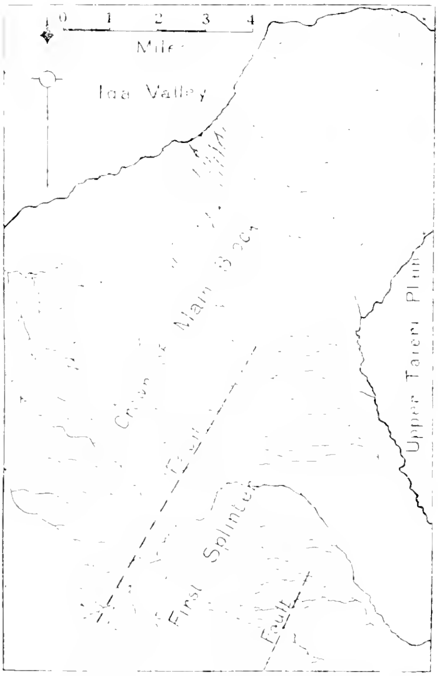


FIG. 1.—Northern end of Rough Ridge (from maps by Department of Lands).

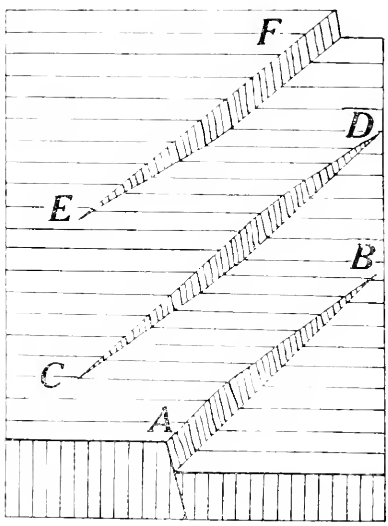


FIG. 2.—Diagram of a splintered fault dislocating a plane surface.

of 10°, is preserved almost perfectly by the existing surface of the interfluves. Though these are narrow, they slope towards the numerous stream-lines only near their edges, which are rounded off. The profiles of the little valleys of the dissecting streams are roughly graded, though incised to but a small depth below the general slope, this depth being, as would be expected, greatest about the middle of the slope. Thus, if the former presence of a cover be disregarded, the cycle of erosion for the surface is still in the stage of youth; and it may remain, and probably has remained, at this stage for a long period, for the conditions are here extremely favourable for long persistence of such pseudo-youthful topography.* In this way only can the frequent recurrence of similar back slopes be explained.

* C. A. COTTON, *loc. cit.*, p. 259.

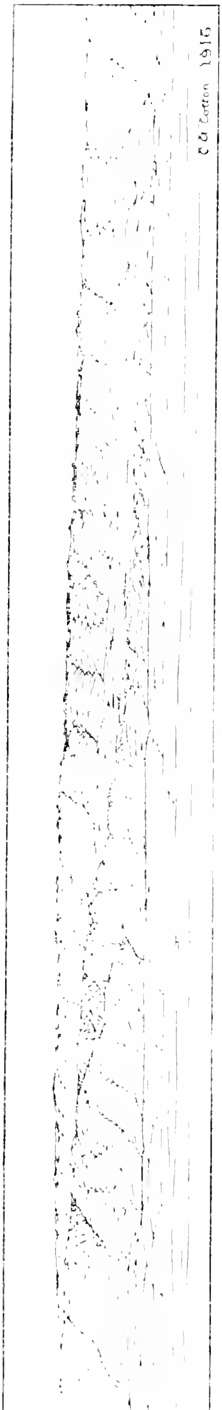


Fig. 3.—The first splinter from the Rough Ridge fault-scarp. View looking north-west.

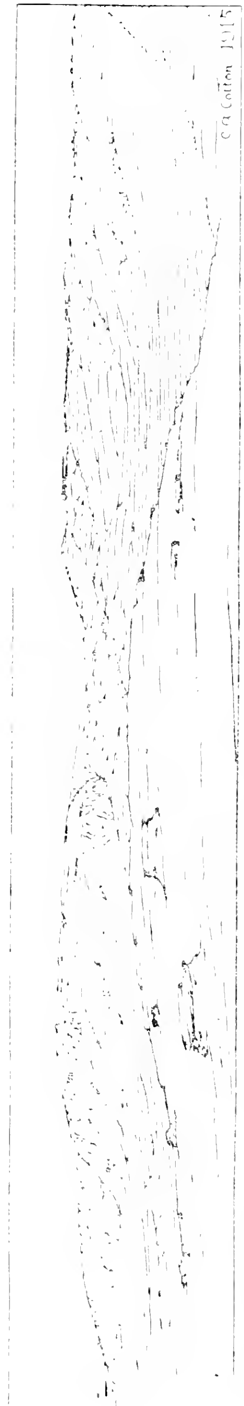


Fig. 4.—The first splinter from the Rough Ridge fault-scarp. The second splinter is seen on the left. View looking south-westward up along the splinter from a point on Little Rough Ridge to the right of fig. 3.

Though the back slope of the Rough Ridge block is remarkably uniform, the stripped surface arches over near the crest-line, becomes horizontal, and then slopes down towards the south-eastern side, or front, of the block. Around the north-eastern end this little-dissected surface has the form of a plunging anticline, and, close to the north-eastern end, even on the front, the strongly warped fossil plain seems to form the slope, though farther to the south it undoubtedly passes into a fault-scarp. The eastward-sloping stripped surface, or fold-scarp, has an inclination of 20°, and is more deeply and maturely dissected than the back slope. Tors survive on the interfluves.

The structure of the schist forming the Rough Ridge block is a broad, open anticline with its axis transverse to the elongation of the block. On the crown of this anticline, which is near the northern end of the block, the ancient eroded surface truncating the anticlinal structure is practically parallel with the foliation of the schist. The deformation to which the uplift of Rough Ridge is due is here shown not only by the form of the surface, but also by the dip of the schist foliation, which arches over the top of the ridge accordant with the surface. Such an agreement between the surface-slope and the dip of the foliation may occasionally be noted in other parts of Central Otago where the schist is flat-lying; but, on the other hand, there are frequent changes of dip which are quite discordant with the general slopes of the surface, and are obviously of more ancient origin. The same is true of the broader structures of the schist—as, for example, the broad anticline referred to above in the Rough Ridge block.

As the eastern front of Rough Ridge is followed southward the fold-scarp is found to be replaced by a fault-scarp. Here, however, near the base of the scarp lies a strip of the schist undermass, the north-eastern part of which is but little above the general level of the neighbouring portion of the Maniototo depression and is separated from the scarp by a narrow strip of planed undermass (see fig. 4). This low, flat outcrop of schist is named Little Rough Ridge, on account of its tor-covered surface. Followed south-westward its surface rises—the displacement on the fault which separates it from the main block decreasing in that direction—so that it is seen to be a splinter with its stripped surface inclined towards the main block (see figs. 3 and 4). This first splinter is bounded on the front, or south-eastern side, by a fault-scarp similar to that of the main block. At the base of this scarp is another low-lying area of schist, which rises south-westward to form a second splinter similar to the first. At the base of the fault-scarp of the second splinter lies a schist surface which emerges from beneath the overmass in the Maniototo depression and rises southward to form part of the plateau into which the Central Otago block mountains and depressions merge when followed southward.

In the fault-angle behind the higher portion of the first splinter a remnant of the cover is preserved.* A glance at figs. 3 and 4 shows that the drainage of the depression behind the splinter, after following what appears to be the normal, longitudinal, consequent course in the fault-angle for some distance, turns south-eastward and crosses the splinter in gorges. This points to some bending-down of the initial surface adjacent to the crest of the fault-scarp, for there is nothing to suggest that capture has taken place, and the stream-courses are probably consequent throughout their length.

* A. McKay, *Report on the Older Auriferous Drifts of Central Otago*, Wellington, 1897 (see map).

Art. XXXI.—*Note on the Mechanical Composition of the So-called Loess at Timaru.*

By L. J. Wild, M.A., B.Sc., F.G.S., Canterbury Agricultural College.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 12th February, 1919; issued separately, 16th July, 1919.*]

The origin of the so-called loess at Timaru, and of other similar deposits on Banks Peninsula and elsewhere in the South Island, is connected with the larger problem of the formation of the Canterbury Plains, and with the question of the direction of the more recent movements of the land in that area. Haast* was of opinion that the deposit is similar in origin to the loess of China described by Baron von Richthofen—that is to say, it is an aeolian deposit. In this opinion he has been supported by Hardcastle,† by Speight,‡ and by Professor A. Heim§ of the University of Zürich. Marshall‖ has also declared his adhesion to Haast's view. Hutton¶ always strenuously opposed this theory, maintaining the deposit to be a marine silt laid down during a period of submergence of the plains; and he quotes Professor Boehm, of Freiberg, in support of his arguments. Since analyses of the deposit as seen typically at Timaru may shed some light on the problem I submit this note, though I admit my contribution of original observations is small when the importance of the question and the time given to it by previous workers are considered.

The following results were obtained by the method of mechanical analysis adopted by the British Agricultural Education Association (see *Journ. Agric. Science*, 1906, vol. 1, p. 470). The particles are freed from one another by treatment first with dilute hydrochloric acid to dissolve inorganic cements, then with dilute ammonia solution to dissolve organic cements. They are then separated by sedimentation.

Table I.—Mechanical Analyses of Samples of the So-called Loess at Caroline Bay, Timaru.

Name of Fraction.	Diameter of Particles in Millimetres.	(1) 2 ft. from Surface.	(2) 20 ft. from Surface.	(3) 30 ft. from Surface.
Coarse sand	1–0·2	0·65	0·92	0·68
Fine sand	0·2–0·04	29·07	40·00	27·76
Silt	0·04–0·01	34·32	35·97	37·05
Fine silt	0·01–0·002	25·95	15·72	24·12
Clay	Below 0·002	0·69	0·39	0·67
Organic matter	..	Trace	Trace	Trace
Dissolved matter and hygroscopic moisture	..	N.d.	N.d.	N.d.

* J. von Haast, *Geology of Canterbury and Westland*, Christchurch, 1879.

† J. Hardcastle, *Trans. N.Z. Inst.*, vol. 22, p. 406, 1890.

‡ R. Speight, *Trans. N.Z. Inst.*, vol. 40, p. 33, 1908; *Trans. N.Z. Inst.*, vol. 49, p. 386, 1917.

§ A. Heim, Quoted by Speight, *Trans. N.Z. Inst.*, vol. 40, p. 33, 1908.

‖ P. Marshall, *New Zealand and Adjacent Islands*, p. 31, Heidelberg, 1912.

¶ F. W. Hutton, *Trans. N.Z. Inst.*, vol. 37, p. 465, 1905.

Haast, when he set forth his theory that this deposit is of aeolian origin, followed Richthofen's explanation of a supposedly similar deposit in China. The required conditions are (1) the production of waste in an impalpable form, (2) steppe conditions for its desiccation, (3) winds to transport it, (4) vegetation to fix it where it settles. In our case it is presumed that the material is rock-flour produced by the Pleistocene glaciers and brought down by rivers; and, since it is generally agreed that the extension of the glaciers was due to the land being at a greater elevation, it is assumed that the coastal plains then exhibited the characters of a steppe region, so that the silt deposited on the flood-plains of the rivers was in condition for transportation by the wind. Under these conditions winds also must be granted. But now comes a difficulty. According to the experiments of Udden,* the average largest size of quartz-particles sustained in air by strong winds is 0·1 mm. in diameter, and Emerson† says that 70 per cent. of loess-particles range from 0·05 mm. to 0·01 mm. in diameter, a statement that is apparently based on the following analyses given by Merrill.‡ It is unfortunate that I have not been able to find any records of mechanical analyses of the loess of China.

TABLE II.—MECHANICAL ANALYSES OF LOESS AND DUST.

Name of Fraction.	Diameter of Particles in Millimetres.	(1) Upland Loess, Virginia, Illinois.	(2) River Loess, Virginia, Illinois.	(3) Loess, Nebraska.	(4) Dust from Snow, Rockville, Indiana.
Coarse sand	1–0·5	0·00	0·00	0·00	0·00
Medium sand	0·5–0·25	0·00	0·01	0·00	0·00
Fine sand	0·25–0·1	0·01	0·10	0·00	0·00
Very fine sand ..	0·1–0·05	7·68	24·84	23·14	0·00
Silt	0·05–0·01	61·85	60·98	54·81	69·37
Fine silt	0·01–0·005	9·60	2·80	2·46	5·80
Clay	0·005–0·0001	15·15	6·15	9·45	9·68
Moisture	..	..	..	5·40	3·17
Organic matter ..	..	..	..	4·96	11·98
Totals	..	94·29	94·88	99·22	100·00

It will be noticed that mechanical analysis by the method generally adopted in the United States separates the material into fractions that differ somewhat in size from those obtained by the British method.

Now, when we look at the composition of the Timaru deposit we find that from 28 to 40 per cent. of the particles have a diameter ranging from 0·04 mm. to 0·2 mm., while there is also a certain small quantity of material over 0·2 mm. in diameter. We have here, therefore, a very strong argument against the aeolian hypothesis.

Richthofen further stresses the importance of vegetation as a means of accumulating the fine particles. Haast quotes him as styling the loess beds "a graveyard of innumerable generations of grasses." In the *Geological Magazine*, vol. 9, p. 297, 1882, Richthofen writes, "Where this dust falls on barren ground it is carried away by the next wind; but where it

* J. A. UDDEN, *Journ. Geol.*, vol. 2, p. 323, 1894.
† F. V. EMERSON, *Journ. Geol.*, vol. 26, p. 532, 1918.
‡ G. P. MERRILL, *Rocks, Rock-weathering, and Soils*, New York, 1906.

falls on vegetation its migration is stopped." Quite as we should therefore expect, we find in one case nearly 5 per cent., in another nearly 12 per cent., of organic matter in the analyses cited above from Merrill. But the Timaru deposit contains merely a trace. Hardcastle attempts to explain this remarkable fact by assuming that "the growth of the deposit was so slow as to nearly allow the rootlets of each generation of plants to suck up the last remnants of the decay of previous ones." But any one who understands what goes on in a soil clothed with vegetation knows that this cannot take place. An article by Sir A. D. Hall in the *Journ. Agric. Science*, vol. 1, p. 241, 1905, may be consulted in this connection.

Speight (*loc. cit.*) has written, "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." As regards marine fossils, setting aside the fact of those recorded by Hutton (*loc. cit.*), which cannot be explained on the aeolian hypothesis, we must surely allow Hutton's contention that negative evidence on such a question is of little weight. There are other cases of undoubted marine deposits which are marked by a poverty of marine fossils. The greywacke is one such; the Buller series of sandstones and conglomerates is another. The Amuri limestone and the Weka Pass stone are also poor in the larger forms that we might reasonably expect.

The presence of remains of *Dinornis* and other land-birds must be interpreted rather as evidence in favour of marine origin than the reverse, the bones having been washed down and covered in the silt by local stream-action. It is obvious that birds require vegetation for their sustenance, and moas could scarcely have lived on Banks Peninsula at a time when loess was supposed to be forming, when it is considered that there is proof that no vegetation was present on the part covered by the deposit—at least there is no trace of it left. It may be noticed, in passing, that the advocates of the aeolian hypothesis call in local stream-action to account for the cases of distinct stratification noticed by Hutton* at Lyttelton and elsewhere, but are unwilling to allow the same agency to account for the covering of the moa-bones.

As regards the peculiar distribution of the deposit, that also is, I think, rather evidence in favour of its marine origin. Its occurrence within the Lyttelton caldera is as reasonably explained by deposition from water as by supposing, as is necessary to the aeolian hypothesis, that while it was deposited on the lower portions of the outer slopes it was also carried over the intervening ridges into the Lyttelton caldera without leaving a trace of its path.

* F. W. Hutton, *Trans. N.Z. Inst.*, vol. 15, p. 411, 1883.

ART. XXXII.—*The Geology of the Middle Clarence and Ure Valleys, East Marlborough, New Zealand.*

By J. ALLAN THOMSON, M.A., D.Sc., F.G.S., Director of the Dominion Museum.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 17th March, 1919; issued separately, 16th July, 1919.*]

Plates XXIV–XXIX.

CONTENTS.

INTRODUCTION.

THE middle reach of the Clarence River occupies a nearly straight valley, some fifty miles long, trending north-east, between the enclosing ranges of the Seaward Kaikoura or Looker-on Mountains to the south-east and the Kaikoura Mountains to the north-west, which rise to heights of 8,516 ft. and 9,465 ft. respectively. The summits of these ranges are twelve to fourteen miles apart across the valley, so that the area of this part of the valley is some 600 square miles. The north-eastern end of this middle reach of the Clarence is enclosed by an encircling rim of lower mountains, 2,500–4,000 ft. in height, and before reaching this point the river turns abruptly to the south-east and breaks through the north-eastern continuation of the Looker-on Range in a rock-bound gorge nearly 4,000 ft. deep. The Middle Clarence Valley is thus difficult of access, and can be entered only by a number of passes through the surrounding mountains, of which the most used are the Burnt Saddle (2,073 ft.), between Kekerangu and Coverham, crossing the north-eastern rim of the valley; the Mount Clear Saddle (3,000 ft.), between Reserve Station and Quail Flat; and the Palmer Saddle (3,185 ft.), from the Conway River to the Palmer River, the two latter passes lying in the south-western continuation of the Looker-on Range. These saddles are traversed by pack-tracks uniting the above-mentioned places, and there are similar tracks running the whole length of the valley. Other less-used tracks enter from the Awatere Valley, the two chief crossing the Tone Saddle (3,800 ft.) and the Barefells Pass (4,250 ft.). It is possible also to reach the Middle Clarence from Hanmer via Jollie's Pass and down the Clarence.

The surface of the valley is rendered very diversified by the existence of a large number of tributaries from each side, many of which enter the main river by gorges some hundreds of feet in depth. Of these, ten on the north-western side and six on the south-eastern side are large enough to be dignified by the name of river, and there are numerous smaller streams. The pack-track along the valley therefore takes on somewhat of the nature of a huge switchback, often rising a height of 1,000 ft. between two adjacent tributary rivers. The difficulty of access between different parts of the valley is accentuated by the size and strength of the Clarence River, which is not easily forded below the Bluff River.

Being cut off from the prevailing rain-bearing winds by high mountain-ranges the Middle Clarence Valley, like the neighbouring Awatere Valley, has a low rainfall, 20–30 in. per annum, and in consequence rain forest is absent throughout its whole extent. The lower slopes are covered with tussock-grass or manuka thicket, while small areas of beech forest occupy the gorges of many of the tributary streams at heights of about 2,000–5,000 ft. The intermediate rocky slopes and gorges bear, when not too steep, a profusion of flowering-shrubs, but there are large areas of bare rock and of talus slopes (screes and shingle-slips) which are almost destitute of vegetation.

The statement is frequently made that the higher peaks of the Kaikoura and Looker-on Ranges are covered with permanent snow. As a matter of fact, however, the higher peaks, though rising far above the estimated snow-line for this latitude in New Zealand, are frequently free from snow for several months in the year, except for a few days after a snowfall, and in the early autumn only small patches of soft ice persist in the shady hollows near the summit. The freedom from permanent snow must be ascribed partly to the steepness of the slopes and, in the case of the Kaikoura Range, partly also to the low rainfall during the summer. Owing probably to this freedom from snow, alpine plants reach a much greater height on the Kaikoura Range than in other mountains in New Zealand, and Aston (1916) has recorded the presence of a species of *Haastia* at a height of 8,500 ft. on Mount Tapuaenuku.

Owing to its inaccessibility and the broken nature of the country the Middle Clarence Valley has hitherto escaped close settlement, and is divided up into a number of pastoral leaseholds, of which the largest is the Clarence

Run, of 114,300 acres. In early days a large number of small freeholds were alienated, and the maps show road-lines throughout the valley, but it is obvious from an inspection of the ground that both freeholds and road-lines were laid down in the office without regard to topography. At one time homesteads existed at the Bluff River and at Coverham, but they have fallen into decay, and the former was at the time of my visit unoccupied, while the latter is used as a musterers' hut. The only permanent settlement at present existing is that at Quail Flat, which serves as an out-station of the Reserve Station and is continuously inhabited throughout the year. In addition to the above there are a small number of musterers' huts, that at the Dee River lying on the main pack-track through the valley. A traverse from Kekerangu to Reserve Station by pack-horse occupies four to five days, the stops being at Coverham, Dee, Bluff, and Quail Flat (optional).

Although the Middle Clarence Valley differs considerably in form and rainfall from the shouldered and flat-bottomed valleys of Switzerland, such as the Upper Rhone, one cannot help predicting that by the utilization of the tributary rivers for electric power and irrigation it will, like them, one day become the scene of a fairly close settlement. That day, however, lies in the distant future, unless the discovery of mineral resources should hasten it.

Before the actual geological exploration of the valley von Haast (1861) had visited the lower Awatere Valley in 1859 and had gained a near view of the Kaikoura Mountains. From the nature of the boulders in the gravel of the river he inferred that the range consisted of eruptive and volcanic rocks, unlike the Spenser Mountains and the Looker-on Range, which he considered to be composed of sedimentary rocks. He further expressed the opinion that to this volcanic action was due the upheaval of the two latter ranges.

Similarly, in the summer of 1866–67, J. Buchanan gained a view of the Middle Clarence Valley from the summit of the Looker-on Range, and observed the long strip of white limestone forming a series of foothills at the base of the Kaikoura Mountains as far south-east as the Bluff River.

A. McKay was the first geologist to enter and explore the Middle Clarence, which he traversed from Kekerangu to Hanmer in 1884–85, also crossing from Reserve Station to Quail Flat. In 1888–89 he similarly explored the Awatere Valley, and the four long reports (1886–1892) in which he recorded his observations long remained the only source of information as to the geology of these areas. They will be more fully noticed in the sequel, and need not be discussed in detail now.

With the exception of Sir James Hector, who accompanied McKay to Coverham in 1885, the Middle Clarence was not revisited by any geologist until 1912, when Dr. Cotton and myself twice went in from Kekerangu as far as the Dee River. In 1916 I again visited the same ground, and made the ascent of Mount Tapuaenuku from the Dee in company with Messrs. B. C. Aston, A. F. O'Donoghue, and H. Hamilton. Later in the same year I crossed the saddle from Reserve Station to Quail Flat and proceeded down the valley as far as the Bluff River. On three separate occasions also I have visited the middle part of the Ure Valley in company with various companions, including on separate occasions Dr. C. A. Cotton and Mr. H. T. Ferrar.

Following on these visits, Dr. Cotton published in 1913 an account of the physiography of the Middle Clarence Valley, and in 1914 a description and explanation of the mode of origin of the great Marlborough conglomerate as developed in the Dee and Mead Gorges. My own publications on this area comprise some brief observations in the Annual Reports of the Geological Survey for the years 1912 and 1913, a paper on the petrography of the intrusives of Mount Tapuaenuku (1913B), an account of the oil-prospects of the Benmore district (1915), a description of the Amuri limestone and flint-beds as far south-east as the Dee Gorge (1916), and a classification of the Clarentian rocks at Coverham (Woods, 1917).

The fossils collected by Dr. Cotton and myself from the Clarentian beds, as well as the earlier collections made by McKay, have been described in detail by Woods (1917), who has demonstrated the Albian age of the beds below the flint-beds, and has thus added a new interest to the geology of the area.

Although the area covered by my visits is much smaller than that traversed by McKay, whose reports cannot, therefore, be superseded, there are several reasons why a new account of the geology of the area should be presented. Both from a structural and from a stratigraphical point of view the district has become a classical one for New Zealand geology, and a more succinct account is desirable. McKay's descriptions both of structure and of stratigraphy are in the main accurate, but are couched in obsolete terminology as regards the physiography, while the stratigraphy is interpreted in terms of the classification then adopted by the Geological Survey, a classification which has now been universally discarded. In particular, is it vitiated by the false correlation of the Cretaceous rocks below the flint-beds (Clarentian) with those of Amuri Bluff (Piripauan), and this has at times led him to an unbalanced description of the rock sequence, emphasis being placed upon beds which are only locally developed and of relatively small importance. In making these criticisms I do not wish them to detract in any way from the great merit which I consider attaches to McKay's work. His report of 1886, although long neglected by other geologists than Hector, marked a new epoch in New Zealand geology by its recognition of the late Tertiary age of the Kaikoura Mountains, and must always remain a classic.

The area covered in this paper is so great, and the country so broken and difficult of access, that a complete survey would occupy more than one season of continuous work, and many years must elapse at the present rate of progress before the district can be worked out in detail. The observations both by McKay and by Dr. Cotton and myself can be looked upon only as reconnaissance, and, naturally, we have visited somewhat different ground, and devoted greater attention to different parts of the area. There are many new observations, therefore, to be placed on record.

General Account of the Geology and Physiography.

Both from a stratigraphical and a physiographical point of view, the rocks of the area may be divided into three main groups, as shown in the following table. McKay did not explicitly recognize this threefold division, and that part of his classification which relates to the present area is appended in the table. Between his Pliocene and Cretaceo-Tertiary groups he interpolated Miocene and Eocene from neighbouring areas. With the exception of the supposed Pliocene conglomerate, however, he implicitly recognized the unity of the middle group of rocks by describing them together under a special section of his first report (1886).

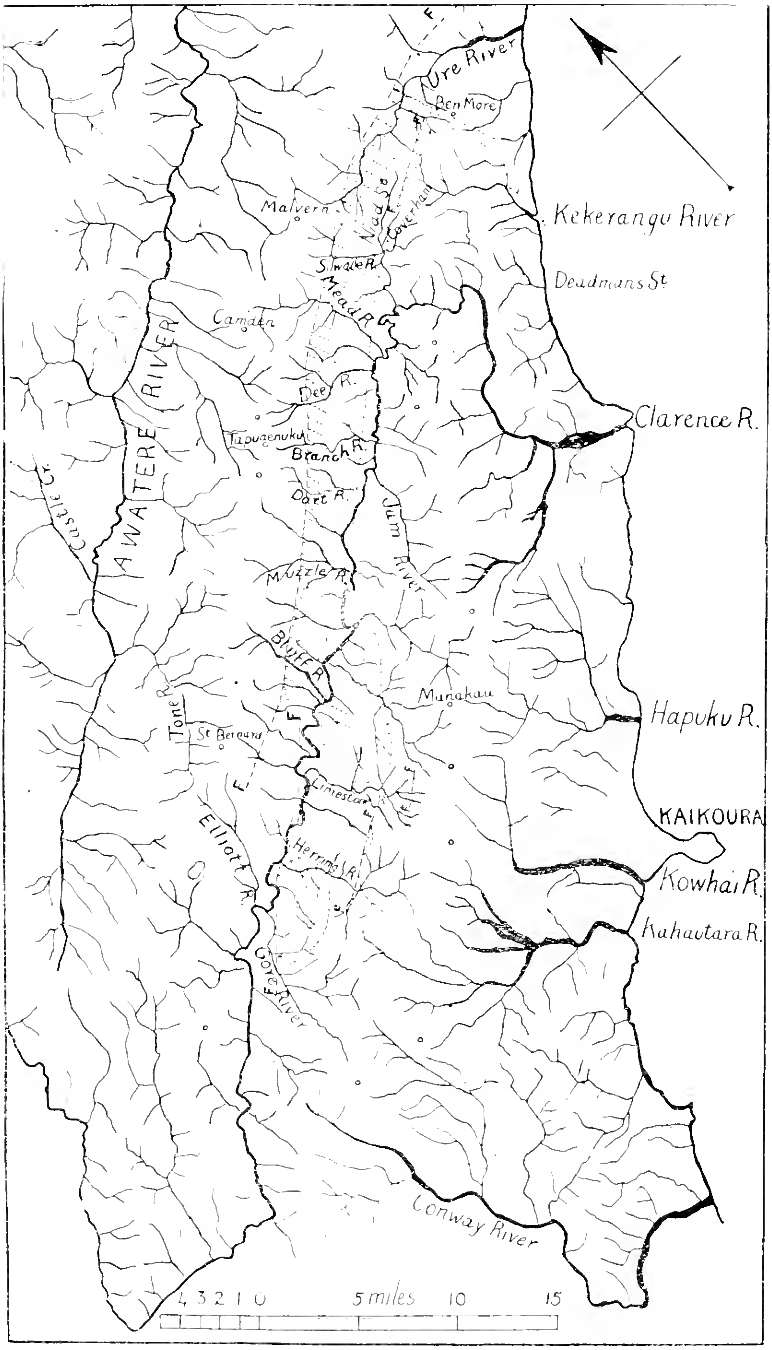


FIG. 1.—Map of eastern Marlborough.

Amuri limestone and higher Notocene beds; /// Clarentian; pre-Notocene and unsurveyed areas blank; FF, faults. The Notocene rocks of the Awatere Valley and of the coastal area are not shown.

Table I.—General Classification of the Rocks.

Stratigraphical.	Physiographical.	McKay, 1886 & 1890.	Nature of the Rocks.
Notopleistocene	Superficial (unconsolidated)	Recent ..	River alluvium, terrace gravels, river fans, talus, and moraines (?).
Notocene ..	Covering strata (generally weak but with resistant strata of limestone and conglomerate)	Pliocene ..	Mudstones (Awatere beds). Conglomerates (great Marlborough conglomerate).
		Cretaceo-Tertiary and Lower Greensand	Mudstones ("grey marls"). Limestone (Weka Pass stone). Tuffs and phosphatic greensands (only locally developed). Limestones and flint-beds (Amuri limestone). Mudstones, sandstones, basalts, and conglomerates (Clarentian).
Pre-Notocene	Oldermass (generally strong).	Older Secondary and Palaeozoic	Greywackes, argillites, and jasperoid sediments with syenitic and basic intrusives.

The Notocene rocks in the north-east half of the valley form an elongated strip a few miles in width on the north-western side of the Clarence River. At the Bluff River there are two separated exposures, the south-eastern of which crosses the river and continues for some distance to the south-west, and farther in this direction other isolated exposures occur. The rocks rest with marked unconformity on the pre-Notocene rocks which underlie them on the valley-floor, and of which, with their intrusives, the higher mountains are exclusively composed. The Notocene rocks dip in almost all exposures steeply to the north-west, and on their north-west side end abruptly against fault-lines, with the exception of the south-eastern outlier at the Bluff River. The most persistent of the faults, known as the great Clarence fault, runs along the base of the Kaikoura Mountains a few miles to the north-east of the river, and is described by McKay as a reversed fault. A monoclinal ridge of limestone, cut through by numerous gorges, has been developed by erosion in the tilted Notocene beds a short distance riverwards from the fault, and, rising to heights of about 3,000 ft., forms a prominent series of foothills to the Kaikoura Mountains. The hills closing the north-eastern end of the valley, rising to 4,081 ft. in Benmore, are a continuation of this monoclinal ridge, the line of strike bending gradually from north-east to south-east.

The probable geological history of the area, as interpreted from the stratigraphy, structure, and physiography, is resumed in Table II.

TABLE II.—SUMMARY OF GEOLOGICAL HISTORY OF THE AREA.

Diastrophic Events.	Corresponding Geological Events.
Orogenic movements.	Production of mountainous land surface, probably outside the area.
Epoch of relative inactivity (probably Hokonuian).	Rapid erosion with deposition of pre-Notocene rocks.
Post-Hokonui orogenic movements.	Folding of pre-Notocene rocks and production of mountains, with resulting erosion.
Stage of early Notocene sea-advance, with local vulcanism.	Continued erosion of adjacent mountains to peneplanation, with deposition of Clarentian beds, including local lava-flows; invasion of pre-Notocene rocks by dykes and sills.
Local epeirogenic uplift.	Local unconformity between Clarentian and Amuri limestone.
Stage of maximum Notocene sea-advance.	Submergence of land: deposition of Amuri limestone and Weka Pass stone, divided by a period of non-deposition.
Stage of late Notocene sea-retreat.	Renewed uplift and erosion of adjacent peneplains, with deposition of "grey marls."
Local intense differential uplift.	Deposition of fluviatile great Marlborough conglomerate by erosion of uplifted blocks.
Late Notocene sea-advance.	Deposition of Awatere beds.
Slight regional or differential uplift.	Initiation of antecedent or anteconsequent drainage.
Kaikoura orogenic movements.	Elevation of Kaikoura and Looker-on Ranges, with folding and faulting of the Notocene beds; development of consequent drainage; heavy erosion of mountains with development of insequent drainage; mature erosion of valley lowland with slight development of subsequent drainage.
Slight regional uplift.	Rejuvenation.

The area has experienced two epochs of major diastrophism—*i.e.*, two epochs of severe earth-movements of an intensity sufficient to raise mountain-chains—which have left their effects clearly marked in the structure of the rocks, while there is evidence for a still earlier epoch in a neighbouring district. Little is known of the age and the conditions of deposition of the pre-Notocene rocks. They are clearly earlier than Clarentian (middle Cretaceous), certainly Mesozoic in part, and quite possibly wholly Mesozoic. They are composed chiefly of greywackes and argillites in endless alternations, both coarse and fine; marine fossils (*Inoceramus* sp.) have been found only in two places, in what are probably the uppermost beds, while sandstones with obscure plant-remains are reported by McKay in a number of places. The rocks were, therefore, probably deposited in shallow water, and with considerable rapidity, in conditions under which marine benthic life did not flourish. Cotton (1918, pp. 56–57) considers that they might be interpreted as the topset beds of a continental shelf undergoing subsidence, but supplied with a considerable but fluctuating supply of waste. These conditions exist during the first stages of sea-advance following a period of mountain-building, so that we may see in the nature of these sediments the evidence of an earlier epoch of major diastrophism, which has, however, left no other recognizable effects in the area under consideration. Probably the mountains then formed lay outside this area. The rocks stand now for the most part in steep attitudes, often showing in section closely folded synclines and anticlines or contorted bedding, with numerous small faults. Their lines of strike vary rapidly from place to place. The lowest Notocene rocks rest upon them with strongly marked unconformity, the surface of unconformity being a practically plane erosion-surface truncating the pre-Notocene rocks at angles approaching a right angle. It is obvious, therefore, that the pre-Notocene rocks experienced a sharp folding to the degree of mountain-building, and were subject to considerable erosion before the deposition of the lowest preserved Notocene rocks began. The epoch of major diastrophism thus disclosed has been termed by me (1917) the post-Hokonui orogenic movement, from the fact that rocks of Hokonuian age are involved in the present area, and that in other parts of New Zealand the youngest Hokonuian rocks — viz., the Wealden plant-beds of Waikato Heads — are similarly involved. In the Clarence and Awatere districts the lowest Notocene rocks (Clarentian) are of middle Cretaceous age, so that the date of cessation of the post-Hokonui movement in this area must be early Cretaceous at the latest.

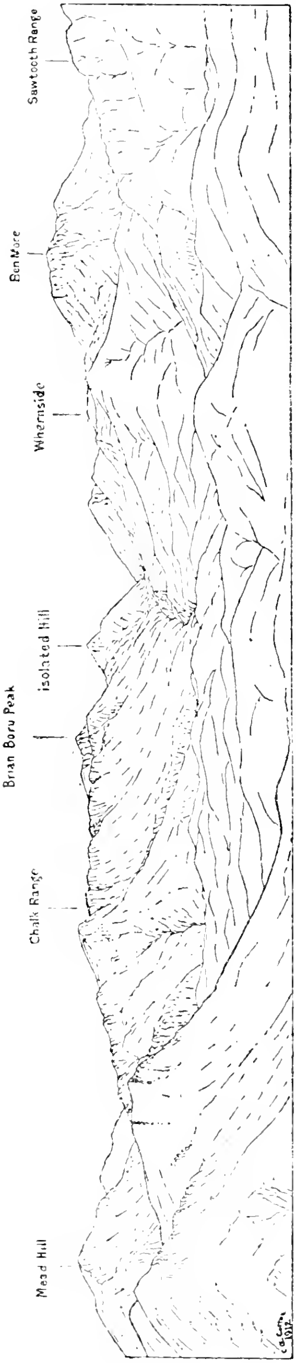


FIG. 2.—Sketch of the north-eastern end of the Middle Clarence Valley (after Cotton).

The evidence for a later major period of diastrophism is afforded by the displacements which the whole Notocene series has experienced subsequent to the cessation of its deposition. A great fault runs along the south-eastern base of the Kaikoura Mountains, along which all the Notocene rocks are deeply involved. For the most part they have experienced a strong tilt, and dip at steep angles to the north-west against the fault, the north-west side of which is occupied by pre-Notocene rocks. From the Swale Valley north-east the Notocene rocks are strongly folded and completely overturned in the upper limb of a recumbent syncline which is truncated by the fault. The production of such structures proves the existence of very considerable earth-pressures after the conclusion of the Notocene deposition, and there are good reasons, as will be shown below, for believing that the Looker-on and Kaikoura Ranges owe their uplift to such orogenic movements of post-Notocene date, which Cotton (1916) has termed the Kaikoura orogenic movements.

Between these two epochs of major diastrophism there ensued a period of relative diastrophic inactivity — the Notocene — during which a great thickness of accordant sediments was laid down. The presence of a thick series of basalts near the base of the Clarentian in the south-west part of the Middle Clarence doubtless points to crustal instability at this period, and there are locally evidences of slight discordance and of disconformity at higher horizons; but such earth-movements as occurred throughout the Notocene, with a single exception outlined below, were epeirogenic and not orogenic in nature, and the general accordance of the whole Notocene is most marked.

The nature and distribution of certain members of the Notocene leads to the belief that these rocks had formerly a much wider extension, and prior to the Kaikoura orogenic movements formed a cover to the pre-Notocene rocks, a cover which has since been removed by denudation where the movements carried it to higher elevations, leaving only a narrow strip in the valley-bottom, where it has been until recently below the effective action of erosive agents—in other words, that the Kaikoura and Looker-on Ranges did not exist as such at the time of the deposition of the rocks in question. If they had so existed, and a long fiord had occupied the site of the Middle Clarence Valley, the deposits of this fiord would have been of the nature of river-delta deposits, mainly conglomerates and sandstones, so long as the mountains existed—*i.e.*, throughout the whole Notocene, since the mountains still exist. Instead we find conglomerates and sandstones only poorly represented in the lower beds, which consist mainly of mudstones, while the middle beds consist of limestones which are in part argillaceous and in part of an indurated chalky and siliceous nature and exceedingly fine-grained. The limestones are succeeded by more or less calcareous mudstones, also fine-grained, and it is not till near the top of the Notocene that coarse detrital matter reappears in the mudstones and in an overlying conglomerate. This in turn is followed by further mudstones. The whole series of sediments, except the conglomerate, has the characters of the deposits of an open continental shelf (*cf.* Cotton, 1918), and not those of delta deposits in a narrow fiord.

The lower and greater part of the limestone may be correlated on lithological and stratigraphical grounds with the Amuri limestone, the upper part of the limestone and the succeeding mudstones with the Weka Pass stone and the "grey marls" respectively of the Waipara district of North Canterbury. These three rocks maintain the same lithological characters and relative positions throughout the whole of North Canterbury and East Marlborough, and it is unthinkable that they can be, in each of the narrow strips in which they occur, only locally deposited rocks, and that they were not laid down under approximately uniform conditions in relatively clear seas over a wide area. They are involved between the mountains not only in the Middle Clarence Valley, but also in the Awatere Valley to the north-west and near the south-eastern base of the Looker-on Range, and it is probable, therefore, that they were formerly continuous over the intervening areas and that the Kaikoura and Looker-on Ranges did not exist as such at the time of their formation, although islands may have existed over their sites. This conclusion has been accepted by Hector, McKay, and Cotton. The great Marlborough conglomerate, however, which occurs near the top of the Notocene deposits of this area, has, on the other hand, all the characters of a narrowly localized deposit, and had not probably at any time a wide lateral extension.

Although the great Marlborough conglomerate is involved equally with all the other Notocene beds in the Kaikoura orogenic movements, the nature of its constituent pebbles and boulders affords proof of considerable differential earth-movements prior to its deposition. It exhibits in the Clarence Valley fairly regular stratification, and appears to be in the main a fluviatile deposit. The majority of the pebbles are derived from the pre-Notocene rocks, and are small and well rounded. In addition, there are larger and often angular boulders, several feet in diameter, of Notocene rocks, including all the beds down to the Clarentian.* It is obvious, therefore, that in the area from which the materials of the conglomerate were derived the Notocene rocks had been elevated above sea-level and exposed to erosion, and, since the underlying Notocene beds are nowhere less than 4,000 ft. thick and reach as much as 12,000 ft., the amount of earth-movement must have been considerable. There is, in the Clarence Valley at least, the further peculiar relation that although the conglomerate contains boulders of rocks exactly similar to the underlying Notocene beds, nevertheless it is perfectly conformable to the underlying "grey marls," and in the Dee and Mead Gorges at least there are transitional beds. This relation is explained by Cotton (1914) by the assumption that faulting took place, not disturbing the horizontality of the beds now underlying the conglomerate, but differentially elevating a neighbouring area to an extent of perhaps 12,000 ft. Since no folding or warping of the Notocene took place, he concludes that the movements must have been block-faulting, with the restriction that the uplifted block alone moved. These movements may perhaps be looked upon as the early stages of the Kaikoura orogenic movements, and must have affected a large part of the Kaikoura Range. Since, however, the conglomerate is involved equally with the other Notocene rocks in the main Kaikoura deformation, it may best be classed as Notocene. This classification is confirmed by the presence above the conglomerate of marine Notocene rocks.

While it is indubitable that the middle part of the Notocene as locally developed—viz., the Amuri limestone, Weka Pass stone, and "grey marls"—formed a cover to the oldermass which has since been removed by erosion from the higher ground, it is not so certain that the Clarentian beds were everywhere also part of the cover. So far as is at present known,

* Near Kekerangu, immediately outside the area, the great Marlborough conglomerate contains large masses of Amuri limestone, some 72 ft. in greatest diameter.

Clarentian beds occur in the South Island only in the Clarence and Awatere Valleys, and in the hill near Charwell Flats, south of the Looker-on Range, where Dr. Cotton and I found "*Modiola*" *kaikourensis* in conglomerates forming the base of the Notocene at that point. Possibly, however, the basal beds of the Notocene in the Puhipuhi Mountains and the Cape Campbell Range are also of the same age. The thickness of the known Clarentian rocks varies rapidly from place to place, suggesting the proximity of land during their deposition. The basal beds from the Herring River to the Bluff River are terrestrial, and the marine rocks, of which the series mainly consists, are throughout terrigenous, consisting of conglomerates, sandstones, and mudstones, with glauconitic rocks but feebly developed. The thickness of the series, 3,000–9,000 ft., exceeds that of the whole Notocene series in localities such as Oamaru, where peneplanation of the oldermass is known to have been complete before sea-advance, and, combined with the lithological characters, affords clear evidence that considerable erosion of not very distant land was going on throughout the whole of the Clarentian. Although the nature of the surface of deposition as seen in unconformable junctions suggests that the relief of the oldermass was not great, the physiographical evidence for peneplanation is not strong, and it is quite possible that during the Clarentian land may have existed on the site of the Kaikoura and Looker-on Ranges, breaking the continuity of the cover laid down on the oldermass. In estimating the minimum extent of the Kaikoura deformations by adding the thickness of the Notocene to the present heights of the mountains, it is therefore wise to omit the thickness of the Clarentian. For the Kaikoura Range, however, it is necessary to take into account the Clarentian volcanics, since the range is seamed with dykes between the present outcrops of these rocks in the Clarence and Awatere Valleys, and at least 1,000 ft. should be allowed on this account.

The total results of the Kaikoura deformations consisted in the formation of two immense tilted blocks, the Kaikoura and Looker-on Ranges, bounded by great fault-scarps on their south-east sides, with an intermediate fault-angle, the Middle Clarence Valley. Hector (1886, pp. xiv, xv) described the nature of the movements as an extremely local but bold anticlinal fold, the crown of the arch of which collapsed with the formation of a deep longitudinal groove, and considered that the thrusting force which produced the reverse fault came from the west. Cotton (1913, p. 227) considered the results of the movements as the production of two anticlinoria, the axes of which correspond with the ranges, with an intermediate synclinorium, one limb, however, being represented by a reversed fault of enormous throw. It appears probable, both from the lack of summit accordance in the north-eastern parts of both ranges and from the strong folding which the Notocene beds have experienced near the Bluff and the Ure Rivers, that the deformation was not simple tilting but was accompanied by folding, and that the initial surface was, at least in places, warped into anticlinoria with an intermediate synclinorium before faulting took place. Since a cover of at least the Clarentian volcanics and the middle Notocene rocks—say, 4,000 ft.—must have once occupied the sites of the Kaikoura Mountains, the total vertical movement must have been at least 13,000 ft.; but if a preliminary folding took place the total displacement along the fault-lines may have been very much less. Cotton (1913) in his diagram represents the great Clarence fault with a throw of 8,000 ft. or 10,000 ft., but states that it is possible that it is considerably more, and that there is no way of arriving at an accurate estimate of its amount (see fig. 3).

The longitudinal profile of the Kaikoura Range, if not actually conclusive of warping, is not inconsistent with such a method of deformation. From Mount St. Bernard north-east to Mount Symons the range has an approximately even crest at a height of a little over 7,000 ft. It then rises abruptly to the Tapuaenuku massif, with several peaks over 8,000 ft., and culminating in Mount Alarm (9,400 ft.) and Tapuaenuku (9,465 ft.). Farther to the north-east a saddle of 5,516 ft. divides this massif from the Camden-Ben Fluick group of peaks, which lie between 6,166 ft. and 6,560 ft. in height. From thence north-east the peaks lessen rapidly in height, the principal being Black Mount (4,835 ft.), Malvern (4,680 ft.), and Blue Mountain (4,080 ft.), and they are separated by relatively deep saddles.

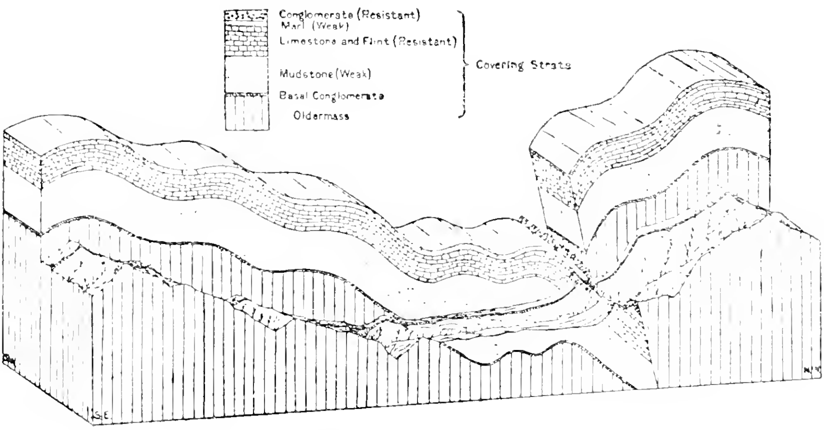


FIG. 3.—Diagram illustrating the type of structure and sculpture in the Middle Clarence Valley (after Cotton).

The range is narrowest between Mount St. Bernard and Mount Symons, and the Tapuaenuku massif is buttressed on the Awatere Valley side by a great spur running from Mount Alarm through Mitre Peak and Mount Gladstone, these three peaks being separated by deep saddles on the spur. Mount Gladstone (7,780 ft.) is three miles north-west of Mount Alarm and is only 1,600 ft. lower, whereas farther south-west the descent from the summit of the range for the same distance is at least 4,000 ft.

The summits of the Tapuaenuku massif are formed of intrusive rocks, which may have enabled them to resist erosion better than other parts of the range; but the summit of Blue Mountain is formed of similar intrusives, and they are probably present throughout the intervening area. The streams draining the lower part of the range to the north-east do not appear in distant views to be more mature than those draining Tapuaenuku, so that it is probable that the original crest sloped fairly steeply from Tapuaenuku to the Blue Mountain. The saddles may be neglected, as they are obviously the result of erosion.

As soon as the earliest Kaikoura deformations raised part of the area above sea-level a drainage-pattern must have been established, which may have been considerably different from the present pattern. There is little reason, however, to suppose that it was markedly different, for the later movements would tend to follow approximately the lines of weakness established during the earlier movements. The drainage-pattern established by the differential uplifts which gave rise to the great Marlborough conglomerate must have been in large part destroyed by the subsequent drowning during the deposition of the marine (Awatere ?) beds which follow the conglomerate. The greater part of the present drainage-pattern appears to be consequent on the later, more intense, deformations. This part includes the Middle Clarence Valley, occupying the tectonic depression between the two mountain blocks, and the numerous large streams entering it on both sides nearly at right angles. The course of the Lower Clarence River in the gorge, however, demands a different explanation.

The Clarence River on leaving the middle valley bends at a right angle, and passes between the north-eastern end of the Looker-on Range and the Sawtooth Range in a rock-bound gorge nearly 4,000 ft. in depth, cut through the pre-Notocene rocks. This bend, as Cotton (1913) has shown, is not an elbow of capture, since there is no gap by which the Clarence could have had its outlet before the hypothetical capture, nor have other eastward-flowing streams made any appreciable progress in breaching the continuous wall of the Looker-on Range. This part of the river-course must therefore be a survival of an older system of drainage, the river cutting down a gorge as the mountains rose.

The Notocene rocks are found at no great distance apart on each side of the range at this point, and it is practically certain that the oldermass was here completely submerged during the later Notocene, so that any pre-existing drainage must have been completely destroyed. The course of the river through the mountains cannot, therefore, be antecedent in the sense of a relict of a pattern existing on an emergent portion of the oldermass during the main Notocene depression. It must be explained, therefore, as an anteconsequent course (*cf.* Cotton, 1917, p. 253)—*i.e.*, a course established during the early stages of the deformation.

The great development of the great Marlborough conglomerate in the area between Kekerangu and the Lower Clarence demands the assumption of local differential movements in this area as well as over the site of the Kaikoura Range, but the mountains then formed may have lain either on the site of the Sawtooth and Looker-on Ranges or seaward of the present coast-line near Kekerangu. The latter is the more probable, since the Sawtooth Range is flanked on the south-eastern side by Clarentian rocks, followed by the Amuri limestone in the Lady Range, which would not be the case if the material of the conglomerate were derived from an uplifted block on this side. The elevation of the Sawtooth Range, then, appears to be due to the anticlinal folding of the later deformations. Prior to these more intense movements one must assume an even or slightly differential uplift after the deposition of the marine beds following the conglomerate, with the formation of a coastal plain sloping to the south-east. On this plain consequent rivers draining south-east became established, and one of these persisted through the later deformations as the lower course of the Clarence River. Probably this anteconsequent drainage removed the greater part of the softer marine beds overlying the conglomerate, so that when the later faulting took place the former were preserved only in the Bluff River and from Deadman's Creek southwards.

The Kaikoura and Looker-on Ranges probably did not escape Notopleistocene glaciation, but its effects have probably been destroyed by the heavy subaerial erosion which followed, since there is no evidence to show that the Middle Clarence Valley was ever occupied by a glacier, while the mountains themselves, so far as explored, now exhibit only the work of normal agents of erosion. It must be remembered, however, that there has been exceedingly little exploration of the higher ground, and that small cirques may exist. In the valley of the Branch River, at a height of about 4,000 ft., I observed from above a peculiar accumulation of debris which seems neither the result of talus slopes nor of stream-action. The upper part of the valley consists of a large depression, circular at the top in plan, filled with a steeply sloping mass of talus in large blocks often many feet in diameter, below which water may be heard trickling. This depression may possibly be a cirque since filled with talus. Farther down the valley, at the point of junction with a large tributary on the right side, there is a large accumulation of shingle running out horizontally from the intervening spur, to which it forms a continuation for some hundred or more yards. The broad top is divided into two parts by a median longitudinal impression. The only explanation of this peculiar accumulation that has suggested itself to me is that it is the commencement of a median moraine formed by the coalescence of two lateral moraines with the intermediate depression not filled. Obviously, however, it is a fairly recent feature, formed after considerable dissection of the range had taken place.

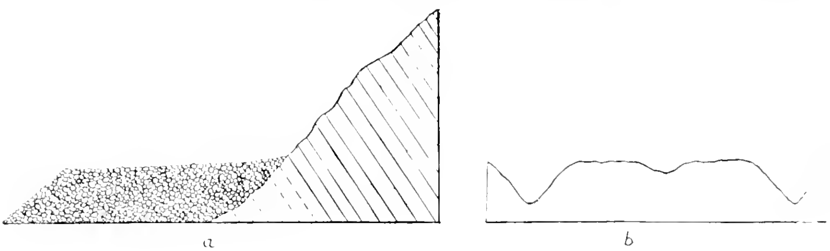


Fig. 4.—Moraine-like accumulation in the Upper Branch—(*a*) in side elevation, (*b*) in front elevation.

The Kaikoura Mountains are asymmetrical owing to the existence of the fault-scarp on the south-eastern side, and have always been so. It is rather on the more gently sloping north-western side, therefore, that snowfields would be likely to accumulate, and the effects of glaciation may be expected to be more intense on that side, which has not been explored. The same holds true for the Looker-on Range. It must be remembered, however, that the north-west side is the more sunny side, and is exposed to the dry north-westerly winds.

Apart from the slight glaciation, the ranges have been greatly dissected by stream erosion, coupled with severe frost-action on the higher ground. Except on actual cliffs, the summits are mantled over with angular blocks of immense size, and Mount St. Bernard, the top of which is dome-shaped, presents the appearance of a gigantic mound of shingle. The upper parts of nearly all the streams consist of huge shingle-slips, and the streams are thus heavily loaded with waste, which nevertheless soon becomes rounded in its transport down-stream. In spite of the immense erosion which is made evident, neither the enclosing ranges nor the Middle Clarence Valley have entirely lost their original asymmetrical character.

The Looker-on Range descends to the valley in spurs of comparatively even and gentle slope, whereas the Kaikoura Range presents much steeper slopes, especially in the lower part, where steep spurs end abruptly near the fault-line. This asymmetry is more marked opposite the Tapuaenuku massif, where a single fault dominates the structure, than in the south-western part of the valley, where there are two or three parallel faults. In the north-eastern part the strip of Notocene rocks lies wholly to the north-west of the river, and is much nearer to the summit of the Kaikoura than to that of the Looker-on Range. Originally the river may have run in the actual fault-angle, and if so it has doubtless been forced to the other side of the valley by the heavy accumulations of talus that must have accompanied the production of the fault-scarp. It is quite possible, however, that the actual angle was not the bottom of the original tectonic depression, and that the present course of the river is approximately the axis of the original synclinorium.

The fault-scarp of the Kaikoura Range along the line of the great Clarence fault is not well preserved north-east of the Dee Stream, where the crowded insequent tributaries of the Limburne, the Mead, and the Swale have dissected the original front scarp. From the Dee south-west for some miles there are steep spurs, passing into veritable facets of some thousands of feet in height, above which appears a prominent bench. It seems probable that this part of the range has undergone a later renewed faulting, for below it the relief forms cut in the Notocene rocks have been, according to McKay's descriptions, completely covered with heavy deposits of gravel. Cotton, who with the writer viewed this part of the valley from a distance, describes it as a stretch of piedmont plain, now dissected, formed by the coalescence of fans of coarse waste.

McKay described and mapped the great Clarence fault as bending obtusely at the Bluff River, and running obliquely to its former course as far as Quail Flat, where it resumed its original direction. It is true that a little to the south-east of the Bluff River the strip of Notocene rocks pinches out, but it appears highly probable that the fault continues on in its original direction for a considerable distance, bounded on each side by pre-Notocene rocks. On the valley side these have not been worn to so low a relief as the Notocene rocks farther north, owing partly to their strength and probably partly to the fact that they form a smaller tilted block facing a parallel fault along the line of the river from Red Hill to past the Herring River, close to which they rise to heights of over 3,500 ft. The line of the great Clarence fault to the south-east of the Bluff River appears, in a distant view, to be marked by a series of well-preserved facets for a number of miles. Doubtless, as between the Dee and the Muzzle, this part of the fault-scarp owes its origin to a later renewed faulting. It may be suggested that the depression in which Lake McRae lies is on the continuation of the great Clarence fault, and that it continues on into the valley of the Dillon River, which is thus, like the Clarence, a tectonic depression.

The greater part of the drainage of the mountain-ranges is, as already mentioned, accomplished by consequent streams which join the Clarence nearly at right angles, together with their insequent tributaries. These streams run approximately south-east and north-west. In the mountains to the west of the Upper Clarence there is a very marked development of streams with north-north-east and south-south-west courses, suggesting a well-developed subsequent drainage. The Elliott River joins the Clarence River with a south-south-west course, immediately opposite the Gore River, which has the same direction, flowing north-north-east. Both these rivers rise in passes through the enclosing ranges, and the line of the two is continued to the south-west by the Conway River, and to the north-east by the Tone River and Castle Creek, tributaries of the Awatere River. This alignment is very marked and can hardly be accidental; but whether it is a case of ordinary subsequent drainage conditioned by the existence of a band of weak rocks, or of an old fault-zone, or is consequent on recent faulting oblique to the general line of the Kaikoura faults cannot be determined on the evidence at present available. It is perhaps significant that this line approximately connects the greatest developments of Clarentian volcanics in the Clarence and Awatere Valleys, suggesting the existence of a pre-Clarentian line of weakness in the same direction.

In the period following the Kaikoura orogenic movements the Clarence River became graded, and the lower slopes of the middle valley, consisting largely of Notocene rocks, were reduced to mature erosion forms. This mature topography has been partially obliterated, south-west of the Dee, by smothering with gravel fans coalescing into a piedmont plain at the base of the Kaikoura Range, and probably due, as explained above, to a renewed uplift along the line of the great Clarence fault. Both the mature erosion forms and these gravel plains have been partially dissected by a revival of erosion caused by a late regional uplift, which elevated the delta of the Clarence River 600 ft. (Cotton, 1914B), and gave rise, after rejuvenation, to well-marked terraces of much less height between Quail Flat and the Bluff River.

In the strip of Notocene rocks involved along the line of the great Clarence fault the hard strata of the Amuri limestone and Weka Pass stone, lying between the softer Clarence mudstones and the "grey marls," stand up as a monoclinal ridge cut through by the numerous gorges of the consequent tributaries of the Clarence River. The south-eastern slopes present precipitous escarpments, passing below into great screes of dazzling white limestone, which cover the outcrops of the highest Clarentian beds and often those of the flint-beds. The north western dip-slopes where not too steep are covered with a rich black soil, and afford the best pastures of the valley. Since the ridge contains no air-gaps, and since the gorges of the streams that cross it often fork within the limestone, Cotton concludes that the drainage must have assumed its present form before denudation had exposed the limestone monocline as a prominent ridge, and that the streams now occupying the gorges may be described as superposed consequents which flowed initially upon great screes from the fault-scarp.

Along the greater part of the great Clarence fault the great Marlborough conglomerate, which is also a resistant band, rests against the pre-Notocene rocks, and does not form a marked feature in the topography; but to the north-east of the Swale Gorge, where it is surrounded on each side by mudstones, it forms a series of hogbacks, the highest of which is known as the Razorback Ridge. This is, nevertheless, much inferior in height to the limestone monoclinal of the Chalk Range near by.

The softer members of the Notocene series, and particularly the mudstones of the Clarentian and of the "grey marls," have been reduced to lower relief with the development of subsequent streams along their lines of strike. In the Clarentian the best-developed subsequents are those of the Nidd, Cover, and Wharf, tributaries of the Swale Stream, which separate low strike ridges, mainly of sandstone. Along the outcrop of the "grey marls" there are a number of short subsequent streams forming a single linear depression, which does not appear ever to have been occupied by a single stream. The grade formerly established in the insequent and subsequent tributaries of the consequents flowing into the

Clarence River has been destroyed by the rejuvenation consequent on the recent epeirogenic uplifts, which has worked back almost to their sources, while a regrading has seldom extended more than a short distance from their mouths.

THE PRE-NOTOCENE ROCKS.

Owing to their monotonous character, and to the general absence of distinctive lithological or fossiliferous strata which might give some indication of their structure and disposition, the study of the pre-Notocene rocks is difficult. I have not attempted it, and must limit myself to such casual observations as I have made. McKay has made a special study of these rocks in certain areas, especially in the mountains between the Wairau and Awatere Valleys, in the Muzzle, and between the Elliott River and the Upper Clarence, and has attempted to establish a sequence in the first and last localities: the lowest beds he describes as grey sandstones and slaty shales with broken plant-remains, and these are followed by a series of red and green rocks which are calcareous near Taylor's Pass, between the Wairau and the Awatere; similar rocks near the Elliott River are again overlain by sandstone.

The directions of strike and dip appear to be very variable, doubtless owing to the folds of a smaller order, and to numerous faults, which tend to obscure the major outlines of structure. On the whole, McKay describes the rocks as striking in a north-easterly direction. with dips to the south-east or north-west. Many of his observations, however, appear to have been made at a distance, and cannot in these cases be accepted as altogether reliable, since joint-control plays a large part in determining the details of outcrop, and greywacke bluffs often trend transversely to the strike. My own observations, resumed in Table III, would tend to show that a strike west of north is prevalent in at least some parts of the area. Cotton (1913, p. 241), arguing from the variability of the strikes and dips, considers it probable that the older axes of folding make an angle with those of the later Kaikoura folding—*i.e.*, that the prevalent strikes are oblique to the trend of the mountains.

TABLE III.—OBSERVED STRIKE AND DIP OF PRE-NOTOCENE ROCKS.

Locality.	Strike.	Dip.
Spur from upper end of Ure Gorge to Blue Mountain ..	N.E.	Nearly vertical.
Tributary of Wharf Stream from Sawtooth Range, at unconformity with the Clarentian	N. 20° W.	Steep, N.E.
The same stream, half-mile up	N. 50° W.	..
Clarence River, upper end of Quail Flat	N. 20° E.	40°, S.E.
Clarence River, lower end of Quail Flat	N. 30° W.	Nearly vertical.
Herring River, at unconformity with north-western Clarentian outcrop	N. 15° W.	Very steep, S.W.
Herring River, at unconformity with south-eastern Clarentian outcrop	N. 15° W.	50°, S.W.
Pack-track from Quail Flat to Reserve Station, half-mile on Reserve side of saddle	N. 30° W.	Steep, S.W.
The same, a few hundred yards nearer Reserve ..	N. 70° W.	Nearly vertical.
The same, half-mile nearer Reserve	N. 35° W.	Nearly vertical.
The same, 200 yards nearer Reserve	N. 50° W.	56°, S.W.
The same, small saddle two-thirds way down	N. 30° W.	Nearly vertical.

The majority of the pre-Notocene rocks show a striking resemblance to the greywacke-argillite series so prominently developed in the Wellington district and in the eastern mountains of Canterbury, but it is perhaps significant that neither McKay nor I have observed the annelid *Torlessia mackayi* Bather, so common in these other areas. The only palaeontological evidence of age found by McKay, besides broken plant-remains, was a fragment of a fern "apparently *Taeniopteris*," from the lowest beds on the west side of the Elliott River. This would tend to prove, if his identification of the specimen and his reading of the sequence are correct, that all the pre-Notocene rocks are of Mesozoic age. They are all, of course, pre-Clarentian—*i.e.*, earlier than the middle Cretaceous. The presence of bands of red and green argillites in the Kaikoura Mountains, however, renders this improbable. During the ascent of Tapuaenuku I observed from above one such band in the hills fronting the fault-line between the Mead and Dee Rivers. The Lands and Survey map of the Tapuaenuku Survey District presumably records a second band of these rocks by the name "Red Hills" given to a spur on the north-west side of the Hodder River. Now, in the similar rocks crossing Taylor's Pass, McKay (1890, p. 116) records the presence of fossiliferous limestones yielding fragments of *Inoceramus* shells. It must be remembered that the Permo-Carboniferous Wairoa limestone also contains fragments of a fibrous shell commonly called *Inoceramus* by McKay, so that it is perfectly possible that the limestone of Taylor's Pass is also Permo-Carboniferous, and that similar rocks occur in the Kaikoura Range.

I have observed in two widely separated localities fragments of fossils which indicate a Mesozoic age for the rocks containing them, but in neither case are the rocks quite typical of the pre-Notocene greywacke-argillite series, and they belong, I believe, to a younger series, though both are most clearly pre-Clarentian. In the lower Dee River, after the basal Clarentian conglomerates are passed, and on the banks of the Clarence River between the Dee and the Limburne, the rocks consist of hard sandstones, not unlike typical greywackes, and much-jointed black mudstones with white bands and large rounded concretions, in which coarse fragments of a fibrous shell like *Inoceramus* are found. Again, in the Herring River, the rocks lying unconformably below the eastern Clarentian outcrop consist of thin and regularly bedded sandstones alternating with shales, none of the rocks being much more indurated than many exposures of the Clarentian. They strike N. 15° W., and dip at 50° to the south-west, whereas the overlying Clarentian rocks strike N. 40° E., and dip at 40° to the north-west, so that the unconformity is exceedingly well marked. From the underlying series I obtained a nearly complete specimen of *Inoceramus*, which I submitted to Mr. H. Woods, of Cambridge, but unfortunately he pronounced it indeterminable as to species. The sandstones also contain plant-impressions. I believe a sufficient collection could be made at this point to determine the age of this series. I discovered its fossiliferous nature only on my way out from the valley and after the pack-horses carrying my luggage had preceded me up the pass, so that it was impossible at that time to spend any length of time collecting.

Sandstones and shales, in general similar to the typical greywackes and argillites, but somewhat less indurated, and containing calcareous concretions, are of wide occurrence in Marlborough. They underlie the Upper Cretaceous beds at Amuri Bluff unconformably, and have been termed by Buchanan (1867) the "marlstones," a name that is certainly inapplicable. Similar rocks were termed by von Haast the "cannon-ball sandstones."

I have observed these concretionary rocks in the Awatere Valley between Middlehurst Station Creek and the George River, and around Awapiri. They are present in the lower Woodside Stream, and thence along the road to the Ure River, and for some distance up this valley. In the Clarence Valley they occur not only at the mouth of the Dee, but at Quail Flat and in the Lower Herring River, and the latter occurrence tends to link them up with the *Inoceramus* sandstones farther up the same river. The rocks immediately under the north-western Clarentian outcrop are concretionary sandstones interbedded with thin argillites, and strike N. 15° W., with a dip nearly vertical but steeply to the west.

There is a series of rocks in the Ouse River which perhaps belongs here; it lies below the Clarentian rocks, but the unconformity is not well marked and was overlooked on my first visit, so that I supposed they were all Clarentian. The rock immediately below the Clarentian basal conglomerate is a thick, massive grey sandstone containing shaly partings. Below this for over two miles the rocks consist of hard black shales and hard sandstones with occasional concretions. There are many small contortions and faults, and the dips are very irregular. Two conglomerates of considerable thickness which appear in the series contain greywackes, quartzites, and red jasperoid rocks, besides soft sandstones, crystalline limestone, and porphyries. At the time of examination I considered them, with the overlying rocks, to be Clarentian, and from their great similarity to Clarentian conglomerates elsewhere it is possible that they are of this age and are involved in the pre-Notocene rocks by faulting; but of this I saw no trace. Unfortunately, owing to the amount of water in the stream, I did not examine the relation of the lower conglomerate to the beds farther down the stream.

Intrusive Rocks in the Pre-Notocene.

Intrusive rocks of various kinds have a great development in the pre-Notocene rocks of the Kaikoura Range, and particularly in the Tapuaenuku massif (Plate XXIV, figs. 1 and 2), the upper part of which is composed almost solely of them. Owing to their hard nature they form the majority of the boulders in the Dee and other tributaries of the Clarence, and also in the Hodder and lower Awatere Rivers. In 1913 I described their petrological characters from specimens collected from the Dee gravels, and, although there are doubtless numerous other types besides those collected there, the general character of the series is clearly enough apparent. The more siliceous rocks consist of quartz syenites and quartz diorites. The less siliceous are mostly fine- and coarse-grained doleritic or gabbroid rocks, frequently containing olivine, brown hornblende, and biotite, and rarely quartz. In addition there are hornblende lamprophyres and doleritic rocks with lamprophyric affinities. The list of rock-varieties given by Hector (1886, p. xxxi) does not appear to be the result of microscopical examination, and may be safely neglected; nor can McKay's identifications of the rock-varieties be regarded as more than a general indication as to their nature.

McKay (1890B, p. 130) considered that the rocks were injected into the pre-Notocene at two widely-separated periods, the older rocks, consisting of diorites, syenites, and felsite rocks resembling elvanite, being confined to the pre-Notocene, while the darker-coloured and more basic rocks were intruded subsequently to the deposition of the lower part of the Clarentian. The latter rocks in the Awatere Valley, between the Otterson and Tone

Rivers, he describes as crowded with dark basic dykes, which can be traced into the pre-Notocene of the Kaikoura Range. The evidence of the Clarentian basal conglomerates is to this extent favourable to McKay's division of the rocks: that the only igneous rocks included in them in either the Clarence or the Awatere Valleys are granites, microgranites, and quartz porphyries. Typical granites or quartz porphyries, however, have not yet been found in the Kaikoura or Looker-on Ranges, and I incline to the opinion that the syenites belong to the same period of vulcanicity as the more basic intrusions, and that this period is coincident with the outpourings of Clarentian lavas in the upper parts of the Middle Clarence and Awatere Valleys. There are four reasons for this belief. In the first place, such a differentiation series is common in intrusive rocks, as witness the association of granophyres and quartz dolerites with the Tertiary volcanic rocks of the British Isles. In the second place, intrusions in the greywacke-argillite series of both Islands of New Zealand are rare, whereas in the Kaikoura Range they are abundant, and lie between two prominent developments of Clarentian lavas. In the third place, boulders of the syenites appear to be totally absent from the great Marlborough conglomerate, suggesting that they had not been uncovered by erosion at the time of its formation. Finally, and most conclusively, I observed that the syenites on the spurs leading to Mount Tapuaenuku contained frequent inclusions and schliere of camptonitic facies.

In the ascent of Mount Tapuaenuku I observed occasional dense amygdaloidal dykes in the pre-Notocene rocks of the upper Dee. At about 6,000 ft., on the spur between the Dee and the Branch, the pre-Notocene rocks have a strike a few degrees west of north. The upper part of this spur, right to the summit, is composed of a reddish syenite, intersected by innumerable dark dykes 1 ft. to 2 ft. thick, which have mostly an east–west trend (Plate XXIV, fig. 2). The neighbouring spurs on each side appear to have the same character. On the exterior these dykes are often dense, but in the centre coarsely crystalline. This proves that the syenite had cooled sufficiently to be fissured before the intrusion of the dark dykes, and perhaps even sufficiently to chill the margins of the dykes, although tachylitic selvages were not observed. The dark dykes, however, are intersected and faulted by one another, proving that they were injected at sufficiently distant intervals to permit of consolidation before the next intrusion.

The greatest development of the intrusives is undoubtedly in the Tapuaenuku massif, but they are probably present in smaller number throughout the range. In the upper Muzzle, McKay states that "the sedimentary rocks are more rapidly degraded than the trap-dykes intersecting them, so that the latter, traceable for long distances, form a remarkable feature in a wild and rugged landscape. . . . . The brecciated slaty beds and mudstones are broken up and so rapidly removed from the slopes of the range on the east side of the creek that the dykes project various heights above the general surface. They trend for the most part north, between barren slopes of black shingle, while a lesser number of dykes running south-east, and some of them east, enclose areas which, while the barriers stand, are completely walled around. The greater number of the dykes trend north, and pass into or under the cluster of peaks south of Tapuaenuku." (McKay, 1886, pp. 50, 51.)

Judging from the small number of igneous boulders in the Bluff River, McKay considers it clear that comparatively few dykes are present in the mountains drained by it, but he observed "several massive dykes of a

[B. C. Aston, photo.

Fig. 1.—The summit of Mount Tapuaenuku, showing the rubble that mantles the higher peaks of the Kaikoura Range.

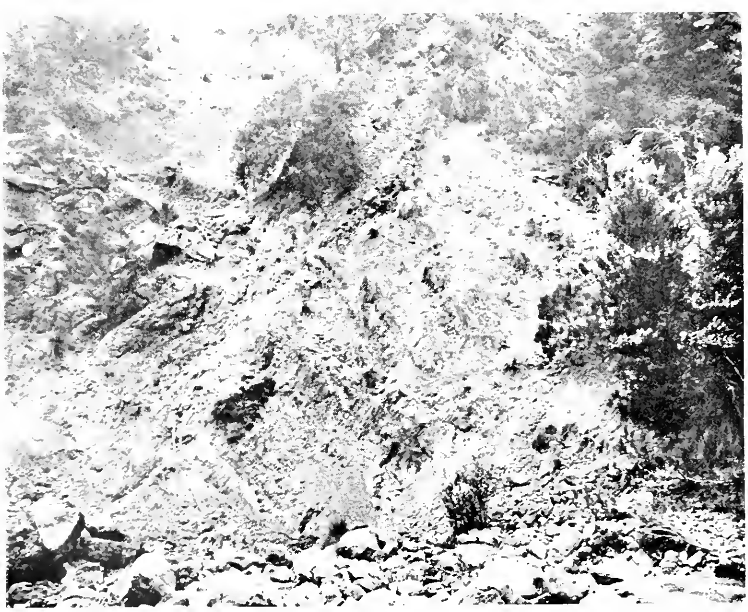
[B. C. Aston, photo.

Fig. 2.—A cliff of "syenite" on a spur leading from the Dee River to Mount Tapuaenuku, showing numerous intersecting dark dykes.

Face p. 308.]

[C. A. Cotton, photo.

Fig. 1.—View from Coverham, looking westward. The foreground consists of Clarentian rocks, in the middle distance the monoclinal ridge of Amuri limestone is cut by the Mead Gorge, and in the distance Mount Tapuaenuku is seen.



[C. A. Cotton, photo.

Fig. 2.—Junction between Clarentian conglomerate (above, left) and pre-Notocene greywackes (below, right) in a tributary of the Wharf Stream.

serpentinous character" in the lower slopes of the range, near the mouth of the gorge. Between the Dee and the Mead River McKay notes the presence of numerous dykes of grey porphyritic syenite and dark porphyritic hornblende rock intersecting the older rocks of the higher part of the range. From the Mead to Blue Mountain the higher ground is unexplored geologically, but the presence of dykes may be inferred from the boulders present in the gravels of the Swale. The summit of the Blue Mountain and for a considerable distance the spurs descending from it are composed of a dark, coarse-grained dolerite, which weathers to a gritty waste in places covered with a reddish, dry soil. There are lighter-coloured patches within the intrusion, the forms of which were not clear. On the spur running from the upper end of the Ure Gorge to the summit the junction with the pre-Notocene rocks was observed. The latter strike north-east at this point, and dip almost vertically, but a little lower down they are sharply contorted. There appeared to be a contact mineral in the argillites near the junction, but it was too much weathered for microscopical determination. At the observed junction the intrusive rock was light-coloured and finer-grained than elsewhere, and other fine-grained specimens were observed in the screes higher up. I have noted below the occurrence, at a lower level in the Blue Mountain Stream, of fine-grained dark dykes invading the Clarentian. Before the formation of the great Clarence fault these rocks presumably stood at a high level, and may be apophyses of the Blue Mountain intrusive.

So little geological exploration of the pre-Notocene rocks of the Looker-on Range has been made that little can be stated as to the abundance of intrusive rocks. I noted the presence of a moderately coarse doleritic dyke a little on the Reserve side of the saddle on the pack-track between the Reserve and Quail Flat. McKay records the presence of some dykes of grey intrusive rock, judged to be diorite, on the east side of the range, north-east of the Kahutara gorges, and dykes of a darker colour and basaltic character on the western side of the same part of the range. A fair percentage of coarse- and medium-grained doleritic rocks is present in the gravels of the Hapuku River, proving the presence of intrusives in the north-east part of the Looker-on Range. McKay states that he is informed that in the gravels of the George River, entering the Lower Clarence on the south side, there is so great an abundance of dark-coloured crystalline boulders as to make it comparable in this respect with the Dee or the Branch. I observed a boulder of lustre-mottled hornblendic rock in Heaver's Creek, but as this occurred below the outcrop of the great Marlborough conglomerate it is unsafe to make any deductions from it as to the presence of dykes in the headwaters of that stream. The tributaries of the Wharf, draining the other side of the Sawtooth Range, contain no boulders of igneous rocks above the outcrops of the Clarentian conglomerates.

McKay has described a great number of intrusive rocks in the country north-west of the Awatere River, and from his descriptions they seem to resemble those of the Kaikoura Range.

THE NOTOCENE ROCKS.

So far as Notocene geology is concerned, the east coast of the South Island may be divided into two main diastrophic districts, characterized by the age and nature of the middle limestone member, the dividing-line being the Rakaia River. The southern district has as the middle member of its sequence a relatively shallow-water and mainly bryozoan limestone.

the Ototara limestone, which is Ototaran, or Middle Oamaruian, in age. The northern district has as the middle member of its sequence two limestones, often separated by a phosphatic band, the lower (Amuri) limestone being relatively deep-water and chalky, and certainly older than Ototaran. The closing member of the marine sequence in the southern district is Awamoan (Upper Oamaruian), whereas in the greater part of the northern district the closing member is Waitotaran (early Wanganuian). Both districts may be again subdivided according to the age of the earliest marine transgression. The sequence in the southern district commences north of the Kakanui River with Ngaparan (Lower Oamaruian) beds, but south of that river there are two or three localities where it commences with Kaitangatan beds. The sequence in the northern district commences with Cretaceous beds, which south of the Hapuku River are Piripauan (Senonian), but north of that river are Clarentian (Albian).

The reasons for uniting the Notocene rocks of north-eastern Marlborough with those of south-eastern Marlborough and northern Canterbury in a common diastrophic district are especially the presence in each area of the Amuri limestone, Weka Pass stone, and "grey marls"; but there are two other characteristics besides the age of the basal beds, which distinguish the two subdistricts. In the northern the Amuri limestone attains an enormous development, being measurable in thousands of feet, instead of in hundreds as in the southern, and flint-beds are well developed. Moreover, although where the full sequence is preserved the Waitotaran beds are present in both subdistricts, in the northern one they are separated from the lower marine Notocene beds by a fluviatile deposit, the great Marlborough conglomerate, which appears to have no counterpart in the Waipara area, although it occurs as far south as Greenhills and Amuri Bluff.

There are several separated outcrops of Notocene rocks in the Middle Clarence Valley, due to involvement along parallel fault-lines, and in one case to involvement in a synclinal depression. The fault-lines run in a north-east and south-west direction, and are inclined very steeply. McKay describes them as reversed—*i.e.*, with dips to the north-west—and I have not made any observations which tend to disprove this; but in the majority of sections the fault-line is obscured by slips and talus slopes. The Notocene rocks in all cases lie to the south-east of the fault, and dip at steep angles against it—*i.e.*, to the north-west—the lower beds resting unconformably on pre-Notocene rocks to the south-east. The outcrops thus take the form of strips, narrow in proportion to their length, and trending north-east and south-west.

The principal strip is that along the great Clarence fault, which extends from the Gentle Annie Stream to the Ure Valley. In the middle part of this strip, from the Bluff River to the Mead River, the Notocene rocks form a simple monoclinal series with minor folding in the lower rocks. At each end the rocks are folded into synclinals, that at the north-eastern end being overturned and truncated by the branching of the fault, so that the succession for some distance to the south-east of the fault-line is reversed, and the beds from the limestone upwards are repeated several times.

Along the middle part of the strip, from the Bluff River to the Mead River, the whole Notocene series up to the great Marlborough conglomerate is preserved in such a way that the latter rock everywhere rests against the fault at the surface. As there is no great difference in level at the surface, this shows that the base of the Notocene has not been greatly warped in a direction longitudinal to the fault-line. This is not the case in the other parallel faults.

At the north-eastern end the structure becomes complex. There is a large area of down-faulted Notocene rocks between the Isolated Hill Creek, the upper Nidd, and the eastern side of Whernside. The limestone of Whernside is continuous with that of Benmore by a narrow strip, and presents a steep scarp to the Benmore Stream, where it probably rests conformably on Clarentian rocks. Along its north-western boundary it is probably faulted against the middle or upper Clarentian. The main monoclinal ridge of Amuri limestone passes from the Chalk Range and Brian Boru in a great curve to Benmore, but the outcrop of the Clarentian rocks is divided into two parts by the infaulted limestone of Whernside. The upper Clarentian beds outcrop under the limestone on the same curve, finally feathering out in the upper part of the Isolated Hill Creek. The lower beds cross the upper Wharf into the watershed of the Kekerangu River, where the whole series is presumably again resumed in the Front Ranges.

Discontinuous strips of Notocene rocks are involved along a second fault, which we may call the Quail Flat fault, running from the Gore River to the mouth of the Herring River, thence approximately along the Clarence River past Quail Flat, and ending on the north-west side of Red Hill. Between the Gore River and the Herring River all beds up to the Weka Pass stone are involved at river-level, and in the Herring River the width of the outcrop is extended by well-marked folding for some miles to the south-east of the fault-line, but farther to the north-east only discontinuous strips of the lower Clarentian rocks are preserved. There is evidently along this line strong longitudinal warping of the base of the Notocene, equal to nearly the whole thickness of the series, besides transverse folding.

A third small strip of lower Clarentian rocks only is involved in another parallel fault, which crosses the Herring River several miles above its mouth. This fault has not been traced on either side of the river. McKay (1887, p. 104) mentions the existence of two other "outlying patches" of Clarentian rocks, the one east of Gridiron Hill, the other one and a half miles to two miles east of Limestone Hill, but whether these are involved along the same or still another fault-line or are simple outliers is not known.

The large outcrop of Notocene rocks which extends from Bluff Hill across the Clarence River (below the junction of the Bluff River) to beyond Limestone Hill has not been satisfactorily explored. It is apparently not involved along a fault-line, but seems to constitute an outlier preserved by a synclinal depression west of the great Clarence and Quail Flat faults. The Notocene here attains its greatest elevation, rising to 4,231 ft. in Limestone Hill.*

In the detailed descriptions following it will be convenient to treat separately the Clarentian, the Amuri limestone and Weka Pass stone, the "grey marls," and the great Marlborough conglomerate.

The Clarentian Rocks.

The Clarentian as defined by me in 1917 comprises all those Notocene rocks in the Middle Clarence Valley lying below the flint-beds at the base of the Amuri limestone. In the neighbourhood of Coverham fossils have

* There are at least three mountains in the Clarence Valley to which this name has been given—one in the Upper Swale Valley, one between the Mead and Dee Gorges, and one on the south-east side of the Clarence River, above the junction of the Bluff River. It is the last that is here referred to.

been obtained from almost the bottom to the top of the series, and have been pronounced by Woods (1917) to belong all to one fauna, which he correlates with the Lower Utatur group of India, which is of about the same age as the Upper Gault and Upper Greensand of England—*i.e.*, Albian. Moreover, all other fossils from rocks having the same relative position in both the Middle Clarence and Awatere Valleys are, according to Woods, of similar age, so that the inclusion of all these rocks under one group-name is justified, although the total thickness of the Clarentian at Coverham surpasses the whole of that of the Notocene in places such as the Waipara district, where rocks from Senonian to Pliocene are represented. This is probably due to the fact that the Clarentian deposition followed close on the post-Hokonui orogenic movements, and erosion on a fairly emergent land-mass was still active. Probably also the Coverham area was not far from the mouth of a large river.

The Clarentian rocks, while preserving for the most part the same general character of sandstones and mudstones, vary rapidly from place to place, and there is no single characteristic stratum which can be followed from end to end of the valley. There are, nevertheless, some notable differences in the rocks at the two ends of the valley. The rocks at Coverham are dominantly black mudstones with occasional calcareous concretions, divided into three main groups by sandstones, and resting on conglomerates. In the Herring River, and thence nearly to the Bluff River, the sequence commences with terrestrial coal-measures, followed by several lava-flows, and these are succeeded by a marine series of sulphurous mudstones, sandstones with pebble-beds, loose sands, and glauconitic sandstones.

Coverham (Plate XXV, fig. 1).—I have suggested the following division of the sequence at Coverham (Woods, 1917, p. 2), but it must be clearly understood that this classification has a strictly local application:—

	Feet.
Sawpit Gully mudstones	3,200
Nidd sandstones and mudstones	550
Cover Creek mudstones	2,000
Wharf Gorge sandstones	450
Wharf mudstones	1,500
Basal conglomerates	250

The conglomerates were examined in a tributary of the Wharf Stream coming from the Sawtooth Range, where they strike at the base N. 40° E., dipping at 45° to the north-west, and near the top strike N. 60° E., with dip 60° to north-west. The underlying pre-Notocene greywackes and argillites strike N. 20° W., with a steep dip to the north-east. The unconformity is well exposed in section (Plate XXV, fig. 2). The conglomerates are, in part, of a peculiar character, not uncommon elsewhere in the Clarentian—viz., that they consist of well-rounded pebbles, a few inches in diameter, of hard rocks such as quartzite, set in a matrix of mudstone. The conglomerate series at this point commences with beds of hard conglomerate alternating with this pebbly mudstone, then some layers of pure mudstone, and then more bands of pebbly mudstone, the whole being about 250 ft. in thickness. The conglomerate consists mainly of well-smoothed ellipsoidal pebbles of hard sandstone and quartzite, up to 8 in. long, but mostly with a major diameter of 3 in. to 4 in., with only a few pebbles of mudstone and soft sandstone near the base. Green and liver-coloured quartzites are relatively rare, but white quartz and bright-red and pink jasperoid quartz are common. Granites and porphyries are only occasionally seen, while dark crystalline rocks appear to be absent. No schist or limestone pebbles were observed. The conglomerates were not followed along their outcrop. They cross the Ouse Stream about a quarter of a mile below the junction of the Wharf as a narrow band of pebbly mudstone only 5–10 ft. thick. As already mentioned, there are two thick bands of conglomerate farther down the Ouse which may possibly be Clarentian.

The Wharf mudstones form both banks of the Wharf Stream between the gorge and the crossing of the pack-track, above which the strike becomes more easterly, and the beds continue into the upper Wharf. The rocks are mainly dark micaceous mudstones without many concretions, and near the junction of the tributary above mentioned yield finely-preserved specimens of *Belemnites superstes* Hector. Near the crossing of the pack-track sandy beds are crowded with the shells of a large depressed *Inoceramus*, and lower down the creek the mudstones contain *Aucellina euglypha* and *Belemnites superstes*. No observations of strike and dip were made, except that in one place on the left side there is a reversal of dip. In the upper Wharf, what are presumably the Wharf beds consist predominatingly of mudstones containing large *Inocerami*, with occasional bands of harder sandstone, forming waterfalls, and thin bands of pebbly mudstone. The beds are thrown into a series of folds, so that a clear section was not observed. The mudstones, however, are very thick. The Wharf beds were again observed in the Ouse, about 200 yards below the junction of the Wharf, in a large cliff on the right-hand side consisting of thin-bedded sandstones and mudstones. The sandstones contain coaly plant-remains, and one block with shell-fragments was obtained, which contained a plicate ostreid shell, part of the dorsal valve of a Terebratellid (the only brachiopod yet obtained from the Clarentian), and a small piece of the test and some minute spines of an echinoid. A concretion picked up at this point contained a gasteropod and a *Dentalium*, and is in the hands of Professor Wilckens, of Jena, for identification.

Still farther down the Ouse, the lowest Wharf beds consist of hard mudstones crowded with a large flat *Inoceramus*, and are the cause of small waterfalls on tributaries coming in on each side (*cf.* Cotton, 1913, fig. 14). No specimens suitable for identification could be extracted, but pieces 9 in. in length were obtained, and the whole shell must be over 1 ft. in length.

McKay's description of the Wharf beds is as follows: "The lowest rocks, as conglomerates, are rather suddenly succeeded by black slaty, marly beds, containing concretions of cone-in-cone limestone, and sandstone bars full of *Inoceramus*, and here and there a belemnite and other fossils characteristic of the Amuri series."

The Wharf Gorge sandstones and mudstones occupy a width of about a quarter of a mile in the Wharf Gorge, which crosses them transversely to the strike, and in the lower part of the Cover Stream. The rocks are dominantly sandstones, in beds 6 ft. thick below and 3 ft. above, and are parted by thin beds of mudstone. The sandstones in the upper part are fissile and slightly micaceous, and contain poorly preserved plant-remains, principally fossil wood, and occasionally the cast of a belemnite. The strike in the lower end of the gorge is E. 10° S., dip 63° to the north. The Wharf Gorge beds extends in an east-north-east direction into the ridge between the Wharf and Cover Streams, but are not there well exposed for study. Where they cross the Ouse the sandstones are not so well developed. They have here a strike of N. 60° E. and dip 45° to the north-west in the lower part, and a strike of N 70° E., and dip 56° to the north-north-west at the junction of the Ouse and Nidd.

McKay describes the Wharf Gorge beds as follows: "The higher beds [*i.e.*, higher than the Wharf beds] are thick bedded sandstones of a grey colour, light-grey or yellow when weathered, parted by thinner beds of black slaty shale."

The Cover Creek mudstones are black micaceous mudstones with numerous small irregular calcareous concretions which are more generally fossiliferous than those of other divisions of the Clarentian. Belemnites and occasionally specimens of *Inoceramus* are also found embedded directly in the mudstones without being surrounded by concretions. There are a few occasional beds of sandstone. The beds below the house at Coverham strike N. 60° E., with dip 55° to the north-west. A little farther up the Cover Creek the strike turns more to the north. The beds cross the lower Nidd and are exposed in the lower Swale, where they have the same characters but are less fossiliferous. The best locality for fossils lies in Cover Creek, about 200 yards above the old sheep-dip. Here were obtained the ammonite *Turrilites circumtaeniatus*, *Belemnites superstes*, *Inoceramus concentricus*, the carapace of a crab, a small compound coral, the skeleton of a fish, numerous fish-scales, and specimens of fossil wood. McKay's description of the Cover Creek and higher beds is as follows: "These beds [the Wharf Gorge sandstones] are followed by softer, more argillaceous or marly strata, until reaching a bed of sandstone, which yields the fossils of the black grit, and thus the sequence of the Amuri series is here somewhat arbitrarily brought to a close. . . . The black grit . . . as a calcareous sandstone contains ammonites, *Inoceramus*, fish-scales, and numerous leaves of a plant common enough in the underlying Buller series. . . . At Coverham, from the horizon of the black grit to the flint-beds underlying the Amuri limestone, there is an enormous development of black micaceous clay-marls, divided into two parts by a band of grey or brown sandstones containing plant-remains. These beds are crowded with calcareous concretions, and, especially in the higher beds, contain *Inoceramus* in great numbers."

Unfortunately the collections preserved by McKay from Coverham were disappointingly small and poor, and the ammonite mentioned above was not amongst them. There is a little uncertainty which is the bed he called the black grit, but it is probably a sandstone in the Cover Creek beds opposite the house, which lies 50–100 ft. below the horizon where *Turrilites circumtaeniatus* was obtained, and which can be traced into the Nidd.

The Nidd sandstones and mudstones cross the Nidd obliquely above the junction of Sawpit Gully with a strike of N. 60° E. and a dip of 55° to the north-north-west, and they cross Sawpit Gully near the bottom. They consist of sandstones with a greenish tinge. 1 ft. to 2 ft. in thickness, separated by 6 ft. to 20 ft. of mudstones. Both sandstones and mudstones contain in abundance a large *Inoceramus*. They are followed, up the Nidd, by sandy mudstones which become flinty above, and contract the valley to a gorge. The mudstones contain a considerable amount of pyrites and exhibit a yellow efflorescence. The flint-beds seem to widen in outcrop to the east in the ridge between the Nidd and the upper Cover, where they form a prominent strike ridge. A little to the south there is a parallel strike ridge, apparently formed by the lower sandstones. The flint-beds do not seem to persist to the west into the Swale, but about a mile and a half above the junction with the Ouse there is a series of banded sandstones and mudstones, striking east-north-east, and dipping 40° to the north-north-west, which probably represents the lower sandstones.

The Sawpit Gully mudstones are clearly exposed in the steep bed of Sawpit Gully (Plate XXVI, fig. 1), and consist predominantly of black mudstones, but occasional thin beds of sandstone are found. There is some folding in the section, but, on the whole, the dip is to the north-north-west, like that of the overlying flints and limestones. Calcareous concretions up to 1 ft. in diameter are common in the upper 400 ft., but below that they are rarer. In the uppermost 15 ft. pyritous nodules are abundant, but they do not persist far downwards. At the actual junction with the flint-beds there is a strong yellow efflorescence. The junction appears to be quite conformable. *Inoceramus concentricus* var. *porrectus* was obtained 20 ft. below the junction and also at about 100 ft. The ammonite *Gaudryceras sayci* was obtained in a large concretion about 300 ft. below the junction.

The Sawpit Gully beds are exposed in the Nidd above the flint gorge, where the valley again opens out in the softer rocks. Near the base there is a band of sandstones and sandy mudstones containing a large species of *Inoceramus*. The higher beds are fine-grained black mudstones with small concretions, in which fragments of crustaceans were observed.

In the Swale, owing to slips and talus slopes, there is not a continuous exposure of the Sawpit Gully beds. Not far from the top there is some sharp folding of the beds, causing local reversals in the direction of the dip (Plate XXVI, fig. 2). From the highest exposure concretions containing numerous specimens of *Aucellina euglypha* and fossil wood and plant-impressions were obtained.

The thicknesses given above for the various divisions of the Clarentian at Coverham were estimated, except in the case of the conglomerates, by measurements from a section drawn to true scale. An average dip of 55° was allowed, but it will be observed that the dip is often steeper and seldom less than that figure. The reversals of dip due to folding are unimportant, but have been allowed for. An almost continuous section of the beds has been observed, and no faults of any consequence were seen. Consequently, unless there is a very strong unconformity between the Clarentian and the Amuri limestone and a repetition of the beds by closely appressed folds, there is no escape from the conclusion that the thickness given is approximately correct. Hector and McKay agree in estimating the total thickness up to the "grey marls" as approximately 12,000 ft. Woods remarks that the thickness, if correctly estimated, is very great in view of the unity of the molluscan fauna.

The beds are marine throughout, and calcareous concretions are abundant, but plant-remains and fossil wood are found in the sandstones and concretions from top to bottom. The black colour also of the mudstones and sandy mudstones is doubtless due to the presence of carbonaceous matter. Glauconite has been observed only in the greenish sandstones of the Nidd beds. The above facts, together with the rapid lateral variation in the sandstones and the presence of the pebbly mudstones in the lower beds, suggest that the whole series was deposited as the topset beds of a continental shelf undergoing rapid depression and near the mouth of a large river, the sands and gravels of which were arrested nearer shore or up the estuary by its drowning.

Hector's subdivision of the beds from Coverham to the Mead Gorge is as follows:—

Contorted sandstones (*Belemnites superstes*); volcanic dykes.
Concretionary marls; large *Inoceramus*.
Sandstone with plants.
Septaria clays, with *Inoceramus*, belemnites, and *Conchothyra*.
Black grit with fish-scales, ammonites, *Inoceramus*.
Black marls with sandstone bands.
Plant-sandstones with *Dentalium majus*, *Nerita*, *Natia*, *Inoceramus* (= Amuri sands).
Belemnite sandstone.
Black marls with cone-in-cone limestone bands.
Green sandstones.
Conglomerates and brown sandstones containing plants and coal.

In attempting to establish a similarity with the Piripauan beds at Amuri Bluff, Hector has given in the above succession too much prominence to the sandstone bands and too little to the black mudstones which make up about 90 per cent. of the succession. The green sandstones mentioned were probably observed on the Kekerangu side of the pack-track from that place to Coverham, where such beds occur.

The Clarentian near Coverham is occasionally penetrated by intrusive rocks which consist of very much weathered amygdaloidal basalts. A dyke trending E. 15° S., nearly vertical but with a slight inclination to the north, appears in the north-east bank of the Swale about a mile above its junction with the Nidd. A similar, somewhat thicker dyke, but possibly the same, outcrops a quarter of a mile farther up-stream. McKay describes a dyke in the Wharf as separating the upper and lower beds—*i.e.*, a sill. It is of similar petrological character, and is either a sill or else a dyke truncating the beds very obliquely. These intrusives are similar to one penetrating the Amuri limestone in the Kekerangu River, and are probably to be correlated in age with the volcanic rocks overlying the Amuri limestone in the Ure Valley and in the Herring River.

Isolated Hill Creek, Ure Valley.—From the Chalk Range the Amuri limestone swings round in a great curve to Benmore, and the underlying Clarentian beds follow suit, but owing to the inaccessibility of this heavily forested and deeply gorged country they have been examined only in the Isolated Hill Creek, a tributary of the Ure River which cuts through the limestones and flints in a gorge between Isolated Hill and the spurs of Benmore. At the top of the gorge the strike of the flint-beds and underlying Clarentian is east-north-east, with dip 36° to the north-north-west. About 1,500 ft. of Clarentian beds are exposed, consisting of dark-grey indurated mudstones or sandy mudstones, rapidly disintegrating into small angular fragments on exposure. Concretions of all sizes up to 7 in. diameter occur sparingly thoughout, but are rarely fossiliferous. One large ammonite was obtained in a concretion from the stream-gravels, but was declared by Mr. H. Woods to be indeterminable. The beds terminate downwards against a fault which has brought down the Whernside block of Amuri limestone and flint-beds against the Clarentian.

The junction between the Clarentian beds and the overlying flint-beds appears not only to be perfectly conformable, but to exhibit a passage between the two formations. It is described in detail below.

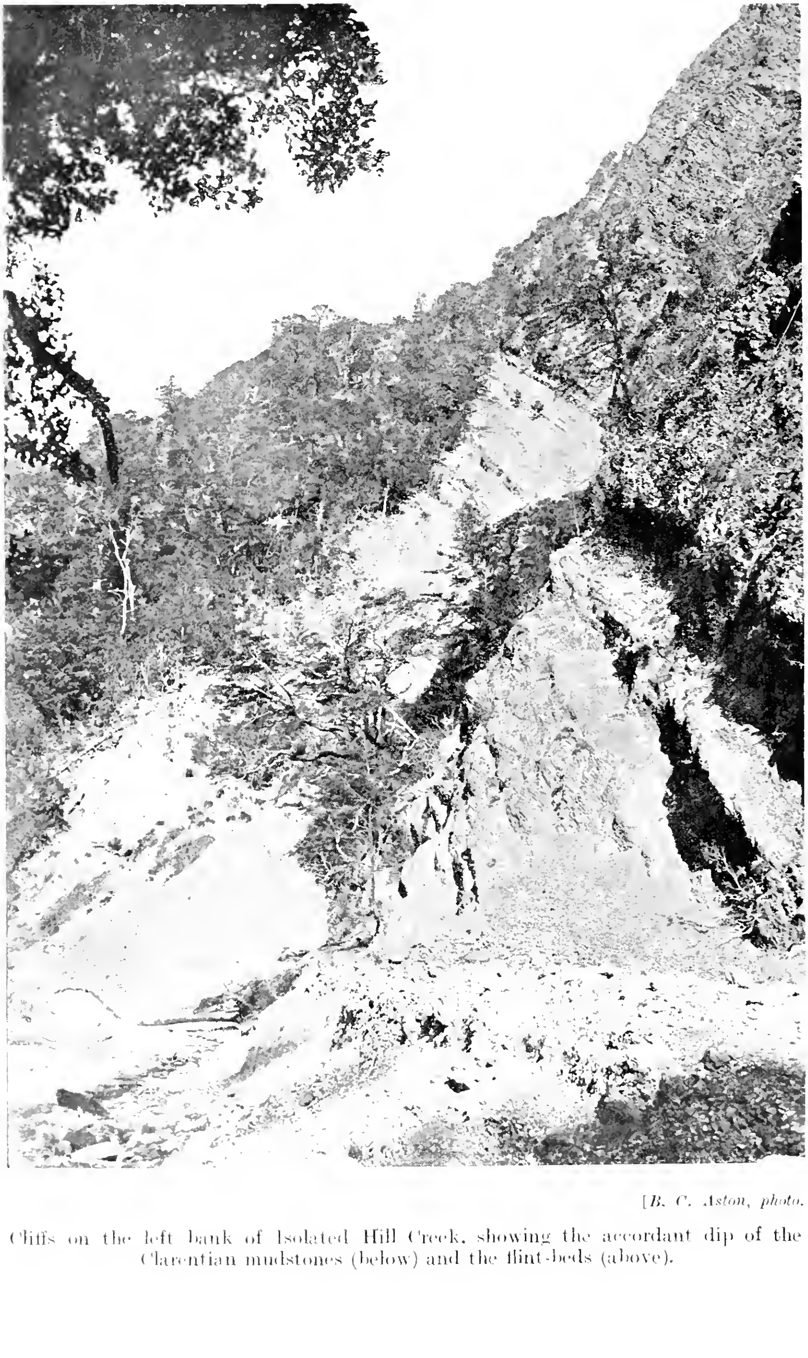
Upper Ure Valley.—The Notocene rocks in the upper Ure and upper Swale Valleys form a great overturned syncline, truncated by the great

[C. A. Cotton, *photo.*

Fig. 1.—The Chalk Range, from the south-south-east, showing Sawpit Gully (in the centre) entering the Nidd Stream (on the left).

[C. A. Cotton, *photo.*

Fig. 2.—Front of rock terrace in the Swale River valley, showing folding in the Sawpit Gully mudstones.



[B. C. Aston, photo.

Cliffs on the left bank of Isolated Hill Creek, showing the accordant dip of the Clarentian mudstones (below) and the flint-beds (above).

Clarence fault and its branches. Where on the upper side of the syncline the sequence is reversed, a small thickness of Clarentian beds lies above the flint-beds, between them and the fault-line. These were observed in the large tributary of the Ure River entering it in a south-east direction from Blue Mountain. About 100 ft. of Clarentian beds are here exposed, consisting of micaceous mudstones weathering purple-grey with a yellow efflorescence on joint-planes. They have the same strike as the underlying flint-beds—viz., north-east—with a dip of about 50° to the north-west—*i.e.*, towards the fault-line. A large concretion lying in the creek at this point was observed to be crowded with fibrous fragments of *Inoceramus*. There appears to be perfect conformity with the flint-beds. The actual fault-line is obscured by slips.

In a tributary of the above creek, entering it from the north-east along the fault-line, some decomposed amygdaloidal basic volcanic rocks were seen to the north-west of the flint-beds, and are therefore probably in the Clarentian series.

Middle Ure Valley.—Pebbly mudstones were observed in the Blue Mountain Creek at the apparent top of a series of hard sandstones and thin-bedded mudstones apparently overlying the Amuri limestone or Weka Pass stone, which is here not more than 150 ft. thick, and strikes in a north-easterly direction, dipping north-west. Probably the series is overturned and the succession reversed at this point, as it is higher up the Ure Valley. The conglomerates contain fragments of *Inoceramus* and pebbles of dark limestone (itself containing *Inoceramus*), besides white quartz and red jasper. A fault crosses the creek about two miles up, and above this, in a branch running to the Blue Mountain, the Clarentian rocks appear to be repeated. There is a succession of hard sandstones with occasional shaly beds, both containing occasional plant fossils, and thin pebbly mudstones containing *Inoceramus* fibres. There are many repetitions of the pebbly mudstones in the creek. Many small dark fine-grained dykes were observed intersecting the sandstones.

Lower Ure Valley.—Clarentian rocks are probably well developed in the hills to the north of the lower Ure, where thin bands of Amuri limestone appear, but exposures are not good and the sequence has not been clearly ascertained. Not far above the crossing of the coach-road a syncline of limestone occurs, underlain by sandstones and mudstones containing *Inoceramus*. The limestone crosses the hills obliquely and terminates against the Awatere beds, probably in a fault-line, and the beds farther up the hills to the west are therefore probably Clarentian. They consist mainly of sandstones, but the top of Hungry Hill is composed of volcanic breccia, which may be Clarentian. McKay correlates it with the Flaxbourne breccias, which lie at the base of the Clarentian series in the Ward district

Mead River.—McKay describes the Clarentian rocks exposed in the Mead River as follows: "In the Mead, the conglomerates at the base of the Amuri series are finely exposed. The succeeding beds are grey sandstones and darker shales thrown into a great number of undulations, which are flat and shallow, or more frequently sharply caught up at high angles, and are often crushed and contorted in a most extraordinary manner. Here beds of this character continue without means of distinction upwards into the Waipara formation, and, scarcely altered in character, reach to the under-surface of the great flint-beds that underlie the Amuri limestone."

To this description I have little to add. No recognizable fossils have been obtained from the Clarentian beds in either the Dee or the Mead, and consequently the beds have not been closely studied. The series appears to be considerably thinner than at Coverham, but the thickness is difficult to estimate owing to the contortions near the base. There is also some sharp folding near the top, and the beds run nearly horizontally for some distance. Before reaching the flint-beds, however, they once more assume the dip of these. The actual junction is not exposed.

Limburne Stream.—The series commences with pebbly mudstone, hard sandstone, and a second pebbly mudstone, all striking nearly east and west, and dipping to the north. The succeeding beds are a series of thin-bedded sandstones and mudstones. No fossils were obtained, and the junction with the flint-beds could not be observed.

Dee River.—The Clarentian rocks are not well exposed on the banks of the Dee River, and have yielded no fossils except fragments of *Inoceramus.* The series commences with a pebbly mudstone followed by a hard sandstone. Higher up the beds appear to be mudstones and thin-bedded sandstones with few or no concretions. The total thickness appears to be much less than that at Coverham.

Branch, Dart, and Muzzle Rivers.—For this part of the district we must rely solely on McKay's observations. He states that the lower part of the Clarentian (so-called Amuri series) is essentially the same as in the Mead and the Dee. The upper part in the Dart River, for some distance below the commencement of the limestone, consist of "grey sandstones and soft, crumbling sandy beds of dark colour, with small calcareous concretions containing *Inoceramus*, and small spheroidal concretions of iron-pyrites. . . . In the Muzzle the beds are highly-contorted sandstones and sandy or marly shales containing, near the under-surface of the Amuri limestone, saurian concretions of enormous size, one specimen of which, yet *in situ* on the east bank of the left branch of the river, is about 14 ft. in diameter." The name of "saurian concretion" was given from a mistaken correlation with the saurian beds of the Piripauan.

Bluff River.—There are two outcrops of Notocene rocks in the Clarence Valley near the Bluff River, separated by an anticlinal core of pre-Notocene rocks. The north-western outcrop is similar in its structural relations to those already described from Coverham to the Muzzle River, and is continuous with them. The south-eastern outcrop will be described later.

In the Bluff River the Clarentian rocks are not well exposed, owing to slips on the banks, and I was unable to observe certain beds evidently exposed when McKay examined the section. The lowest beds I observed were about 600 ft. of thick-bedded mudstones and sandstones, with a dip to the south-east—*i.e.*, away from the limestone. Higher up the river there are sandstones on the west bank with a normal dip—viz., 75° to the north-west—the strike being N. 50° E.

McKay describes the succession as he observed it as follows: "The lower beds of the Amuri series are for a short distance obscured along both banks of the river. Rocks belonging to the younger series first show on the south-west bank of the river as banded sandstones with shaly beds between. These are overlain by sandstones and conglomerates, some of the conglomerates containing fragments of a large *Inoceramus* and great numbers of a large form of *Trigonia*. . . . Belemnites, usually as fragments, are also found in these conglomerates. The sandstones are almost destitute of fossils. To the north-west, and higher in the section, these beds are followed by dark sandy beds with concretions, the outer part of which consists of cone-in-cone limestone; and these are succeeded by the Amuri limestone."

Gentle Annie Stream.—The Notocene beds continue from the Bluff River into the Gentle Annie Stream, where the Amuri limestone occurs in a syncline. The Clarentian beds below the limestone to the south-east are not well exposed, but the presence of muddy sandstones dipping to the north-west was observed.

Herring (or Seymour) River.—The exposures of Clarentian rocks described from Isolated Hill Creek, Coverham, and the Mead to the Gentle Annie all belong to a continuous strip forming the lower member of the Notocene rocks involved in the great Clarence fault. From Bluff Hill to the Gore River there are other outcrops of Notocene rocks involved along the more north-easterly parallel faults, except for the large outcrop between Bluff Hill and Limestone Hill, which seems to occupy a synclinal depression. Many of these outcrops include only Clarentian rocks, while in others a nearly complete succession of the Notocene is included. The Clarentian rocks in this area commonly commence with terrestrial coal-measures, and volcanic rocks are well developed. The most complete and typical succession is that of the Herring River, which will be considered first, although it disturbs the geographical sequence of the account.

In the lower Herring River the unconformity of the Clarentian and pre-Notocene rocks is well exposed. The latter consist of concretionary ("cannon-ball") sandstones and thin argillite bands, striking N. 15° W., with a very steep dip to the west. The Clarentian rocks strike, at the base, N. 30° E., and dip 44° to the north-west—*i.e.*, down-stream. The Notocene series is folded into a syncline and anticline before reaching the Quail Flat fault-line near the junction with the Clarence River, and the syncline brings the Amuri limestone down to the river-level, thus separating two exposures of the higher part of the Clarentian beds.

The lowest rocks are coal-measures, 50 ft. thick, forming cliffs of a reddish colour. The series commences with a seam of lignite a few feet thick, followed by carbonaceous shales, grits, sands, and ferruginous sandstones, with thin seams of lignite. Some of the sandstones and shales are crowded with plant fossils. Then follows a series of volcanic rocks about 320–340 ft. in thickness. Four well-marked lava-flows can be recognized, but there may be more. The rocks have not been examined microscopically, but appear to be olivine basalts. The lowest lava is not columnar, and is 60–70 ft. thick, and it is succeeded by more coal-measures, varying from 7 ft. to 15 ft. in thickness. The second flow, which is coarsely porphyritic, is columnar for the lower 20 ft., passing into breccia for the upper 20 ft. The third flow of fine-grained basalt is 15 ft. thick, and is columnar throughout. The fourth flow lies 150 ft. farther up, and is about 50 ft. thick. The outcrops of the interbedded rocks at river-level are covered by basalt screes, but may be exposed on the higher slopes of the valley-sides. The fourth lava is immediately followed by mudstones.

Farther down the stream the section of the succeeding Clarentian beds is far from continuous, as the banks on each side are much slipped, probably owing to the predominance of loose sandy beds. Such rocks as are exposed are mudstones, sandstones, sometimes with pebble-beds, and a thick series of mudstones with yellow efflorescence in beds about 1 ft. thick, alternating with soft sandstones in beds of 18 in. to 2 ft. thick. Higher up in the succession the mudstones become more massive and the sandstone intercalations disappear. Altogether there are probably over 1,000 ft. of strata between the top of the lava and the base of the Amuri limestone. The uppermost 60 ft. consists below of 20 ft. of pale-green sandstone, passing up into bright-green glauconitic sandstone, and finally into hard glauconitic limestone. There is some appearance of unconformity in the overlying Amuri limestone (*cf.* p. 328).

In the north-west wing of the anticline farther down the river the lowest beds seen are about 200 ft. of sulphur mudstones. These are succeeded by about 50 ft. of sulphur sands, of which the upper 15 ft. is glauconitic.

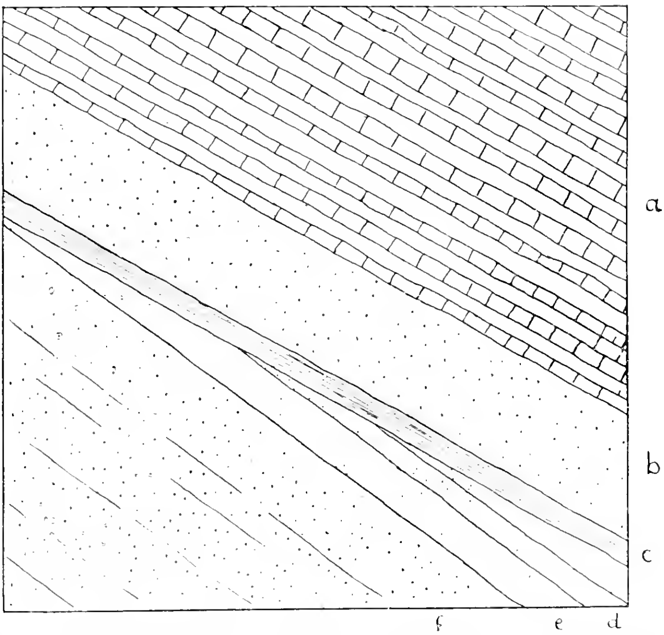


FIG. 5.—Junction of Clarentian and Amuri limestone, north-west wing of anticline, Herring River. *a*, Amuri limestone; *b*, glauconitic sandstone; *c*, mudstone; *d*, brown glauconitic sandstone; *e*, green glauconitic sandstones; *f*, sulphur sands.

The latter bed is apparently truncated at a gentle angle and overlain unconformably by a thin bed of mudstone, which in turn is followed conformably by a glauconitic sandstone, 10 ft. thick, and that by the Amuri limestone. The cliff in which this section is exposed cannot be scaled, and the ground slopes away steeply at the bottom, so that it was difficult to be certain of the unconformity.

McKay recognized only two "great sheets" of volcanic rock, and made a collection of fossils from sandstones and pebble-beds resting on the upper surface of the second sheet. The fossils determined by Woods were *Arca* (*Barbatia*) sp., *Trigonia glyptica*, *T. meridiana*, *Modiola kaikourensis*, *Belemnites superstes*. I did not recognize this bed, but a little way down the river from the uppermost lava I picked up in the river-gravel a boulder of conglomerate containing *Trigonia glyptica*.

The upper beds are described by McKay as "soft grey sandstones, and black, sandy, sulphurous, micaceous beds, with cone-in-cone concretions, overlaid by greensands, which, associated with thin beds of volcanic rock (on the north-east bank of the river only), underlie the Amuri limestone." These upper beds of volcanic rock I did not observe.

Quail Flat.—The Quail Flat fault runs from the mouth of the Herring River for some distance along the bed of the Clarence River, then enters the southern bank to pass though Quail Flat, crosses the river again at the southern end, passes through two southerly projections of the north bank, and finally again enters the north bank to run behind Red Hill, where its presence was inferred by McKay. The base of the Notocene rocks must be considerably folded longitudinally along this line, since at Quail Flat and farther north-east only lower Clarentian rocks are involved at approximately the same height as that at which the Weka Pass stone occurs only two miles to the south-west.

The Clarentian rocks are exposed on the southern bank of the Clarence River near the upper and lower ends of Quail Flat, the intervening spaces on the bank being occupied by pre-Notocene rocks. At the upper end of the terrace the pre-Notocene rocks for some hundreds of yards are greywackes and thin-bedded argillites striking N. 30° W. and dipping nearly vertically. Farther up the river conglomerates appear, the line of junction striking N. 65° E., and dipping apparently vertically. The conglomerates consist mainly of rather decomposed, well-rounded basalt pebbles, with a greasy matrix recalling the fossiliferous tuff of Limestone Creek, Awatere Valley. They contain pieces of carbonized fossil wood. Up the river these are succeeded by coal-measures striking north-east, dipping 58° to the north-west, and consisting of thin-bedded mudstones, carbonaceous shales, and sandstones, with elliptical masses of ferruginous sandstone. These rocks strike south-west into a projection of the terrace-bank, and the continuation of the succession is then obscured for about 100 yards. At the end of the projection a volcanic rock appears, and this is followed by a succession of greasy conglomerates and coal-measures similar to the last. It seems probable that the junction between the first-described conglomerate and the pre-Notocene rocks is a fault.

McKay's description of this outcrop is more detailed, and he mentions no break in the succession. The first-mentioned exposure of coal-measures he describes as followed by thick beds of volcanic rock, divided by tufas, conglomerates, and shales, the highest stream of volcanic rock being followed by conglomerates, grits, sandstones, &c. From the beds between the first and second volcanic rocks he obtained leaf-fossils and fresh-water shells, and underneath the higher stream some very fine specimens of dicotyledonous leaves.

At the lower (down-stream) end of Quail Flat the pre-Notocene rocks are concretionary ("cannon-ball") sandstones with thin argillite bands, striking N. 20° E., and dipping 40° to the east-south-east at the lower junction with the Clarentian rocks. The latter series commences with mudstones and lignite seams, striking N. 20° E., and dipping 60° to the west-north-west. The higher beds, exposed up-stream, are sandstones, followed by more lignites. Higher up the succession is obscured by slips, but pre-Notocene rocks appear in cliffs 200 yards farther up the river, so that presumably the fault-line closing the sequence here enters the river-terrace.

This exposure was evidently much clearer at the time of McKay's visit, for he describes a number of beds I did not observe. "At the eastern end of the section the lowest bed is a soft greensandstone, which is followed by grey sandstones, with irregular beds of coaly shale. These latter beds contain elliptic masses and irregular bands of ironstone, which are full of plant-remains. A very large dicotyledonous leaf, with *Dammara* leaves, *Taeniopteris*, &c., occur in the ironstones and in the sandstones and sandy shales which overlie the lower beds. Casts of trees 18 in. to 2 ft. in diameter lie at the foot of the cliff along the river-bank, and these can be seen *in situ* surrounded by a thin layer of bright coal. Hard calcareous sandstones overlie these beds, with which are layers of ironstone, and in these beds dicotyledonous leaves and large specimens of *Taeniopteris* are abundant. About 100 ft. from the lowest beds of the series fine splintery black shales are crowded with long slender leaves having parallel venation: and in these beds and a greensandstone band parting them into an upper and lower division fresh-water shells, as casts of *Cyclas* and one or two species of univalves, are found in great abundance. Fine-grained grey and gritty sandstone follows, with soft sandy beds between, and in these, besides the plants already named, *Polypodium* (?) occurs in fronds of large size and well preserved in the sandstone beds. For the next 150 ft. the beds overlying are soft and hard sandstones alternating, sands and sandy shales, and small nests of coal; and, beyond these, 50 ft. or 60 ft. of dark-green volcanic rock separate this lower part of the section from the higher beds, which are much the same in character" (1886, p. 102).

North Bank, Clarence River, opposite Tytler Stream.—Owing to a bend in the Clarence River the fault strikes across the river below Quail Flat and passes through a projection of the northern bank, on the end of which a small patch of Clarentian coal-measures is preserved. I did not cross the river to observe these, but McKay has given a section of them under the heading of "Clarence Crossing, Quail Flat" (McKay, 1886, p. 101).

McKay describes in general terms a similar outcrop three miles below Quail Flat, presumably also on the north bank of the river.

Red Hill.—According to McKay's description, the Quail Flat fault runs on the north-west side of Red Hill, which is composed of lower Clarentian rocks, while a narrow strip of pre-Notocene rocks occurs to their south-east side, along the banks of the Clarence River The lowest Clarentian rocks he describes as gritty sandstones and pebble-beds without distinct fossils. Next follow sandstones and grey, brown, or dark-coloured shales with plant-remains, not very well preserved, and thin coal-seams, 1 ft. to 18 in. in thickness. From a sandstone under the lowest coal-seam two fresh-water shells were collected. The succeeding beds are grey and soft yellow sandstones, with dark shales and plant-remains, including dicotyledonous leaves, a narrow leaf with parallel venation, and four or five species of fern. These are in turn followed by basaltic rock-tufas and sandstone conglomerates, alternating in an irregular manner, and finally by sandstones and pebble-beds, which in the north-eastern end of Red Hill are calcareous and contain concretions 1 ft. to 15 in. in diameter.

Clarence River below Bluff River.—There is a very considerable development of Notocene rocks from Bluff Hill across the Clarence River to Limestone Hill, which has not been satisfactorily explored either by McKay or myself. As seen from the north-east end of the valley Bluff Hill seems to form a syncline, and this impression is confirmed by the outcrop of lower Clarentian rocks on the north-west side of the Notocene outlier at the mouth of the Bluff River and north-west of Limestone Hill, where in a small creek I observed coal-measures similar to those of the Herring River, overlaid by volcanic rocks. McKay (1886 p. 68) also states that the Buller series—*i.e.*, the coal-measures—underlies the first great sheet of volcanic rocks in Limestone Hill. Unfortunately, neither here nor in the Clarence River was the base of the series observed. If this great outcrop of Notocene rocks terminated to the north-west along a fault-line one would not expect Clarentian rocks except along its south-eastern boundary.

There must be a nearly complete section through this Notocene outcrop where it is crossed by the Clarence River, but as the river here flows in a gorge it cannot be closely followed. McKay describes the section as follows: "The lowest beds are sandstones and conglomerates, containing marine fossils. . . . These fossiliferous sandstones are overlaid by a considerable thickness of volcanic rocks, varying from 50 ft. to 200 ft., and these in turn by sandstones, conglomerates, and shales, followed by a second series of volcanic rocks overlaid by the limestones and grey marls closing the sequence."

The fossils collected by McKay were determined by Woods as follows: *Trigonia glyptica*, "*Modiola*" *kaikourensis*, *Thracia* sp., and *Belemnites superstes*.

The base of the Clarentian is not here exposed, and it is quite possible that coal-measures are present. The lowest rocks I observed were grey sandstones about 26–30 ft. thick, with occasional pebble-beds, striking north, and dipping 25° to the east. These are followed by about 40 ft. of thin-bedded sandstones alternating with mudstones, and then about 300 ft. of massive sandstones with pebble-beds which are sometimes fossiliferous. The pebbles consist of quartzite, greywacke, grey gritty sandstones, jasperoid quartz, and occasionally quartz porphyry. The fossils collected included a belemnite, *Trigonia glyptica*, "*Modiola*" *kaikourensis*, *Thracia* sp., *Aporrhais* sp. and other gasteropods, and *Dentalium* sp. Evidently these are the beds from which McKay collected.

These beds are succeeded by a fine-grained basalt, here 50–60 ft. thick, with large amygdaloidal masses of calcite containing quartz crystals in druse cavities. This is separated from an upper lava or series of lavas by 30–40 ft. of sandstones. The upper lava is scoriaceous at the base, and porphyritic. Its thickness could not be exactly estimated, owing to faults and slips, but appeared to be upwards of 200 ft. It is followed by a bed of mudstone, about 20 ft. in thickness, full of volcanic material, and this again is followed by a third lava, fine-grained and more decomposed and at least 20 ft. thick. The dip of the beds at this point has flattened or appears to have flattened owing to the river flowing along the strike. The next-higher beds appear to be soft sandstones with ironstone concretions, dipping steeply. There appears to be a great thickness of these beds and further lavas before the limestone is reached, but the section was not followed.

On the opposite side of the Clarence River, in the Red Bluff, the section is similar except that the third band of lava was not observed. The top of the second lava is followed by upwards of 10 ft. of mudstones and thin-bedded sandstones.

The Amuri Limestone and Weka Pass Stone.

The rocks in the Middle Clarence Valley termed collectively the Amuri limestone are lithologically similar to the limestone of Amuri Bluff, and occupy a somewhat similar stratigraphical position, but they have a very much greater thickness and probably represent a greater range of time. Geographically they are nearly continuous with the limestone of Kaikoura

Peninsula by way of the Front Range at Kekerangu and the Puhipuhi Mountains, and there can be no doubt that the Amuri limestone of Amuri Bluff correlates with some part, but it is almost certainly only the upper part, of the limestone of the Clarence Valley. It would therefore be more appropriate to name the formation from its greatest development in the Clarence Valley, but the name "Amuri limestone" is too well established to be displaced.

McKay correlated the uppermost part of the limestone formation in the Clarence Valley with the Weka Pass stone, describing the rocks as calcareous sandstones. Although in the north-east part of the valley there appears little justification for any such distinction, in the Herring River beds of greensand with phosphatic nodules and volcanic tuffs separate an upper, light-brown limestone from the lower, white Amuri limestone. Everywhere in North Canterbury and at Amuri Bluff and Kaikoura Peninsula a bed of phosphatic greensand or glauconitic limestone separates the Weka Pass stone from the Amuri limestone (*cf.* Speight and Wild, 1918), and it seems probable that the phosphatic band in the Herring River represents the same horizon and that the upper limestone must correlate with the Weka Pass stone.

The Amuri limestone in the Clarence Valley, excluding the flint-beds, consists mainly of two types of limestone, the one a snow-white, very fine-grained, hard, almost flinty rock, composed almost solely of carbonate of lime and silica; the other an equally fine-grained but somewhat softer, argillaceous limestone, also light-coloured but not so white, and very often with a greenish tinge. The former rock forms thick strata, and also alternates in thin beds, up to 1 ft. thick, with the latter, which is less commonly found in thick beds. The former may for convenience be termed the chalky type, and the latter the marly type.

The base of the limestone formation is in most exposures formed of beds consisting wholly or partly of black flint, but in the upper part of the flint-beds the flints are often light-coloured. Where the beds are partly of flint, the latter form large lenticules and the outer part consists of flinty limestone of the chalky type. In many places, however, the outer part is grey and crystalline, the crystals consisting of dolomite set in a matrix of flint. I have described the peculiar nature of these beds fully in my former paper (1916). Flints also occur sporadically in the upper parts of the limestone, but are not abundant and are not aggregated into definite rows.

Mead Gorge.—The greatest thickness of the Amuri limestone is that of the Mead Gorge, where I estimated it as follows:—

	Thickness in Feet.
Argillaceous limestone (Weka Pass stone)	150
Marly limestone	400
Chalky limestone	280
Marly limestone	420
Chalky limestone	90
Chalky limestone and flint-beds	1,410
	2,750

The dip of the various beds is constantly to the north-west, at angles varying from 45° to 70°, the average angle being between 50° and 55°. The junction with the underlying Clarentian beds is not exposed. The lowest flint-beds seen are of a lenticular character, in layers of 8 in. to 18 in., the beds swelling out around the flint lenticules in such a way that the surface of the bedding-planes is irregular (see Thomson, 1916, pl. ii, iii). The outer layers are composed of crystalline dolomite. Higher up the flint-beds become less lenticular and the exteriors are hard chalky limestone, layers of which also appear between the layers containing flint. Then follows a considerable thickness of hard chalky limestone with flint-beds subordinate, and finally another series consisting dominantly of flint-beds, the top being 1,410 ft. above the lowest observed beds. Above this flint is of relatively rare occurrence, but is by no means absent from the chalky limestones. The marly limestones in part consist of the thin-bedded alternations of chalky and marly limestones above described. No traces of fossils were observed in any of the above beds.

Limburne Gorge.—The Amuri limestone in the left branch of the Limburne consists of flint-beds at the base, then hard chalky limestone, marly limestone with chalky bands, and hard chalky limestone above. The uppermost beds are obscured by slips, and the top band of marly limestone and the Weka Pass stone are probably present, as in the Mead and the Dee.

Dee Gorge.—The flint-beds and the chalky and marly limestones succeed one another in the same order as in the Limburne and the Mead, and the thickness is probably about the same. The uppermost limestone, the Weka Pass stone, is a grey-white argillaceous limestone, without the typical cuboidal jointing of the Amuri limestone. No fossils were observed.

The flint lenticules at the base are present in beds averaging 8 in. thick, but some are as much as 2 ft. thick where the lenticules occur. The crystalline dolomitic rock is not abundant, and is most developed where the flint lenticules are thickest and most irregular. The great majority of the flint lenticules in the lower beds, and all in the upper beds, are not accompanied by crystalline exteriors, but by hard, flinty, chalky limestone. Mr. B. C. Aston has made the following analyses of specimens from this locality :—

Laboratory Number.	Nature of Sample.	SiO_2.	Fe_2O_3 and Al_2O_3.	$CaCO_3$.	$MgCO_3$.	P_2O_5.
779A ..	Flinty portion of lenticule ..	92·41	2·95	2·36	2·03	Trace.
779B ..	Near middle, carbonates largely removed by weathering	92·52	3·25	1·86	1·77	Trace.
779C ..	Exterior, also much weathered	81·97	3·70	6·53	7·61	Trace.
780 ..	Dense bluish limestone with minute carbonate crystals	32·73	1·69	60·42	5·26	Trace.
781A ..	Flinty portion of lenticule ..	88·12	3·48	5·07	2·75	Nil.
781B ..	Intermediate portion of lenticule	58·15	4·15	30·98	6·42	Trace.
781C ..	Exterior of lenticule	77·82	3·93	11·49	5·58	Trace.

Chalk Range.—McKay estimates the thickness of the Amuri limestone and Weka Pass stone in the Chalk Range at 2,500 ft., of which the lower 1,000 ft. consists of flint-beds. The middle beds he describes as soft chalk marls, followed by more compact flaggy limestones, which in the highest peak of the range contain beds of a green colour. Above these are beds resembling the Cobden limestone, with large radiating fan-shaped fucoids. The latter is followed by a calcareous sandstone, the Weka Pass stone, and these two uppermost beds contain layers of greensand and quartz sand alternating with the more calcareous strata. It should be observed that McKay described the Weka Pass stone in the Mead and Dee Gorges also as a calcareous sandstone, but it is certainly more argillaceous than arenaceous in these localities.

I observed the base of the flint-beds in Sawpit Gully. The junction with the Clarentian appears to be perfectly conformable, though quite sharp. The lowest flint-beds are dark throughout, and contain no dolomitic exteriors. The uppermost Clarentian beds contain much pyrite in nodules, and show a yellow efflorescence. Microscopic examination of the lowest flint-beds suggest that they are replacing rocks in part clastic.

Isolated Hill Creek.—In the Ure Gorge the sequence of the various beds of the Amuri limestone is difficult to interpret, owing to the complex folding and faulting that has taken place. The flint-beds at the base are, however, well exposed in the Isolated Hill Creek, which has cut a gorge through them (Plates XXVII, XXVIII). They appear to be much thinner than in the Chalk Range, and not much more than 500 ft. in thickness. The junction with the underlying Clarentian rocks is well exposed, and is not only conformable, but appears to show a transition between the two groups of rocks. Near the base black flints in hand-size nodules and lenticules lie in a coarsely crystalline dolomitic matrix, and the flints themselves contain many crystals of dolomite. Followed downwards, the flints contain fewer and fewer crystals, and at the same time become less pure and lighter in colour till they can hardly be distinguished from hardened mudstone, while the matrix also alters gradually into a grey micaceous mudstone. The above transition takes place within 2 ft. of rock. Forty feet below this transition there is a thin layer of impure flints and dolomite, the crystals of dolomite being relatively large. In the intermediate 40 ft. of mudstone there are large concretionary masses, 3 ft. in length and 18 in. across the bedding, consisting of lenticules of black flint in a crystalline dolomitic matrix.

It might be argued that the flint is secondary and has invaded the uppermost beds of the Clarentian, obscuring the true junction. But even if the flint-dolomite is secondary it is replacing calcareous rocks, and the transition in this case is from Clarentian mudstone to limestone by the intermediary of calcareous concretions, and I see no escape from the conclusion that the Amuri limestone is here conformable to the Clarentian.

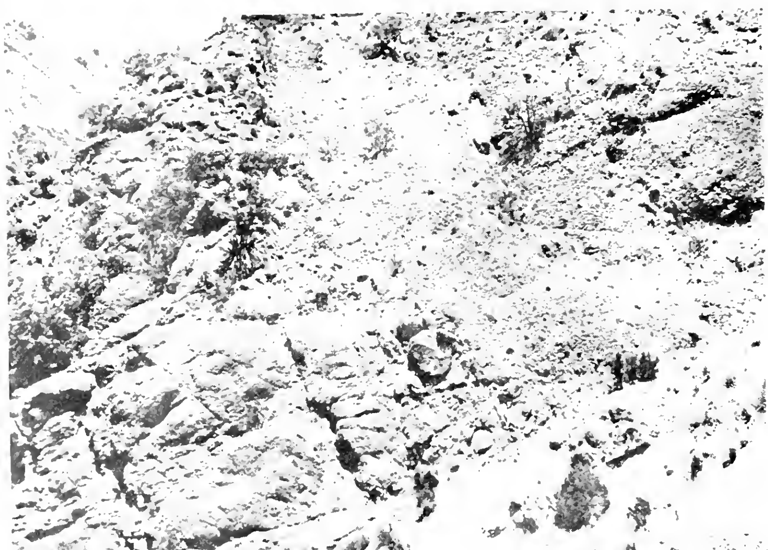
Upper Ure Valley.—In the upper inverted limb of the overturned syncline behind the Chalk Range the Amuri limestone forms a hogback ridge, cut through on the northern side of the Ure River from Limestone Hill to the White Bluffs by several gorges. From the smaller width and height of this hogback ridge it appears at first sight that the limestone is here considerably thinner than in the Chalk Range, on the lower limb of the synclinal. I observed the basal beds, here lying uppermost, in the large tributary from the Blue Mountain, but could not penetrate down the gorge to observe the upper beds. The beds are here striking in a north-east direction, and dipping at angles of 40° to 60° to the north-west. The sequence will be described as if the beds were not overturned. The Clarentian mudstones are followed perfectly conformably by thin lenticular flint-beds with mudstone intercalations, passing up into greener flints with dolomite crystals, the whole being some hundreds of feet thick. These are followed by hard chalky limestone with reddish-brown blobs of flint, also several hundred feet thick, and these again by limestone with black flint lenticules, beyond which the section could not be followed. The total flint-beds do not seem much inferior in thickness to those of the Chalk

[*B. C. Aston, photo.*

Isolated Hill from Isolated Hill Creek. The light-coloured rocks in the foreground are Clarentian mudstones, the steep cliffs in the middle distance consist of flint-beds, and the higher parts of the mountain are Amuri limestone.

[C. A. Cotton, photo.

FIG. 1.—The ridge between the Dee and the Limburne as seen from the south-west. The monoclinal ridge of Amuri limestone forms Limestone Hill on the right and in the centre the great Marlborough conglomerate outcrops.



[C. A. Cotton, photo.

FIG. 2.—Great Marlborough conglomerate in the Dee Gorge, showing a coarse band in the middle. View looking south-west.

Range, and it is probable that the hogback is formed of these alone, and that the softer marly limestones succeeding do not form a salient in the relief, so that the total thickness of the whole series may be equal to that of the Chalk Range.

Middle Ure Valley.—In the Ure Valley above Waterfall Creek the river runs obliquely across the strike, and the following rocks were observed in ascending order: (1) Hard mudstones, (2) hard sandstones, (3) gap in succession, (4) thick red decomposed volcanic lava, (5) gap in successon, (6) limestones, much folded and puckered, with dip and strike constantly changing, forming the river-banks as far as the Ure Gorge. From some green bands in the lower end of the gorge I collected specimens of *Teredo* tubes indistinguishable from those of *Teredo heaphyi* Zittel.

From the section in the Blue Mountain Stream which enters the Ure along the red volcanic rock, it appears probable that the above succession is reversed. The lava is in this stream followed (apparently) by white mudstones or marls with poor plant fossils, and these by about 150 ft. of limestone, mostly a white or reddish, fine-grained, rather chalky variety, with green bands and much tufaceous material. The limestone is in turn followed by sheared mudstones or muddy sandstones, and may be separated from the latter by a fault. Then follows a further series of similar limestone overlaid by the Clarentian rocks already described, with pebbly mudstone near the apparent top.

If, as I suppose, the succession is here reversed, the volcanic lava follows some part of the Amuri limestone, and quite probably occupies the same position as the tuffs in the Herring River section—*i.e.*, between the Amuri limestone and Weka Pass stone; but some earlier volcanic activity must have occurred to account for the tufaceous bands in the Amuri limestone itself.

Branch, Dart, and Muzzle Rivers.—McKay has not made many observations of the Amuri limestone between the Dee and Bluff Rivers, but states that the flint-beds become much thinner south-west of the Dee, have disappeared altogether in the Dart, and are not found farther to the south-west. I observed these beds, however, in the Bluff River and Gentle Annie Stream, so that it is improbable that they are totally absent in the intervening terrain. McKay states that the Branch Gorge is impassable, but estimates the thickness of the limestones as 1,200 ft. in the Dart Gorge and not much less in the Muzzle, though in the latter it is repeated by faulting. In the Muzzle he states that "there is evidence that the higher beds [*i.e.*, the Cobden limestone and Weka Pass stone] are gradually encroaching on the lower and more characteristic Amuri limestone beds," and mentions finding in the former fragments of a fibrous plicated shell "which probably belong to *Inoceramus.*"

Bluff River.—McKay's two descriptions (1886, pp. 78 and 97) of the Amuri limestone and Weka Pass stone in this section do not tally altogether with my observations. The highest bed is, he states, a calcareous sandstone, 15–25 ft. thick, containing various species of *Pecten*, including *P. zitteli*, and overlies soft chalk-marls. The lower beds he describes as "a compact fine-grained rock," and he states that "in its higher beds the harder limestone alternates with soft marly beds, and bands of hard calcareous greensandstone are of frequent occurrence. . . . A little to the south-west the Amuri limestone rests on the saurian beds as a gritty, impure limestone."

The lowest beds I observed were about 40 ft. of much-contorted flint-beds, dipping to the north-west. Above these the section is obscure, but sandy mudstones were observed. It is possible and probable that the upper limit of the flint-beds is a fault and that the sandy mudstones are Clarentian. A little farther up the river, on the western bank, the main exposure of the Amuri limestone series occurs. The lowest beds seen are flint-beds, about 100 ft. in thickness, in beds of from 3 in. to 6 in., with black flints with grey exteriors in the lower part and white flints with hard chalky exteriors in the upper part. The upper beds are separated by muddy, glauconitic partings 2–3 in. thick. From these I obtained two brachiopod specimens, neither specifically determinable, although one was a species of *Terebratulina*. The above beds were overlain by hard chalky limestone with white flints, and from this specimens of *Teredo* were obtained. To this succeeds about 10 ft. of calcareous greensandstone with small pebbles and pyrite concretions. This is overlain by 12 ft. of hard chalky or flinty limestone with muddy, glauconitic partings, and this in turn is followed by another 10 ft. or thereabouts of calcareous greensandstone, greatly contorted. Then succeed upwards of 30 ft. of thin-bedded alterations of chalky and marly limestone. Above this the section was obscured by slips, and the chalk marls and Weka Pass stone mentioned by McKay could not be observed.

Gentle Annie Stream.—The upper outcrop of flint-beds above described in the Bluff River can be traced across country to the Gentle Annie Stream, where they are underlain by Clarentian muddy sandstones. The limestone series forms a regular syncline on the north-east bank of the stream, but an absolutely continuous succession cannot be observed. The flint-beds are followed by a hard rubbly limestone, which is also probably flinty. This appears to be followed by a hard glauconitic limestone about 30 ft. thick, which contains in the middle a layer with rounded masses of white limestone somewhat similar to the chalky limestone but probably concretionary. The next-higher bed observed is hard chalky limestone, and this is succeeded by alternations of marly and chalky limestone forming the core of the syncline.

Bluff Hill and Limestone Hill.—The sequence of beds in the Amuri limestone of Bluff Hill and Limestone Hill has not been made out. The extent and thickness of the outcrops make it probable that the formation is of considerable thickness, perhaps comparable to that in the Mead area. McKay states that calcareous sandstone and indurated fucoidal chalk-greensands abounding in fossil shells form the higher and middle parts of Limestone Hill.

Herring River.—Notocene beds are thrown into a broad syncline and anticline in the Herring River, but the beds above the Amuri limestone are denuded from the axis of the syncline, and are exposed only on the two sides of the anticline in a tributary entering the river on the left side. Time permitted of the detailed examination of only two exposures.

On the south-east side of the syncline the lower beds of the Amuri limestone are seen resting on Clarentian calcareous greensandstones with apparent unconformity which is probably real (fig. 6). The greensandstones dip regularly to the north-west, and are truncated above at a gentle angle by a surface which has also an apparent dip to the north-west. The succeeding limestone consists of marly limestone with numerous thin alternations of chalky limestone, which become closer together in the upper part, the whole as exposed being between 50 ft. and 100 ft. thick. The lowest beds of the limestone follow the truncated surface regularly, but a few feet up the beds are sharply folded in the manner shown in fig. 6. It is, of course, possible that the surface of separation is not a true unconformity, but a fault or thrust-plane; but I observed no sign of crushing or slickensides along the surface.

On the north-west wing of the anticline, in a cliff some distance above the river-bed and about half a mile above the junction with the Clarence River, there is a good exposure of beds from the upper Clarentian to the Weka Pass stone. The apparently unconformable nature of the junction has already been described (p. 320). The Amuri limestone is about 200 ft. thick, the lower 150 ft. consisting of a thin-bedded alternation of argillaceous shaly limestone with harder white bands which are slightly glauconitic,

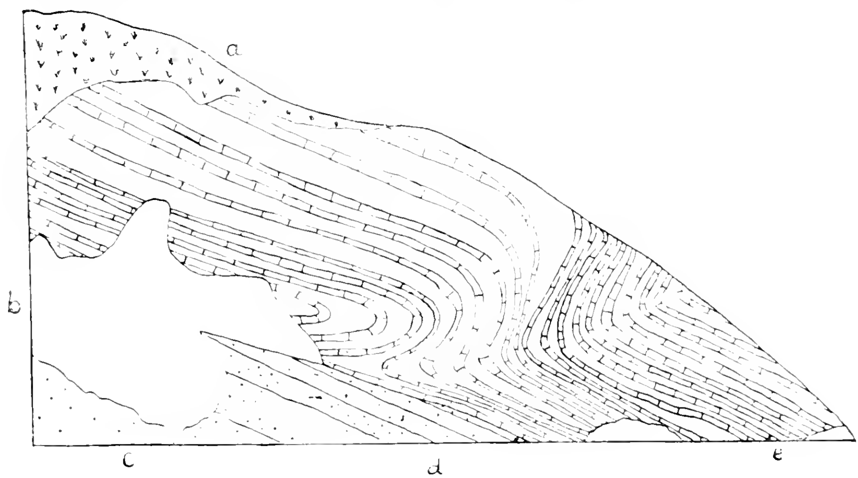


FIG. 6.—Diagram of junction of Amuri limestone and Clarentian greensandstones, south-eastern wing of syncline, Herring River. Only a few of the alternations of chalky and marly limestone can be shown. *a*, tussock; *b*, talus; *c*, sands; *d*, calcareous greensandstone; *e*, Amuri limestone.

while the upper 50 ft. is a glauconitic calcareous mudstone. This is succeeded conformably by 4 ft. of bright-green glauconitic calcareous sandstone with dark phosphatic nodules, and this in turn passes without a break into a dirty brown-green greensand. Both the latter beds contain Oamaruian fossils sparingly.

A few inches of nodular rock follows, very similar to the phosphatic greensandstone separating the Amuri limestone and Weka Pass stone in the Weka Pass. This is in turn succeeded by a thin bed of limestone, 15 in. thick, containing small green fragments which appear to be of volcanic origin. The next bed is a mudstone, about 6 in. thick, with numerous "fucoids," and above this is another bed of limestone, about 6 in. thick, with green fragments. Above this comes about 6 ft. of fine-grained basic tuffs alternating with thin brown calcareous sandstones. The next 10 ft. is occupied by dark tuffs: on these rest another series, about 5 ft. thick, of limestones with green fragments, in beds of about 1 ft. thick, separated by soft shaly material. Finally there is another 4 ft. of dark tuffs, passing up gradually into a massive limestone some hundreds of feet thick. The latter was not examined in detail here. On the opposite side of the river, lower down, it is seen to consist of various types of calcareous sandstone and argillaceous limestone, weathering to light-brown cliffs, and is separated into two parts by a thick band of mudstones very similar to the "grey marls." The strike at the middle of the bend round to the Clarence River is N. 15° E., dip 45° to the west. At the junction with the Clarence the strike is N. 50° E., and the dip 60° to the north-west. The limestone continues down the Clarence River for about 300 yards, and is here an argillaceous limestone with numerous partings, some of which contain dicotyledonous leaf impressions. Marine fossils occur sparingly, and are chiefly Oamaruian mollusca.

Age and Origin of the Amuri Limestone.—The only fossils found in the Amuri limestone of the Middle Clarence Valley are the *Teredo* tubes in chalky limestone from the Bluff River and from the Ure Gorge, and the indeterminable brachiopods found in the glauconitic partings in the flint-beds of the Bluff River. The *Teredo* tubes are indistinguishable from those of the Oamaruian *Teredo heaphyi* Hutton, but it is doubtful whether these deserve specific recognition, and fossils of such a nature are certainly insufficient for purposes of correlation. Probably by renewed collecting determinable brachiopods may be obtained from the Bluff River flint-beds which will suffice to fix the age of these beds. Meanwhile, in the lack of direct palaeontological evidence, the determination of the age of the limestones must remain a matter of inference. A lower limit of age is fixed by the underlying fossiliferous Clarentian mudstones of Sawpit Gully, which contain middle Cretaceous fossils up to within a few feet of their junction with the flint-beds. An upper limit is fixed by the overlying phosphatic greensandstones and Weka Pass stone of the Herring River, both of which contain Oamaruian fossils of at oldest Oligocene age, and, in other areas where these horizons are unfossiliferous, by the still higher "grey marls," which are Oamaruian.

Woods (1917, p. 2) has argued from the facts that the Amuri limestone in North Canterbury and East Marlborough is always overlain by Oamaruian (Miocene) rocks, and is underlain in the former area by Piripauan (Senonian) beds but in the latter area by Clarentian (Albian) beds, that the limestone must be unconformable both to the Piripauan and Clarentian, and that it is probably Eocene.

In 1916, before I had visited the Herring River and Bluff River sections, I discussed the lithology, thickness, distribution, and stratigraphical relations of the Amuri limestone, including the flint-beds, and suggested that it was in large part a chemical deposit. I stated my belief that it was everywhere conformable to the underlying rocks, ranging in age from Piripauan to Oamaruian in North Canterbury, and from Clarentian to Oamaruian in the Middle Clarence area, and that the flint-beds represented a definite horizon absent from the southern area. The discovery by Speight and myself of fossils in an interbedded tuff near the top of the limestone of the Trelissick Basin proved the Lower Oamaruian age of the top of the limestone in this locality. A corollary of the conformity with the underlying beds, by which the conclusion may be tested, is that the underlying rocks of the intermediate district—viz., the Puhipuhi Mountains—where the limestone is intermediate in thickness, must at the top be intermediate in age between Piripauan and Clarentian. Unfortunately, a spell of bad weather prevented my attempted examination of the Puhipuhi Mountains in 1916, and no further opportunity of exploring this area has presented itself. Meanwhile the discovery of the probable unconformity under the limestone in the Herring River area throws new light on the problem.

In 1917 Park suggested that the fossils found by Speight and myself in the Trelissick Basin, and earlier reports by von Haast and himself of Recent brachiopods from the "concretionary greensands" in the Waipara district, proved that the latter were unconformable to the Senonian "saurian beds," and that they, with the overlying Amuri limestone, were Oamaruian. In the same year I showed that the top of the "concretionary greensands" was Senonian, and that if any disconformity exists—for there is no unconformity of the beds—it should be looked for above the "concretionary greensands" in the dark carbonaceous mudstone into which the Amuri limestone passes down. Probably a collection of Foraminifera could be made from this mudstone which might settle its age if a large enough fauna were found. With regard to the supposed *Waldheimia lenticularis* from the "concretionary greensand," unfortunately the specimens do not appear to be preserved, and I have searched this horizon in vain for further specimens. No reliance is to be placed on the identification, for determinations of brachiopod species even by Hutton as late as 1904 were very unreliable, and *Neothyris lenticularis* does not occur fossil below the Wanganuian, and even there it is not at all common. The only *Neothyris* species known to me from the Oamaruian is *Neothyris novara* (von Ihering).

The problem of the age of the Amuri limestone is closely bound up with that of its mode of deposition. In 1916 I pointed out that the hard, chalky type consists predominantly of exceedingly fine-grained calcite, in which matrix isolated but unbroken tests of Foraminifera, chiefly *Globigerina*, occur sporadically, but skeletons of siliceous organisms appear to be absent. That they were formerly present but have disappeared by solution seemed improbable, since there are no spaces of dissolution such as exist in the English Chalk; and although the pressures to which the limestone has almost everywhere been subjected might be considered capable of closing such spaces, this could hardly have happened without the crushing of the delicate tests of *Globigerina*. Although the fact that the flint-beds are thickest where the limestone is thickest would find an easy explanation were the flint the result of a downward migration of silica derived from siliceous organisms in the overlying limestone, the absence of casts of these organisms seemed to prevent the acceptance of such hypothesis, and I put forward the suggestion that the silica of the flint and also the dolomite frequently found with it were chemically precipitated and that the limestone itself was in large part a chemical deposit, but in part composed of foraminiferal tests settling gently into the chemically formed calcareous mud. At the same time I stated, "Much of the above is speculative, but will serve a useful purpose if it calls attention to the peculiar nature of the Amuri limestone, the flint-beds, and the sulphur sands, and provokes an alternative explanation." This hope has been partially realized by the observations published by Marshall (1916, 1917) and by Speight and Wild (1918) on the presence and origin of the flint, but as none of these writers appears to have considered the possibility of chemical precipitation of any of the silica or carbonates of the limestone, and as none of them has discussed the subject from the point of view of the whole problem, it seems desirable to restate it in the light of the evidence now obtainable.

Marshall (1916) agrees with me that by far the greater part of the Amuri limestone over the whole of North Canterbury and Marlborough consists of very fine-grained calcite, while at Weka Pass the chambers of *Globigerina*, which are generally isolated, are fairly numerous. He states that Radiolaria are not infrequent at Amuri Bluff, and mentions sponge-spicules and several examples of a radiolarian at Kaikoura. In the highly siliceous and flinty varieties at Ward and the Ure River no remains of siliceous organisms could be distinguished, but he considered it probable that they had been dissolved. No explanation of the fine-grained calcite base was presented, but he considered the whole rock a pelagic deposit accumulated from the remains of marine organisms.

Marshall in 1917, after the discovery of calcified sponge-spicules in the hydraulic limestone of the Kaipara and Whangarei districts, re-examined specimens from Ward. He considers it probable that diatoms and Radiolaria are present, though much calcified and much destroyed by solution, and sees in these the origin of the silica of the flint-beds. His argument may be fairly summed up as follows: By far the greater part of the limestone consists of very fine-grained calcite, but chambers of *Globigerina*, which are generally isolated, are fairly numerous. The rock is therefore a *Globigerina* ooze. Radiolaria are not infrequent at Amuri Bluff and Kaikoura, sponge-spicules occur at Amuri Bluff, and it is probable that calcified diatoms and Radiolaria are present at Ward. Therefore the flint in the limestone is probably derived from the skeletons of siliceous organisms. This is rendered the more probable from the occurrence of diatomaceous and radiolarian ooze in limestones of similar age and character in the North of Auckland and at Oamaru. The argument would gain strength by the omission of the diatomaceous earth at Oamaru, which few if any other New Zealand geologists will admit to be of the same age as the Amuri limestone. The facts adduced by Marshall are consistent with the conclusions he derives from them, except that the fine-grained matrix of the limestone is not explained; but they are also consistent with my suggestion of chemical precipitation of carbonates and silica during the formation of the Amuri limestone. All that is necessary to add to my account is the presence of Radiolaria and diatoms in the postulated shower of Foraminifera which helped to form the limestone, the presence of some siliceous sponges, and some secondary migration of the silica.

Speight and Wild (1918) record the presence of flint both above and below the phosphatic layer at Kaikoura and Amuri Bluff, and conclude that its presence cannot be regarded as a criterion of age. Flint *in situ* just below the nodular layer occasionally shows burrows filled with glauconitic material, and so the authors remark that, unless the boring animals were able to penetrate flint itself, the flint must have been precipitated subsequently to the boring of the limestone. I have not claimed that the presence of flint in the Amuri limestone is a criterion of age, pointing out that small flints similar in mode of occurrence to those of the English Chalk are common in the limestone at Amuri Bluff, which I considered as much younger than the lower part of the limestone at Coverham. What I did suggest was that the massive flint-beds occurring at the base of the limestone from the Puhipuhi Mountains northwards occupied a definite stratigraphical horizon, and Speight and Wild's observations throw no light on this point. In suggesting that the silica of the flints was deposited chemically I did not claim that there was no secondary migration of the silica. In case I did not make this clear, I wish now to state that I consider that both the flint of the flint-beds and the sporadic flints occurring at higher horizons are concretionary in their nature, and are the result of the redeposition of silica originally scattered throughout the beds in which the flint occurs. The fact that the evenness of the bedding-planes gives place to rolls around the largest flint lenticules seems to prove this for the flint-beds. The structure of the flint-dolomite exteriors is also more in accord with a secondary than with an original deposition.

Cotton (1918), in examining by the deductive method the kind of deposits to be found in the continental shelf, showed that with advances and retreats of a subsiding shelf corresponding to fluctuations in the ratio of waste-supply to rate of subsidence there may be intercalations of foreset and pelagic beds in the topset beds towards the outer part of the shelf, while farther seaward there will be no intercalations of topset beds but an alternation of pelagic and foreset beds. In this way, he suggests, may perhaps be explained the intercalation of the Amuri limestone between mudstone and marl in Marlborough. Interpreting the chalky limestone as pelagic and the marly limestone as foreset beds passing into pelagic, the frequent alternations of these two kinds of rock in Marlborough receive a satisfactory explanation. Moreover, since both kinds of beds were laid down on the broad continental slopes, and since fluctuations in the supply of waste are regional, it is probable that bands showing such alternations must have a wide geographical range, and can therefore be used in correlation over neighbouring areas. In respect to the pelagic beds Cotton's deductions are unaffected by the method of deposition, whether partly chemical or solely by accumulation of tests of marine organisms.

The following are the reasons for considering that the chalky variety of Amuri limestone is in large part chemically deposited :—

(1.) *Its lithological nature.* As Marshall states, by far the greater part of the rock consists of very fine-grained calcite, with isolated but fairly numerous tests of *Globigerina.* If this fine-grained material is derived also from broken tests of Foraminifera, there must have been great comminution of the tests before consolidation, and it is difficult to imagine any agency which could effect this and yet leave the tests of *Globigerina* in such perfect condition. If, on the other hand, the fine-grained material is the result of solution of tests and recrystallization, it is again difficult to see why the tests of *Globigerina* have escaped the destruction of form the others have suffered. On the other hand, there is no difficulty in imagining the tests settling gently into a fine mud of chemical origin, and preserving their form during the recrystallization that has certainly in some cases taken place.

(2.) *Its chemical nature.* Specimens of chalky limestone from districts where the flint-beds occur and others from districts where flints are rare show alike a considerable silica-content. The mean of ten analyses I have collated gives 10·25 per cent. of silica. As the rock contains exceedingly little terrigenous sediment, this silica must be mainly ascribed to siliceous organisms if chemical deposition is ruled out; but neither the remaining skeletons nor the probable casts of such skeletons are present in sufficient amount to account for such a large percentage of silica. The position becomes worse if we add in the silica of the flint-beds, supposing this to be derived by solution and migration of silica from the overlying limestone and not from redeposition *in situ* of the silica of radiolarian or diatomaceous oozes.

The presence of dolomite in the flint-beds is difficult to explain if the limestone is a deposit accumulated in deep, cold water solely from skeletons of marine organisms. The total amount is not very great, and perhaps not more than might be expected if it represents a downward migration and accumulation at the base of all the magnesium carbonate originally present in the whole mass of limestone, but it creates a considerable difficulty if the flint-beds are considered as siliceous oozes of organic origin reprecipitated *in situ*.

(3.) *Its lack of fossils.* Although the *Globigerina* oozes of the present oceans do not afford a suitable bottom for some forms of benthic life—*e.g.*, brachiopods—yet they are by no means devoid of other forms. Moreover, the European Chalk, which presumably represents a pelagic deposit laid down in not very deep water on the continental slopes, is not conspicuously poor in fossils but can be zoned by means of them. The Amuri limestone, on the other hand, is practically without any fossils of benthic organisms from bottom to top, and this can hardly be due to their destruction after consolidation, since the tests of *Globigerina* and also sharks' teeth have endured. This means, then, that benthic life was practically absent during its accumulation. The presence of bands of alternations of marly and chalky limestone proves that the limestone is not an abyssal deposit, but was laid down on the slopes of the continental shelf. The absence of benthic life is in accord with a hypothesis of the precipitation of a calcareous mud by the presence of solutions in the bottom waters inimical to animal-life. It is not necessary to postulate the presence of sulphur bacteria to produce such solutions, for it has recently been shown that albuminous bacteria can produce similar effects.

There is reason to believe that the formation of the flint took place soon after deposition, and before the beds were folded and jointed. The flints are themselves much jointed, and, moreover, in the overturned syncline between the upper Ure and Coverham the flint-beds overlie the limestone in the reversed upper limb and underlie it in the lower limb. Supposing the flint-beds to result from a downward migration of silica, it is very doubtful whether silica-bearing or other solutions could have passed freely through the marly limestones before these were jointed. It is noteworthy that the flint-beds are always associated with massive chalky limestones, and where these fail, as in the Herring River, there are no flint-beds. If, then, the alternations of chalky and marly limestone imposed an obstacle to the downward migration of silica, the flint-beds in the Mead section must result from the redeposition of the silica of only the lower 1,500 ft. of limestone, of which they compose the greater part. The amount of silica in these lower beds is so great that it could not be explained, apart from the chemical theory, without concluding that these beds were originally in large part radiolarian or diatomaceous oozes. Why such oozes should be so completely altered as to retain no evidence of a former organic origin is a problem which must be answered by the opponents of the chemical theory.

The above reasons seem to me to establish a *prima facie* case for the chemical precipitation of calcium carbonate during the deposition of the Amuri limestone. If this took place it is not difficult to believe that there was deposition also of magnesium carbonate or of dolomite in a similar manner. The chemical deposition of silica presents a greater difficulty to the imagination, and I do not consider that the evidence for this is so strong, although, as I have shown above, there are also difficulties in accepting any other explanation.

In seeking to infer the age of the Amuri limestone, the question arises whether it is a continuously-formed deposit or whether there may be within it disconformities or planes corresponding to periods of non-deposition. The junction between the limestone and the phosphatic greensand at the base of the Weka Pass stone in North Canterbury and South Marlborough appears to represent such a plane, since, although there is perfect parallelism of dip and strike of the two rocks in all exposures, the surface of the Amuri limestone is perforated by borings filled with glauconitic material and the loosened fragments of limestone lying at the base of the greensand are phosphatized.

Barrell (1918) has shown that in epicontinental beds, such as form the greater part of the geological record in North America, disconformities must be much commoner than was formerly supposed. These beds, however, were deposited in shallow epicontinental seas not often more than a hundred fathoms in depth. His conclusions cannot be made to apply to rocks such as compose the bulk of the Notocene in New Zealand, which have been deposited on a continental shelf fringing a deep ocean, and, for the greater part, on the outer slope of this shelf. Here, as Cotton (1918) has shown, when foreset beds fail through insufficiency of waste to compensate subsidence, or for other reasons, the deposition of pelagic beds immediately commences. It is difficult to imagine conditions which can bring about a disconformity between pelagic and foreset beds, such as exists at the above-mentioned junction. If the pelagic beds are in large part a chemical deposit, however, it is not difficult to imagine a change of conditions which would put a stop to chemical deposition, and the formation of purely organic ooze might be so slow as to allow time for the boring of the last-formed bed and the phosphatization of its upper surface before the deposition of the foreset greensand began.

The absence of other phosphatic layers in the Amuri limestone makes it probable that other similar disconformities do not exist, and the enormously greater thickness of the formation in the Mead area than of that at Amuri Bluff and farther south proves without any doubt that in the former area it must have taken much longer to accumulate. If, however, the limestone is in large part a chemical deposit, and if chemical deposition was more active in forming the lower part than the upper part, the time taken to form the greater thickness may not have been much more than twice that taken for the lesser thickness, although the ratio of the thicknesses is as four to one. The fact that in both areas the limestone is covered by the phosphatic greensands and the Weka Pass stone makes it probable that the top of the limestone is of the same age in both areas. Consequently the base of the limestone must be much older in the Mead area than it is at Amuri Bluff.

To believe with Woods (1917) that the Amuri limestone of the Mead–Coverham area is disconformable to the Clarentian and that it is Eocene places a much greater strain on the imagination than to believe that it is conformable and ranges in age from the top of the Clarentian to the base of the Oamaruian. It would mean that the Clarentian beds were emergent without tilting all through the Cenomanian, Turonian, Senonian, and Danian, and yet suffered no subaerial erosion such as would truncate their structures or dissect their surface, and that in the succeeding Eocene transgression so rapid was depression that there was no marine erosion or deposition of clastic beds, but instead the immediate formation of pelagic beds. It implies also that a similar succession of events happened at Amuri Bluff, except that emergence lasted only throughout the Danian and lower Eocene; but the depression, which was large and sudden, must have been much later than that in the Clarence area, since the limestone there is four times as thick. On the other hand, it is only to be expected that the deposition of pelagic beds was continuous on the outer slopes of the continental shelf which must have been formed immediately after the post-Hokonui deformations, and the differential movement of the Kaikoura deformations were certainly large enough to elevate even bottom-set beds above sea-level and certainly extended over a great part of the area covered by the Notocene continental shelf. There is thus no *a priori* reason why conformable pelagic and foreset beds extending from Clarentian to Oamaruian should not be found. The perfect conformity of the limestone to the Clarentian in the area where it is thickest—viz., from the Dee Gorge to Benmore—and the presence of apparent passage beds in the Isolated Hill Creek is most easily explicable on the theory of actual conformity.

The unconformity in the Herring River does not militate against the above conclusion. The limestone is here very thin, and consists of alternations of chalky and marly limestone which must be correlated with the similar band in the Bluff River and the upper of the two similar bands in the Mead Gorge. Two hypotheses in explanation are possible. The Clarentian beds may have been emergent during the period when the lower part of the limestone in the Mead Gorge was formed, or the upper part of the beds in the Herring River described as Clarentian may be foreset beds younger than the youngest Clarentian beds of the Coverham section. They consist of sulphur sands and mudstones similar to those of the Piripauan, and are followed by greensands as in the Piripauan. This resemblance may be more than accidental. The only Albian fossils found at this end of the valley come from beds near the base of the series.

The absence of flint-beds in the Herring River, however, and their presence in small amount under a small thickness of limestone in the Bluff River, makes it unsafe to predict that the beds immediately beneath the flint-beds of the Hapuku Mountains are Turonian. They may be also Clarentian and separated from the overlying limestone by an unconformity. In the Kekerangu area the limestone appears to be thin and separated by fairly thick mudstone bands, and again in the hills to the north of the lower Ure the limestone is quite thin. Obviously there is still a great deal to be learned about its thickness, nature, and relationships in East Marlborough, and any final conclusions about its age are premature.

The "Grey Marls."

The term "grey marls" was first applied by McKay to beds of more or less calcareous mudstone following the Weka Pass stone in the Weka Pass. Similar beds at Amuri Bluff had previously been termed the *Turritella* beds by von Haast, and the *Leda* marls by Cox, who correlated them with the so-called *Leda* marls of Whangape Lake, Waikato. The term "grey marls" was accepted by Hector and applied to beds of similar position and age throughout North Canterbury and Marlborough, and also, owing to a false correlation by McKay, to mudstones underlying the Ototaran limestones of Oamaru and South Canterbury. The "grey marls" were considered by Hector and McKay the closing member of the Cretaceo-Tertiary formation, the succeeding Mount Brown beds in the Weka Pass district being termed "Upper Eocene." So far as Marlborough is concerned, the Cretaceo-Tertiary formation of Hector and McKay had this justification: that the conformable Notocene sequence so far as known closed with the "grey marls," the great Marlborough conglomerate being considered unconformable, while the Awatere beds represented a younger Tertiary transgression. Outside the diastrophic district of North Canterbury and East Marlborough, in the South Island at least, no correlative beds of similar nature and position are known, and I suggested in 1916 that the term "grey marls" if confined to mudstones following the Weka Pass stone in this district remains a useful geological term, but that its usefulness is destroyed if it is used indiscriminately for Tertiary mudstones of any age or position.

The "grey marls" are generally fine-grained or sandy mudstones with little calcareous matter except as actual fossils, although concretions are sometimes found. They form cliffs of a grey colour, in opposition to the bluer and generally more calcareous Wanganuian papas of the North Island and of the Awatere series, and frequently exhibit the peculiar conchoidal weathering of indurated but massive mudstones, and seldom show shaly partings. Very frequently the beds become more sandy and may be described as muddy sandstones. Bedding-planes are in general obscure. Fossils are present in almost all exposures, but are often scanty and frequently crumbling. The larger fossils are chiefly molluscs and corals, while Foraminifera are in places plentiful. Echinoids are occasionally present, but brachiopods are almost absent.

In the Middle Clarence area I have studied these beds only in the Mead, Limburne, and Dee Gorges, and must rely on McKay's descriptions for other parts of the area.

Mead Gorge.—McKay describes the beds as "about 400 ft. of greenish-grey sandy marls, which contain concretions and a few fossils, not sufficiently well preserved to be of value in determining the age of the beds. Casts of *Dentalium* and *Solenella* were obtained, and fragments of a nacreous shell are abundant in some part of the softer beds."

The Mead Gorge flares out in crossing the "grey marls" and forms a sort of basin-shaped excavation, the sides of which are in great part slipped. A continuous section is exposed only at the top of the cliffs on the south side, but the cliffs are here practically unscalable. The junction with the Weka Pass stone is well exposed on the north side, the latter rock striking N. 18° E. and dipping 55° to the east. It is an argillaceous limestone, somewhat shaly, and passes up quite gradually into hard, somewhat fissile mudstones, of which only about 30 ft. are here exposed. On the south side the lower part of the "grey marls" is covered by slipped material, except near the top of the cliff. The upper part on this side appears to be quite conformable to the overlying great Marlborough conglomerate, but shows no well-defined bedding. There are a number of small greywacke pebbles in the uppermost part of the "grey marls," seeming to establish a passage to the conglomerate.

Fossils are present in the upper part of the "grey marls," both isolated and in concretionary blocks. It appears possible, however, that these blocks are not concretions *in situ* but are derived, for they are frequently angular in outline and exhibit the broken-off ends of shells on their exteriors. The blocks are small at a horizon 10 ft. from the top, but are as much as 18 in. in diameter at 100 ft. from the top. There are in addition many ellipsoidal and rope-like masses which appear to be concretions *in situ*.

From a horizon 130 ft. from the top I collected *Cardium patulum* Hutt. (?). A horizon 100 ft. below the top yielded *Voluta arabica* Mart., *Dentalium mantelli* Zitt., and *Paphia curta* Hutt. At 30 ft. I collected

Turritella murrayana Tate, *Polinices gibbosus* (Hutt.), *Siphonalia conoidea* Zitt. (?), *Miomelon corrugata* (Hutt.), *Ancilla hebera* Hutt., *Malletia australis* (Q. & G.), *Chione meridionalis* (Sow.) (?), and *Paphia curta* Hutt.: at 25 ft., *Turritella murrayana* Tate, *Ancilla hebera* (Hutt.), *Glycymeris globosa* (Hutt.), *Zenatia acinaces* (Q. & G.), *Dosinia magna* Hutt., and *Paphia curta* Hutt.; at 20 ft., *Clio* (*Styiola*) *rangiana* (Tate), *Turritella murrayana* Tate, *Ancilla hebera* (Hutt.), and *Limopsis aurita* (Brocchi). Other isolated fossils found in the slips included *Struthiolaria cincta* Hutt., *Ancilla pseudaustralis* (Tate), and *Limopsis aurita* Brocchi. One of the supposedly derived boulders yielded *Calyptraea maculata* (Q. & G.), *Ancilla hebera* (Hutt.), *Anomia walteri* Hector (?), *Glycymeris globosa* (Hutt.), *Mactra scalpellum* Reeve, and *Paphia curta* Hutt. Another similar boulder obtained from a slip contained *Turritella murrayana* Tate, *Calyptraea maculata* (Q. & G.), *Dentalium mantelli* Zitt., *Anomia walteri* Hector (?), *Glycymeris globosa* (Hutt.), *Mactra scalpellum* Reeve, and *Paphia curta* Hutt. All the above determinations and those that follow from the Dee Gorge were made by the late Mr. H. Suter.

Limburne Gorge.—The gorge of the left branch of the Limburne is narrow, and where it opens out on the "grey marls" is much slipped, so that no exposures *in situ* can be observed. The rocks present in the slips are mudstones of the usual type.

Dee Gorge.—In the north branch of the Dee the lowest beds of the "grey marl" series are separated from the Weka Pass stone by a fault of low angle. They consist of hard sandstones forming yellow cliffs, and are succeeded above by mudstones of the usual type. From the lower part of these, in cliffs on the south side, I obtained *Turritella murrayana* Tate. In the upper part of the mudstones, about 20 ft. below the top, there are thin bands of mudstone alternating with thin bands of sandstone containing plant-remains. There are also occasional small pebbles of greywacke in the mudstones and some thin beds of fine conglomerate. The junction with the overlying conglomerate is not seen at this point. From these upper mudstones I collected *Acmaea* or *Patella* n. sp., *Turritella murrayana* Tate, *Struthiolaria tuberculata* Hutt., *Polinices gibbosus* (Hutt.), *Siphonalia subnodosa* (Hutt.), *Dentalium mantelli* Zitt., *Glycymeris globosa* (Hutt.), and *Cytherea chariessa* Sut.

A little farther up the stream the junction with the conglomerate may be observed over a distance of about 12 ft. It is perfectly sharp at this point, and there is no bedding observable in the uppermost "grey marls," which are mudstones.

In the south branch of the Dee the hard sandstones at the base of the "grey marls" have the same dip and strike as underlying Weka Pass stone, but the actual junction is not seen. In a subsequent stream entering this branch from the south-west along the strike of the "grey marls" the latter series appears to be about 300 ft. thick. The lower beds on the south-east side are hard sandstones, while the upper beds on the opposite side are softer mudstones, in which, however, no shell-beds were observed. The junction with the overlying conglomerate is exposed, and appears to be a gradual passage, lenses of fine conglomerate appearing in the upper few feet of the mudstones.

In a second small subsequent tributary entering the south branch farther up on the same side there are a few lenses of sandstone near the top of the "grey marls," but no shell-beds. A crinoid stem was collected about half-way up this creek. The uppermost mudstones contain pebbles of greywacke, and there is a good deal of mudstone in the bottom of the conglomerate.

McKay does not describe the "grey marls" in the Dee River, but his section represents the junction with the overlying conglomerate as unconformable, the erosion surface on the "grey marls" being gently undulating.

Upper Swale and Ure Rivers.—McKay describes the "grey marls" on the western side of the Chalk Range as blue or greenish-grey unfossiliferous marly beds, about 300 ft. thick, resting conformably on the Weka Pass stone. They are repeated by folding or faulting farther to the westward.

Farther to the north-east the "grey marls" apparently disappear through the pitching of the inverted syncline to the south-west, Amuri limestone being continuous across the Ure River from Brian Boru and Isolated Hill to the White Bluffs. In the middle Ure, below the gorge, I have already described the beds which underlie the Amuri limestone, but which, owing to the probable inversion of the strata, may represent the Weka Pass stone and "grey marls."

Dart River.—McKay describes the "grey marls" as about 500 ft. thick and resting conformably on the limestone. Fossils occur as nests in and sparingly distributed through the grey or greenish marly clays, including *Galeodea senex* Hutt., *Ancilla* sp., and *Pecten* aff. *zitteli* Hutt. Fine-grained concretions similar to those in the Mead Gorge are found, but do not yield fossils.

Muzzle River.—Here again the "grey marls," according to McKay, are about 500 ft. thick. Resting on the Amuri limestone is a band of tufaceous calcareous greensand with *Waldheimia* sp. and *Cristellaria haasti*. Higher beds consist of dark-grey or greenish sandy clay, parted by thin beds of calcareous sandstone, some of which are richly fossiliferous and yielded *Cristellaria haasti*, *Pecten zitteli*, *Venus* ? sp., a small, strongly-ribbed *Pecten*, small univalves, *Rhynchonella* sp., and Echinoid fragments.

Bluff River.—McKay does not describe the nature or thickness of the "grey marls" in this section, but mentions the occurrence of *Pecten zitteli* and *Galeodea senex*, with casts of *Malletia*, *Leda*, corals, &c.

Herring River.—McKay does not describe the "grey marls" in this area, but his section shows their presence between the Weka Pass stone and the great Marlborough conglomerate, and they are enumerated as "grey marls containing *Dentalium*, *Natica*, Foraminifera." In describing the conglomerate, he mentions that at the top of a high cliff on the left of the junction of the Herring River with the Clarence River the Weka Pass stone is in contact with the older rocks (pre-Notocene) along the fault-line, and this I also observed. At lower levels McKay describes an agglomerate resting on the "grey marls," and consisting of blocks of Amuri limestone, Weka Pass stone, saurian concretions, and blocks and concretions of middle Tertiary rock without any evidence of stratification. He seemed uncertain of their dip, but estimated the thickness at 200 ft., and considered them involved in the fault-angle. It is difficult to see how, if the Weka Pass stone, which is dipping towards the fault, rests against it at the top of the cliff, younger beds can be present against the fault at lower levels. McKay did not recognize the layer of mudstone, similar to the "grey marls," which separates the Weka Pass stone in this area into an upper and lower band, and I believe he has taken an exposure of this rock for the "grey marls" and has mistaken a talus deposit for the great Marlborough conglomerate. In this case the "grey marls" are absent in this section. A closer study of the upper beds of this area is desirable.

Age and Formation of the "Grey Marls."—Owing to the great range of the majority of Oamaruian Mollusca, the list of fossils so far collected from the "grey marls" is insufficient in itself to prove whether the beds are Lower, Middle, or Upper Oamaruian. If, however, a correlation with the "grey marls" of the Weka Pass district is admitted, it is necessary to consider them Middle Oamaruian or Ototaran, since in that locality they are followed by the Mount Brown beds, the uppermost limestone band of which is Awamoan, and the middle or main band Hutchinsonian on the evidence of the rich brachiopod fauna. It is, indeed, possible that part of the Mount Brown beds is Ototaran, so that the "grey marls" can hardly be younger than that stage.

According to diastrophic considerations, the presence of thick beds of mudstone following limestone in such a series as the Notocene is evidence of a gradual sea-retreat, causing renewed denudation of the thick soil-mantles accumulated on the peneplained land which formed the coasts of the middle Notocene seas. If this sea-retreat is in the main due to movements of the hydrosphere, then the correlation of the "grey marls" throughout North Canterbury and Marlborough appears well based. The uniform lithological characters of the upper part of the Amuri limestone, the phosphatic greensand, the Weka Pass stone, and the "grey marls" throughout these areas supports the belief that the changes of the deposits are mainly due to movements of the hydrosphere. The chief difficulty lies in the conception of gradual emergence in the district north of the Rakaia River at the very time (Ototaran) when there was greatest submergence south of that river. Perhaps the true explanation is that the whole of the Ototaran is comprised within the Mount Brown beds, which were formed in a period of renewed depression. This would involve the consideration of the "grey marls" as Waiarekan, but there would still be the difficulty of the gradual emergence in the northern district at the time of a marine transgression in the southern area, so that there seems no escape from an hypothesis of warping in minor diastrophic districts, to some extent masking the effects of movements of the hydrosphere.

The Great Marlborough Conglomerate and Awatere Beds.

The conglomerate which closes the Notocene series in the greater part of the Middle Clarence Valley (Plate XXIX, fig. 1), in common with similar conglomerates in other parts of Marlborough, was termed by McKay the "great post-Miocene conglomerate," from the belief that certain Tertiary sandstones which occur as boulders within it were of Miocene age. The Miocene of Hector and McKay's classification comprised the beds now classed as Awamoan and Waitotaran, the latter stage being later than Miocene, so that the name used for the conglomerate is unsuitable. Although McKay considered that the conglomerate contained boulders of sandstones of the Awatere series, which ranges from Awamoan to Waitotaran, there is reason to believe that in the Clarence Valley there are no boulders of rocks younger than Oamaruian in the conglomerate, which itself appears to be an Oamaruian rock. It is preferable, therefore, to use a local name for the rocks, and I suggested in 1913 the alteration of McKay's name to "great Marlborough conglomerate." Under the latter name Cotton in 1914 described fully the nature of the conglomerate and discussed its relationship to the underlying formations in the Mead and Dee Gorges, and for these localities I have little to add to his account, which is freely quoted below.

McKay's conception of the conglomerate as post-Miocene necessarily involved a considerable unconformity between it and the "grey marls," which he classed as Cretaceo-Tertiary. Perhaps in consequence of this he did not examine the junctions between the two rocks very carefully. In all his sections the conglomerate is shown as resting unconformably on the "grey marls," generally with very slight truncation of the beds of the latter, but in the Mead Gorge the truncation shown is very marked. Hector's section shows the conglomerate overlapping the "grey marls" on to the Weka Pass stone, but this is in marked disagreement with his plan. Dr. Cotton and I examined carefully all the exposed junctions in the Mead and Dee Gorges and could find no evidence of unconformity. If there is any, it is more probably between the upper and lower parts of the rocks above described as "grey marls," for a violent unconformity may escape recognition in mudstone cliffs. The upper "grey marls" are certainly Oamaruian, so that even were an unconformity present below them the conglomerate would still be much older than McKay supposed.

Cotton (1914) has discussed the question of the unconformity of the conglomerate fully, and has shown how a false impression of unconformity in the Mead Gorge may be received. In the first place, owing to the widening-out of the gorge where it crosses the outcrop of the weak "grey marls," the junction has an apparent dip which the eye is tempted to compare with the true dip of the Weka Pass stone as seen below on dip slopes. In the second place, the surface of the junction, originally plane, is now broken by a number of small faults, giving it an undulating form in section. Cotton records the strike of the junction plane as N. 25° E., and the dip as 47° to the west-north-west. My observation of the strike of the Weka Pass stone was N. 18° E., and the dip 55° to the west-north-west. The slight differences between these figures are less than occur within similar thicknesses of the Amuri limestone lower down in the section.

A further argument in favour of conformity is the presence of greywacke pebbles and of plant-bearing sandstones in the upper "grey marls" of the Mead section, and of conglomerate lenses in a similar position in the Dee section. Hector has described similar plant-bearing sandstones at the base of the conglomerate in Shades (? Deadman's) Creek and in Heaver's Creek. In the latter locality I was unable to separate these from the upper "grey marls." In the Mead section their intercalation with Oamaruian mudstones is certain.

In almost all exposures McKay records the presence of crystalline rocks belonging to the intrusive dykes which seam the pre-Notocene rocks in the Tapuaenuku massif. A careful examination of all the exposures in the Mead, Dee, and various exposures near Kekerangu convinced Dr. Cotton and myself that these rocks are practically absent, or at least rare. In almost all exposures there are small boulders of doleritic and porphyritic igneous rocks which bear a closer resemblance to the Clarentian volcanic lavas of the Clarence and Awatere Valleys than to the intrusives, and syenites such as compose the bulk of the upper part of the Tapuaenuku massif appear to be quite absent. McKay considered that the crystalline material in the gravels of the Swale and Ure Rivers was derived from the conglomerate; but in the latter river this is certainly not the case, the bulk of the material coming from the dark, coarse-grained dolerite of the Blue Mountain, of the existence of which McKay was not aware.

Mead Gorge.—As already mentioned, the upper part of the "grey marls" contains pebbles of greywacke, and concretionary masses with fossils which may possibly be derived boulders. Cotton describes the basal layer of the conglomerate as a bed 2 in. thick of conglomerate formed of small rounded pebbles of greywacke. "Next follows 2 ft. 6 in. of bedded sandstone, covered by 1 ft. of mudstone, and that again is followed by many feet of fairly coarse conglomerate interbedded with sandstone and mudstone bands 1 ft. to 3 ft. in thickness, and with bands of very coarse conglomerate." The boulders in the conglomerate bands are of varied sizes, about one-third being over 6 in. in diameter, and blocks of to 2 ft. in diameter being common. Still larger blocks occur, but are rare. Small pebbles of greywacke are very abundant throughout, and are smooth and well-rounded. "There is in addition a large proportion of fine, sandy material filling the interstices, and the conglomerate is cemented into a very hard rock." The rocks represented are—pre-Notocene greywacke and jasperoid pebbles, forming the bulk of the finer material; sandstone blocks of all sizes, probably mostly Clarentian; small boulders of basalts resembling those of the Clarentian of Herring River and Mouat's Lookout in the Awatere Valley; Amuri limestone, not very abundant, in blocks up to 6 in. in diameter, but rarely larger; water-worn blocks of fine Tertiary sandstone, crowded with shells, and resembling in appearance and fossil-content the supposedly derived boulders in the underlying "grey marls."

Dee Gorge (Plate XXIX, fig. 2).—The lower part of the conglomerate is very well bedded by thin sandstone bands. The material is generally similar to that in the Mead, and the presence of Clarentian rocks is proved by the presence of blocks of sandstone containing fragments of *Inoceramus*. A very large block of flint-beds was observed near the base on the north side, but in general the size of the boulders, as in the Mead, is smaller than in the exposures of the Kekerangu area. For further details Cotton's description should be consulted.

Upper Swale and Ure Rivers.—There are several separated outcrops of the conglomerate in the upper Swale Valley, presumably owing to its repetition of folds or faults, but their relations are unknown except in the case of the most easterly, which McKay examined and found resting on the "grey marls." Mr. A. Tomlinson, of Awapiri, Awatere Valley, informs me that these conglomerates are reddish in colour and form three sharp ridges known as the Razorbacks. In the upper Ure, as seen from the summit of the Chalk Range, there is a main outcrop of conglomerate running from behind the Whaleback across the river and terminating opposite Whitewash Creek. This outcrop evidently occupies the core of the overturned syncline. Two smaller outcrops are seen on the watershed between the Ure and the Swale, dipping towards Limestone Hill, which is formed by the Amuri limestone of the upper limb of the syncline.

Dart River.—McKay describes the conglomerate as resting on the "grey marls." The series is 500 ft. thick, and dips 50° to 60° to the north-west. The lower beds are coarser than the middle and upper parts. In the middle beds there are gritty sandstones with broken shells and black shales with abundant plant-remains forming coaly streaks. The upper part, which is well stratified near the top, is mainly formed of moderate-sized pebbles, with beds of black shale.

Muzzle River.—McKay describes the beds as of about the same thickness as in the Dart and the Dee. In the west branch they are standing vertical and rest against the fault. In the eastern branch they form a syncline resting on the "grey marls," and the junction along the fault is obscured. Fossiliferous blocks of Tertiary rocks and concretions and fossiliferous blocks from the Clarentian are abundant in both sections.

Bluff River.—McKay describes the conglomerate as much thicker than elsewhere to the north-east, and as very coarse in its lower part, containing blocks of Amuri limestone 10–35 ft. in diameter, together with boulders of Clarentian rocks and fossiliferous Tertiary concretions mingled with well-rounded pebbles of sandstone and volcanic rocks. The higher beds of the conglomerate are much finer than the middle and lower parts, and alternate with beds of sandstone, forming a passage to an overlying series of sandy clays with ribs of hard sandstone which are difficult to distinguish from the "grey marls."

Seymour River.—As has already been stated in describing the "grey marls," it appears improbable that the great Marlborough conglomerate is present in this section, and more likely that the agglomerate described by McKay really represents an old talus deposit. The only doubt is caused by his reference to the presence of "blocks and concretions of middle Tertiary rock."

Deadman's Creek.—Although this section lies outside the area here described, the relationships of the great Marlborough conglomerate are of great importance in any discussion of its origin. Deadman's Creek lies immediately south of Deadman's Hill on the coast south of Kekerangu. Hector and McKay have referred to it as Shades Creek, but the true Shades Creek is still farther to the south.

The sequence commences with Amuri limestone or Weka Pass stone, here argillaceous and with many layers of mudstone. This dips north-west —*i.e.*, up-stream—and is succeeded by "grey marls." Above this comes a strong band of the great Marlborough conglomerate, some hundreds of feet thick. Unfortunately the junction with the "grey marls" is obscure, but the lower 15 ft. of the conglomerate consists of fine sandstones. The succeeding 60 ft. of the conglomerate is fairly coarse, although blocks larger than 3 ft. in diameter are rare. The majority of the boulders are well rounded, and they consist preponderatingly of pre-Notocene greywackes and jasperoids and Clarentian sandstones. Volcanic rocks similar to the Clarentian lavas are commoner than usual. Boulders of Amuri limestone are moderately abundant, and flints are occasionally seen. Boulders of fossiliferous Tertiary sandstone are not very common, and are generally of small size and uniform in character.

The gorge of the creek in the conglomerate is impassable, and the creek-bed below is described by McKay as "choked with huge fossiliferous blocks from 3 ft. to 15 ft. in diameter, from which a collection of Awatere fossils of such variety and excellence could be made that the like could not be obtained from any one locality where the beds occur *in situ*." Hector agrees with McKay in believing that these blocks are derived from the conglomerate. As a matter of fact, no blocks of such size were observed in the conglomerate, and those in the creek-bed are undoubtedly derived from a series of shell-beds *in situ* apparently resting on the conglomerate. To these I have given the name of the Deadman's Creek beds. They consist of sandstones crowded with shells along certain layers, some bands containing predominantly *Polinices*, others *Turritella*, and others *Glycymeris*. About 100 ft. of these beds are exposed in the cliffs, and another 100 ft. along the creek-bottom, where they contain pebbles, the majority of which are of greywacke and quartz, but one pebble of basalt was observed, and some blocks of fossils, apparently derived. The junction of these beds with the underlying conglomerate was not clearly made out. The dip of the two rocks is the same—about 60° up-stream—and in the cliffs they appeared to be conformable, but in the bottom of the creek the junction appeared to be faulted.

From these Deadman's Creek beds I collected fossils, which were determined by the late Mr. H. Suter as follows: *Turritella murrayana* Tate, *T. concava* Hutt., *Struthiolaria tuberculata* Hutt., *Polinices gibbosus* (Hutt.), *Siphonalia subnodosa* (Hutt.), *Voluta arabica* Mart., *V. depressa* (Suter), *Glycymeris globosa* (Hutt.), *Dosinia greyi* Zitt., and *Protocardia sera* Hutt. This is certainly an Oamaruian assemblage, and very similar to that of the sandy shell-beds of the White Rock River (Awamoan).

The cliffs farther up the stream are slipped for some distance, and there is a gap in the observable succession corresponding to about 100 ft. of rock with the same dip. Then another band of the great Marlborough conglomerate appears, about 600 ft. thick, dipping about 60° to the north-west (up-stream). This is similar in character to the first-mentioned band, and passes up gradually into a very regularly bedded series of thin sandstones and fine conglomerates with occasional layers of mudstone, passing in turn up to massive mudstones in the Ericaburn. Above this the dip becomes reversed, and the mudstones can be again traced downwards into sandstones and thin conglomerates. Beyond this there is a break in the observable succession, and massive mudstones with large calcareous concretions and a few friable fossils form large cliffs in the Ericaburn about half a mile above its junction with Deadman's Creek, and present a great resemblance to the Awatere mudstones in the upper part of Starborough Creek (Awatere Valley). The thickness of the beds above the conglomerate up to the point of reversal of dip was estimated at about 700 ft.

It is exceedingly unlikely that there are two bands of great Marlborough conglomerate separated by 300 ft. of marine sandstones, and it is almost certain that a fault intervenes between the two outcrops. The boulders of fossiliferous Tertiary sandstones in the conglomerate are so similar to those formed by the present creek from the Deadman's Creek beds that it seems exceedingly likely that it is to these latter beds that we must look for the source of the boulders of the conglomerate in this locality. In this case a fault must be interposed just above the lower conglomerate, and the Deadman's Creek beds must be regarded as a facies of the "grey marls."

Origin and Age of the Great Marlborough Conglomerate.—Both Hector and McKay regarded the great Marlborough conglomerate as fluviatile in origin. "This singular conglomerate probably originated through erosion by a great river-system which has since disappeared, and the subsequent dislocation of the land-surface that it had covered with its alluvial detritus in the form of shingle river-beds and great fan-shaped accumulations spread out into the plains" (Hector, 1886, p. xxxvi). McKay (1892, pp. 4–5) described the rocks as having usually the character of glacier morainic matter and more or less well-rounded river-gravels. "On the whole it is a drift formation, and the evidence is conclusive that the drift of the material was from south to north, or from the south-west to the north-east." The evidence for this drift he found in the nature of the fossiliferous Tertiary sandstones which were not found *in situ* in the area occupied by the conglomerates but closely resembled rocks developed in the Mason River and Lottery Creek, far to the south-west, and also in the presence in the coastal area near Kekerangu of boulders of the Tapuaenuku intrusives. We have already seen that this assumption is unnecessary, since the Deadman's Creek beds to the north-east consist of fossiliferous

Tertiary sandstones, and there are probably other beds of a similar nature as yet undiscovered in other parts of the area embraced by the outcrop of the conglomerate. There are also a small number of blocks of Tertiary sandstone in the upper part of the "grey marls" in the Mead and Dee Gorges.

Park (1910), who examined only the exposures of the Kekerangu River and Deadman's Hill, concluded that the conglomerate was a glacial moraine of Pleistocene (early Notopleistocene) age. This hypothesis involves the formation of the great Clarence and other faults in the late Notopleistocene, and is quite untenable. In any case, the evidence for the fluviatile origin of the lower beds of the series is overwhelming.

Cotton (1914) agrees with Hector and McKay that the conglomerate as developed in the Middle Clarence Valley is of fluviatile origin, but considers it not necessarily the work of a single river. The line of outcrop thirty miles in length indicates that it was there deposited as a piedmont alluvial plain and not as isolated fans. The evidences of fluviatile origin are chiefly the rough sorting of the material into coarser and finer bands, and the presence of fine regular sandstone bands, often lenticular, coupled with an absence of distinct false bedding or an arrangement of foreset beds that would indicate beach or delta conditions of subaqueous deposition. The character of the conglomerate presents striking analogies with the terrestrial deposits in Owen's Valley, California, and satisfies most of the criteria drawn from the study of alluvial and fan deposits.

As has already been stated in the general account of the geology and physiography, Cotton accounts for the peculiar features of the conglomerate—viz., that it lies conformably on the "grey marls" but contains materials of all the underlying Notocene beds—by assuming that a neighbouring area was differentially elevated to the extent of perhaps as much as 12,000 ft. without seriously disturbing the horizontal altitude of that portion of the Notocene series which, a little later, had the conglomerate deposited upon it. Since folding and warping seem to be out of the question, as the surface of the "grey marls" is not appreciably tilted, he concluded that the differential movement must have been block-faulting, with the restriction that the uplifted block alone moved. The presence of small normal faults dislocating the conglomerate and "grey marls" is held to be significant in this connection, since block-faulting usually takes place along normal faults, and for a long period after the main faulting the formation of small normal faults continues, dislocating the fan deposits resulting from the erosion of the earlier fault-scarp. Cotton, it should be noted, confined his explanation solely to the conglomerate as developed in the Mead and Dee Gorges. Whether it is equally applicable to all other exposures of the conglomerate cannot be decided without a much more intensive study of these exposures than has yet been made, but its frequent if not invariable association with the "grey marls" is significant.

In all the exposures in the Clarence Valley, and in the majority elsewhere, the conglomerate rests on a surface of the "grey marls." The chief exceptions, as described by McKay, are at Greenhills (south of the Looker-on Range), in the Kekerangu River, and in the hills between Ward and Lake Grassmere. At Greenhills McKay's section (1886, p. 81) shows it resting, apparently conformably, on the Amuri limestone, but he states that "somewhat obscurely conglomerates are seen on the east side of the saddle mentioned, and it is at the same time quite apparent that the limestone could not terminate in the manner it does without being suddenly cut off by a fault somewhat in the manner shown in the following sketch" (the section above referred to). It is quite possible, therefore, that here also the "grey marls" are present. In the Kekerangu River McKay and Hector represent the conglomerate as resting with marked unconformity on a surface of pre-Notocene rocks, but McKay remarks that "from the absence of Amuri limestone and Awatere rocks the evidence that these [conglomerates] are identical with those in Heaver's Creek is not quite conclusive." I observed three bands of conglomerates in going down the Kekerangu Gorge. The first two resemble the pebbly mudstone of the Clarentian, the third and thicker band resembled more the great Marlborough conglomerate, but appeared to be faulted down among the pre-Notocene rocks. The relations of the outcrop near Lake Grassmere are not at all well known. In searching for it in 1912 I ascertained that part of the area mapped by McKay as great Marlborough conglomerate is in reality occupied by the basal Clarentian (?) conglomerates of the Notocene series forming the hills to the eastward from The Rocks to beyond Ward, so that the great Marlborough conglomerate may in this locality form a narrow strip interposed between the Awatere beds and the Clarentian (?) rocks. It appears probable that it is here involved along the fault-line which separates the Awatere and Cretaceous rocks between Ward and The Rocks. In all the other known outcrops of the great Marlborough conglomerate on the coast near Kekerangu, in Heaver's Creek, and in Deadman's Hill and Deadman's Creek it is resting on the "grey marls," as it does in the Clarence Valley. This is very significant, because the "grey marls" form a very weak stratum and are now almost everywhere deeply eroded compared to the neighbouring Amuri limestone and pre-Notocene rocks. If the great Marlborough conglomerate were so much younger than the "grey marls," as McKay supposed, and the latter were emergent during a considerable part of the Tertiary, one would expect to find the conglomerate at least as frequently on the Weka Pass stone or Amuri limestone as on the "grey marls." I am disposed, therefore, to accept the conformity of the conglomerate with the "grey marls" not only in the Clarence Valley but in the coastal area near Kekerangu. This involves the ascription to it of an age similar to that of the Mount Brown beds in North Canterbury, which follow the "grey marls" conformably —*i.e.*, Upper Oamaruian.

The relationship of the great Marlborough conglomerate to the Awatere series thus becomes of interest. The upper Awatere beds near Seddon are Waitotaran, but the lower beds in Tachall's Creek, near Ward, contain Oamaruian molluscs, and are probably at least as old as Awamoan. The junction of these lower beds with the Clarentian of the hills north of the Ure River could not be observed, and, as no conglomerates were seen, it is possibly faulted. In the Awatere River, near the Jordan accommodation-house, the basal Awatere beds consist of conglomerates and sandstones, and rest with marked unconformity on the pre-Notocene rocks, while all the pebbles in the conglomerates are of pre-Notocene rocks. In the lower beds in the Medway River Mr. L. J. Wild collected species of *Cucullaea*, so that these too appear to be Upper Oamaruian. The Awatere beds appear to be repeated with exactly similar relationships in the blue cliffs forming the north-west corner of Palliser Bay. There is a thin basal conglomerate resting unconformably on an unweathered surface of greywackes and argillites. The succeeding mudstones contain an Oamaruian fauna, while the higher mudstones near the Ruamahanga River contain a Waitotaran fauna. Obviously, then, in the north-eastern part of the South Island and the south-eastern part of the North Island a marine transgression commenced in the Upper Oamaruian and continued into the Waitotaran. It appears to have covered areas of pre-Notocene rocks not submerged in the earlier Notocene transgressions, since no boulders of these rocks are found in its basal conglomerates so far as examined, and this could hardly be the case if a cover of Notocene from Clarentian to Oamaruian had been stripped off the pre-Notocene. The Awatere series is absent from the upper part of the Awatere Valley, and probably never covered this area, since in the lower valley the beds are involved along the Awatere fault and it would be reasonable to expect to find them similarly involved in the upper valley if they were ever present there. It appears, therefore, as if differential earth-movements were at least a partial cause of the Awatere transgression. We have, then, an emergence of the Clarence and Kekerangu areas during the formation of the great Marlborough conglomerate, and a transgression of the sea over the Awatere area, and both these events took place in the Upper Oamaruian. It appears that they followed one another in the order named, and that the Awatere transgression affected the Clarence and Kekerangu areas.

In Deadman's Creek the upper outcrop of conglomerate is followed by a well-bedded marine series of sandstones and fine-grained conglomerates passing up into mudstones. The geology of the area between the upper part of Deadman's Creek and Clarence Mouth is unknown, but from the accounts given me by settlers it seems that there is a considerable extent of blue mudstone, or "papa," containing fossils at Parakawa. The marine rocks following the conglomerate can hardly be other than the representatives of the Awatere transgression, which may have a considerable development in this district From McKay's descriptions it is evident that similar rocks are present following the conglomerate in the Bluff River. He states that these beds are so like the "grey marls" in appearance that it is hard to distinguish them. As at Deadman's Creek, they are separated from the coarser layers of the conglomerate by beds of sandstone and fine conglomerate. Obviously the evidence of fossils is necessary to confirm this correlation of the marine beds above the conglomerate with the Awatere beds.

The existence of these overlying marine beds proves that the Clarence and Kekerangu areas, in which a fluviatile deposit was forming, gradually became submerged. The presence of a fairly thick series of sandy mudstones at the Bluff River suggests that the submergence was considerable—at least over 600 ft.—since the beds are apparently foreset, and that the continental shelf of which they formed a part had an abundant supply of fine waste. Cotton estimated the differential movement necessary for the formation of the conglomerate as perhaps as much as 12,000 ft. (the maximum thickness of the Notocene up to the top of the "grey marls"), but, as the average thickness of the Clarentian is only about 3,000 ft., a differential elevation of 6,000 ft. would be sufficient to account for the features of the conglomerate. If the elevated area were also tilted, as is conceivable, an elevation of half this amount might suffice. In the formation of 400–600 ft. of conglomerate the relief of this elevated area, especially near the fault-scarp, would be considerably reduced, and by a subsequent drowning of, say, 1,000 ft. the relief would be further reduced. The nature of the beds of the marine series following the conglomerate is not inconsistent with Cotton's explanation of its origin. Although it is not necessary to conclude that the conglomerate was everywhere submerged and covered with the marine beds, it appears quite probable that this was so. The physiographical evidence is consistent with the supposition that a regional or very slightly differential elevation preceded the main Kaikoura deformation, and from the coastal plain thus formed the overlying soft mudstones and sandstones might be largely stripped by subaerial erosion before the involvement of the Notocene along the great Clarence and other faults. In any case, it could only be by a favourable sequence of events that such beds, if involved, could be preserved during the subsequent erosion that has occurred. If they had been so involved and subsequently eroded, there would be at first a fault-line scarp formed, and the steep scarps south-westward from the Dee may be, in part, of this nature.

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POSTSCRIPT (FEBRUARY, 1919).

After the above paper was written I had an opportunity of spending two days at the Awapiri out-station in the upper valley of the Swale. The structure of the Notocene rocks in this area proved much too complex to unravel in the time available, but the following points were ascertained. At the upper end of the Swale limestone gorge the upper part of the Amuri limestone rests against the great Clarence fault without the interposition of the "grey marls" and great Marlborough conglomerate. Farther to the north-east an alternation of Amuri limestone and conglomerate occurs, doubtless due to faulting, so that the limestone is repeated at least three times. From a stratigraphical point of view the most interesting fact ascertained was the presence of a mudstone resembling the "grey marls" and containing rare Oamaruian fossils, which apparently lies between the limestone and the conglomerate. This mudstone is in places crowded with small and large rounded boulders of Amuri limestone. This observation points to the probability of an unconformity between the "grey marls" and the lower beds. I hope to have an opportunity of revisiting this area in the near future and furnishing a connected account of its structure and stratigraphy.

ART. XXXIII.—*Descriptions of New Zealand Lepidoptera.*

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

Communicated by G. V. Hudson, F.E.S.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 12th February, 1919; issued separately, 28th July, 1919.*]

THESE notes are based as usual on material kindly sent by Messrs. Hudson and Philpott, and include ten new species. The discovery of an example of the Diplosaridae shows that the possibilities of surprise are not yet exhausted.

CARADRINIDAE.

Aletia falsidica Meyr.

A ♂ (36 mm.), received from Mount Earnslaw (Hudson), has antennae shortly bipectinated (*a* 1, *b* 1½), towards apex simple: this character establishes the distinction from *grisceipennis*, which has antennae of ♂ simple.

HYDRIOMENIDAE.

Chloroclystis semochlora n. sp.

♂♀. 26–28 mm. Head, thorax, and abdomen green, patagia tipped with grey hairs beyond a black bar. Palpi 2, green, tip whitish. Antennal ciliations fasciculated (3½). Forewings broad-triangular, termen hardly waved, rounded, rather oblique; green; basal, second, and third fasciae deeper olive-green, especially third, somewhat curved, waved, slightly marked with black on edges, third preceded and followed by slight whitish suffusion in disc; fourth fascia composed of three waved slightly curved somewhat darker lines, edged posteriorly above middle by a curved black line edged with white posteriorly and followed by a roundish grey spot becoming whitish anteriorly; fifth fascia indicated by small black marks between this spot and costa, elsewhere by faint traces of whitish lines and some black marks on veins; subterminal line pale bluish-green, waved-dentate; a fine black interrupted terminal line: cilia pale-greyish, towards base triangularly barred with darker grey. Hindwings with termen rather unevenly rounded; grey-whitish, on dorsal half with more or less marked grey waved transverse lines, two of these towards tornus suffusedly blackish on dorsal area; a grey terminal fascia enclosing a waved-dentate whitish line; lower half of termen sometimes suffused with light green; a fine interrupted blackish terminal line: cilia pale grey, with indications of darker bars.

Mount Egmont, 3,000 ft., in February (Hudson); two specimens. Sent with *paralodes* (to which it is nearest) and regarded as a form of it, but larger, greener, and quite distinct by absence of black band on abdomen, broader wings without the black markings of *paralodes*, but with a characteristic grey spot beyond median band, and somewhat shorter fascicles of antennae.

Xanthorhoe eupitheciaria Guén.

Closely related to *cinerearia*, but slightly larger, apex of forewings somewhat more pointed and termen less rounded, ground colour of forewings and hindwings whitish, not appearing grey.

I have regarded this as the mountain form of *cinerearia*, but Mr. Philpott is, I believe, of opinion that it is specifically distinct, and this is probably correct. If so, the name *eupitheciaria* Guén. is properly applicable to it; Walker's synonyms are, according to my notes, all referable to *cinerearia* proper. I possess *eupitheciaria* from Mount Arthur, Mount Hutt, and Lake Wakatipu (3,000–4,000 ft.), and it seems common in the mountains of the South Island.

Xanthorhoe obarata Feld.

I agree with Mr. Philpott's suggestion that *X. cymozeucta* Meyr. is only a synonym of *X. obarata* Feld. My examples of *X. obarata* were old and not in very good condition, but I think there is no true distinction.

SELIDOSEMIDAE.

Selidosema prototoxa n. sp.

♀. 31 m. Head and thorax whitish-grey, partially tinged with brownish, with scattered black specks. Palpi $2\frac{1}{2}$, grey. Abdomen pale greyish-ochreous, sprinkled with fuscous on basal half. Forewings somewhat elongate-triangular, termen rounded, rather oblique; pale fuscous, strewn with irregularly scattered black specks, longitudinally suffused with pale grey (faintly greenish-tinged) in disc above middle, and irregularly on subdorsal area: a short suffused black submedian streak from base; first line dark fuscous, from $\frac{1}{4}$ of costa to $\frac{1}{5}$ of dorsum, acutely angulated in middle, lower half slightly curved; median fuscous, nearly straight, rather irregular; second line dark fuscous, from $\frac{2}{3}$ of costa to $\frac{3}{4}$ of dorsum, rather incurved, more strongly on lower half, nearly followed by a thick parallel dark-grey shade; subterminal line slender, whitish, edged with dark fuscous, nearly obsolete towards middle, strongest near dorsum; some white subdorsal suffusion between these lines, strongest before subterminal; teeth of subterminal line connected with termen by more or less marked blackish interneural streaks: cilia pale-greyish (imperfect). Hindwings with termen unevenly and irregularly rounded; pale-greyish, with indistinct darker specks, more distinct and blackish-tinged towards termen: an indistinct waved grey subterminal line: cilia pale-greyish.

Tokaanu, in April (Hudson); one specimen. The black basal streak and peculiar form of first line make this species very distinct.

CRAMBIDAE.

Crambus meristes n. sp.

♂♀. 16–19 mm. Head, palpi, and thorax dark brown, palpi whitish towards base beneath. Abdomen dark grey. Forewings elongate, posteriorly dilated, costa slightly arched, apex obtuse-pointed, termen slightly rounded, somewhat oblique; dark brown; a moderate ochreous-white median longitudinal streak from base to termen, slightly narrowed towards extremities: cilia grey. Hindwings dark grey: cilia grey or whitish-grey, or in ♀ whitish, with grey subbasal line.

Longwood Range, 2,700 ft., in December (Philpott): seven specimens. Sent (together with examples of *aulistes* and *saristes* from other localities) by Mr. Philpott as *aethonellus*, showing that his remarks in *Trans. N.Z. Inst.*, vol. 49, p. 215, are founded on misconception of these species, which are closely allied but distinct, and seem not to occur together. I therefore indicate the points by which these three other species may be clearly separated from *meristes* and one another—viz., *aethonellus* by the defined white line along costa throughout, *aulistes* by the white line on posterior half of costa only (sent by Mr. Philpott from Flagstaff Hill), and *saristes* by the peculiar form of median streak, which has the terminal fourth suddenly much more slender, the end of the preceding portion tending to show a slight pointed projection beneath it (this is the Seaward Moss species). True *aethonellus* I have from Mount Hutt and Takitimu Mountains.

TORTRICIDAE.

Tortrix antichroa n. sp.

♂. 16 mm. Head light grey. Palpi $2\frac{2}{3}$, whitish-ochreous suffused with pale grey. Antennal ciliations $1\frac{1}{3}$. Thorax yellow-ochreous. Abdomen rather dark grey. Forewings suboblong, slightly dilated posteriorly, costa anteriorly moderately, posteriorly slightly arched, without fold, apex obtuse, termen faintly sinuate beneath apex, slightly oblique; fuscous, with faint violet tinge, somewhat sprinkled with ferruginous; a yellow-ochreous patch occupying basal $\frac{2}{5}$ of wing, edge straight, rather oblique, finely whitish, followed by dark-fuscous suffusion; a small fuscous mark in disc at $\frac{1}{4}$; several darker strigulae or small spots on posterior half of costa: cilia fuscous suffusedly mixed with ferruginous. Hindwings dark grey, somewhat lighter anteriorly: cilia light grey.

Mount Egmont, 3,000 ft., in February (Hudson); one specimen. In colouring recalls *Epichorista hemionana*, but broader-winged.

DIPLOSARIDAE.

This family (which may be placed above the Cosmopterygidae) is new to the New Zealand fauna. In general characters it approaches the Cosmopterygidae, but is distinguished from that family by the absence of the pronounced costal shoulder with scale-projection at about $\frac{1}{3}$ of hindwings, the costal edge being quite regularly arched. The family as hitherto known is entirely restricted to the Hawaiian Islands, where it constitutes the mass of the Micro-Lepidopterous fauna, the known species approaching 300, and indicating a probable total of quite 500. The following species (quite certainly a characteristic member of the family) is the first discovered elsewhere, and is therefore of very great interest; but it must be observed that the *Tineina* of the other Pacific islands are hardly at all known yet (I wish some one would explore them), and some may be found there. The new species would seem, however, to be an extreme straggler from the centre of development.

Irenicodes n. gen.

Head with appressed scales, side tufts somewhat raised; ocelli small, posterior; tongue developed. Antennae $\frac{4}{5}$, in ♂ moderate, filiform, simple, basal joint moderately elongate, without pecten. Labial palpi moderately long, curved, ascending, rather slender, with appressed scales, terminal joint shorter than second, acute. Maxillary palpi rudimentary. Posterior tibiae clothed with long hairs above. Forewings with *1b* short-furcate, 2 from angle, 3 absent, 6 and 7 out of 8, 7 to costa, 11 from middle. Hindwings $\frac{3}{4}$, narrow-lanceolate; cilia 3; 2–4 parallel, 5 absent, cell open between 4 and 6, 6 and 7 stalked.

This genus represents an advanced form of the family, and therefore offers no assistance towards the problem (at present insoluble) of the geographical origin of the oldest portion of the Hawaiian fauna.

Irenicodes eurychora n. sp.

♂. 13 mm. Head and thorax pale-ochreous. Palpi whitish, second joint suffused with grey anteriorly except at apex. Antennae grey. Abdomen dark grey, anal tuft ochreous-whitish mixed with grey. Forewings narrowly elongate-lanceolate, long-pointed, acute; pale brownish-ochreous; a costal streak of dark-fuscous irroration from base to near apex, and a similar somewhat narrower dorsal streak attenuated to extremities from base to near tornus; cilia grey, towards base scaled with pale ochreous. Hindwings dark fuscous; cilia rather dark grey.

Paekakariki, in March (Hudson); one specimen.

Oecophoridae.

Borkhausenia ancogramma n. sp.

♂. 16 mm. Head ochreous-grey-whitish sprinkled with fuscous. Palpi ochreous-whitish, basal half of second joint and a subapical ring dark fuscous, terminal joint $\frac{2}{3}$ of second, with dark-fuscous subbasal and subapical rings. Antennal ciliations under 1. Thorax fuscous somewhat mixed with ocherous-grey-whitish, suffused with dark fuscous towards margins. Abdomen whitish-ochreous mixed with light-brownish. Forewings elongate, costa gently arched, apex obtuse, termen rounded, rather strongly oblique; pale ochreous irregularly sprinkled with light-brownish and a few dark-fuscous scales; a thick dorsal streak of pale ground-colour from base to near tornus, sprinkled with light fuscous on a patch beyond middle and with dark fuscous on dorsal edge towards base, margined above by an obtusely angulated dark-fuscous streak (suffused above with fuscous) from base of costa to plical stigma, posteriorly rather expanded and with a short prominence beneath second discal stigma, extremity obliquely truncate, surrounded posteriorly with fuscous suffusion and some dark-fuscous scales; stigmata dark fuscous, plical rather obliquely before first discal, second discal transverse, an additional cloudy dot on margin of dorsal streak between first and second discal; blotches of fuscous suffusion on costa at $\frac{1}{4}$ and middle, latter connected by second discal stigma with dark posterior margin of dorsal streak: a fuscous spot on costa at $\frac{4}{5}$, with very faint indications of subterminal line; two cloudy fuscous costal dots near apex: cilia whitish-ochreous speckled with light-brownish. Hindwings very pale greyish: cilia whitish-ochreous.

Wainuiomata, in December (Hudson); one specimen. The antennal ciliations are perceptibly shorter than in the much less strongly marked *innotella*, in which they are fully 1.

Izatha amorbas Meyr.

Having received a second specimen with the palpi in better condition, I find that (as has been already suggested by Mr. Philpott) the species is properly referable to *Izatha*, not to *Trachypepla*.

PLUTELLIDAE.

Orthenches glypharcha n. sp.

♀. 10–11 mm. Head white. Palpi white, with a bronzy lateral line. Antennae white, ringed with dark fuscous, basal portion lined with dark fuscous. Thorax white with a faint bronzy-tinged central line, patagia shining bronze. Abdomen light grey. Forewings elongate, costa moderately arched, apex pointed, termen slightly sinuate, rather strongly oblique; bright shining bronze: markings shining white: a streak along fold from base to $\frac{2}{3}$; an oblique streak from costa before middle to fold; an oblique streak from costa beyond middle not reaching half across wing, and a slightly oblique streak from dorsum before tornus, their apices connected by a purple-black mark; a purplish-black dot on tornus; three small wedge-shaped spots on costa posteriorly; three or four small marks or dots along termen, one below middle forming an erect strigula: cilia grey, basal half bronzy, round apex with three or four white bars. Hindwings grey: cilia light grey, with darker subbasal shade.

Mount Egmont, 3,000 ft., in February (Hudson). A striking and novel form of the genus, with interesting suggestions of relationship to *Protosynaema* and *Glyphipteryx*.

LYONETIADAE.

Erechthias externella Walk.

Mr. Hudson states that *monastra* Meyr. is apparently ♀ of this species, as he has long series of both forms, all *externella* being ♂ and all *monastra* ♀; I fully concur in this conclusion.

TINEIDAE.

Tinea sphenocosma n. sp.

♀. 11 mm. Head whitish irregularly and suffusedly mixed with fuscous. Palpi fuscous, tip white. Thorax dark fuscous, posterior margin rather broadly white. Abdomen dark grey. Forewings elongate, rather narrow, costa gently arched, apex obtuse-pointed, termen slightly rounded, rather strongly oblique: dark fuscous, closely strewn with irregular whitish dots or small spots except towards costa; eleven slightly oblique transverse or wedge-shaped white spots from costa, first five extended as streaks nearly half across wing, fifth enlarged into a spot at extremity: cilia fuscous with two darker shades, a direct projecting fine dark-fuscous bar at apex, margined on both sides by triangular white spaces, beneath apex a triangular white spot opposite eleventh costal. Hindwings trapezoidal-ovate, fuscous, darker and strongly purple-tinged posteriorly: cilia grey.

Wellington, in December (Hudson); one specimen. It is perhaps possible that this is the other sex of *accusatrix* (of which I have two ♂ specimens only), resembling it in the peculiar apical projection; but the differences in other respects are so great that I must regard it as distinct until further evidence is available: the wings are much broader, especially the hindwings, which in *accusatrix* are ovate-lanceolate, acute, and termen of forewings much less oblique; the conspicuous round black apical spot is entirely absent, and the white markings in cilia round apex quite differently arranged.

Archyala haiosparta n. sp.

♂. 11 mm. Head whitish, somewhat mixed with fuscous on crown (partly rubbed). Palpi grey. Thorax fuscous mixed with dark fuscous and sprinkled with whitish. Abdomen dark grey. Forewings elongate, rather narrow, costa moderately arched, apex obtuse-pointed, termen very obliquely rounded; violet-fuscous, irrorated with blackish, sprinkled and strigulated with white, especially thickly strigulated along dorsum: about six obscure oblique dark-fuscous streaks from costa, reaching nearly half across wing; a small white spot on dorsum before tornus; two or three whitish dots on costa towards apex: cilia fuscous with two darker shades (imperfect). Hindwings dark grey, suffused with deep purple posteriorly: cilia grey, with darker subbasal shade.

Wainuiomata, in December (Hudson); one specimen.

Talaeporia scoriota Meyr.

Further specimens received from West Plains, Invercargill (Philpott), show that *globulosa* Meyr. is only a strongly marked variety of this.

Nepticulidae.

Nepticula perissopa n. sp.

♂♀. 6–7 mm. Head and eyecaps whitish-ochreous, centre of crown dark grey or blackish. Thorax dark violet-fuscous. Abdomen grey. Forewings broad-lanceolate; pale greyish-ochreous, more or less suffused (especially in ♂) with violet-grey, and coarsely and irregularly strewn with dark-fuscous scales, especially towards apex, where in ♀ they form a suffused dark blotch occupying $\frac{1}{4}$ of wing; an elongate dark-fuscous spot on fold at $\frac{1}{4}$; an elongate blackish spot in disc beyond middle, in ♀ surrounded by a nearly clear space: cilia pale greyish-ochreous, basal $\frac{2}{3}$ coarsely irrorated with blackish round apex and upper part of termen. Hindwings grey: cilia light ochreous-grey.

Mount Egmont, 3,000 ft., in February (Hudson); two specimens.

ART. XXXIV.—*The Vegetation of Banks Peninsula, with a List of Species (Flowering-plants and Ferns).*

By ROBERT M. LAING, B.Sc.

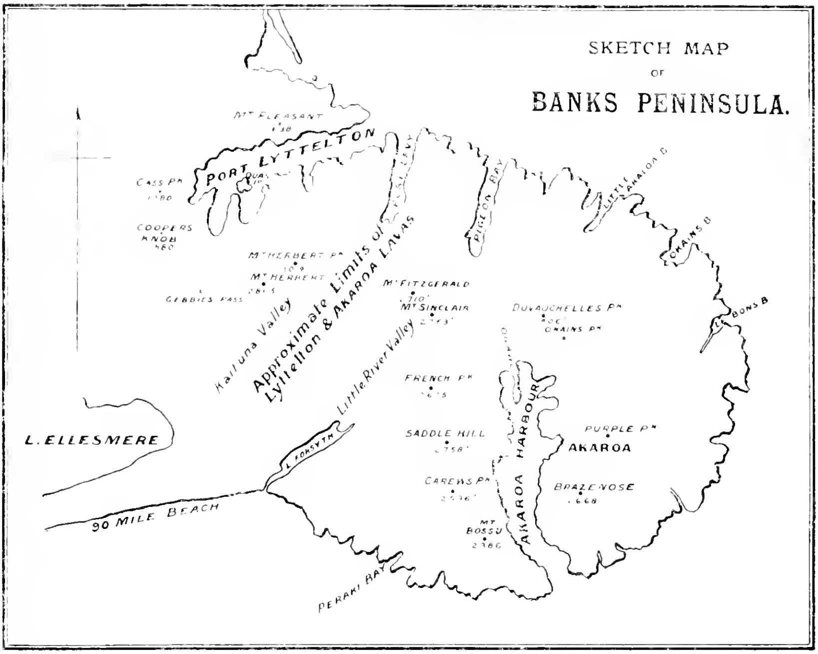
[*Read before the New Zealand Institute, at Christchurch, 7th–8th February, 1919; received by Editor, 2nd April, 1919; issued separately, 19th August, 1919.*]

THE INDIGENOUS VEGETATION OF BANKS PENINSULA.

Physiographic.

BANKS PENINSULA, on the east coast of the South Island of New Zealand, is such a well-defined and isolated area that it is remarkable that it has not received more attention from botanists. The list of papers at the end of this article shows how scanty has been the botanical work done on this group of hills. Indeed, there is at present no reliable list of the species occurring there. This is the more to be regretted as no portion of the area except the coastal cliffs and the salt marsh now remains in its original condition: and no doubt even on the cliffs some introduced species of plants are to be found. The complete destruction of the forest and the annual burning of the tussock areas have so altered the plant associations that it is difficult to reconstruct them, even in imagination, with accuracy. Some species are now undoubtedly lost, many more have been introduced from without, and the relative numbers of those present have been, of course, totally reproportioned. Any attempt to describe in detail the distribution of species over the area before the arrival of the white man must of necessity fail, but the rough outlines of that distribution can still be determined.

The following paper therefore attempts to give that information, and to provide a list of the indigenous species that should be useful to future students of the area. It is not necessary to describe the chief physiographic features of the area, as this has already been done in the papers of von Haast, Hutton, and Speight, which are readily accessible. Suffice it to say that Banks Peninsula stretches out to the south-east from the centre of the eastern side of the Canterbury Plains. It is oval in shape, and about thirty-five miles long and twenty wide. It consists of a congeries of hills rising at the centre in Mount Herbert to a height of just over 3,000 ft., and in Mounts Sinclair and Fitzgerald to a slightly less height. From these and other peaks long ridges with steep sides run out in all directions, enclosing occasionally narrow flats containing several hundred acres of land. Beyond the flats and between the outer ridges are the smaller bays. On the seaward side the ridges terminate in cliffs 300 ft. to 500 ft. high: and on the landward side slope down to the plains, cliffs being absent. Two large harbours, on the sites of old volcanic calderas, break into the hills, and are surrounded by steep walls which rise in rocky cliffs and escarpments to the height of 2,000 ft. in Akaroa Harbour, and somewhat less in Lyttelton Harbour. The longest valleys are the Little River and Kaituna Valleys, each some seven miles in length, both at one time, throughout part at least of their lengths, arms of the sea. To the south-west lies a large, shallow, brackish mere—Ellesmere—formed by the blocking-up of the mouth of the Selwyn River. This action is due to the shingle drifted up the coast from the mouth of the Rakaia River by the southern current.



Some Localities not marked on Map.

Allandale, between Governor's Bay and Teddington.
Aylmer's Valley, one of the valleys behind Akaroa.
Balgueri Valley, behind Akaroa Township.
Barry's Bay, near the head of Akaroa Harbour.
Castle Rock, also known as Mount Herbert Peak.
Charteris Bay, at the foot of Castle Rock.
Caton's Bay, on Lake Forsyth, near Little River.
Damon's Bay, north of Akaroa East Head.
Dover Castle, rocky wall overlooking Heathcote Valley.
Flea Bay, north of Damon's Bay.
Gollan's Bay, at the foot of the Zigzag, Lyttelton-Sumner Road.
Island Bay, between Akaroa Heads and Peraki.
Long Bay: There are three Long Bays on the peninsula, but indications are given in the text as to the one referred to.
Long Lookout Point, east of Little Akaloa Bay.
Ohinitahi, on Lyttelton Harbour, between Governor's Bay and Teddington.
Okute Valley, running from Saddle Peak to Little River.
One Tree Hill, between Lyttelton and Port Levy.
Otahuna Valley, running from Cooper's Knobs to the plains.
Rapaki, Maori settlement between Lyttelton and Governor's Bay.
Stony Bay: The one referred to is between Little Akaloa and Okain's. There are two bays of the name on the peninsula.
Taylor's Mistake, between Sumner and Lyttelton Heads.
Teddington, at the head of Lyttelton Harbour.
Tikao Bay, opposite Akaroa, on the harbour.
Timutimu, west head of Akaroa Harbour.
Waikerikikeri, bay south of Le Bon's, and popularly known as Hickory.
Wainui, between Tikao Bay and the Heads.

We are dealing, then, with an area which consists of long, moderately steep hill-slopes, radiating out from the central heights. It is broken on its outward sides by harbours, bays, and valleys, with steep cliffy sides. There is comparatively little flat land. Alpine shingle-slips are completely wanting, and screes are of rare occurrence. Bogs and swamps are of very small extent, and consist of the damp spots in the neighbourhood of springs and streams. Salt marshes and meadows, however, abound, chiefly in the neighbourhood of Lake Ellesmere. The highest hills rise above the forests into subalpine grasslands. On three sides—the north, south, and east—the peninsula is surrounded by the ocean; but on the western side it meets the Canterbury Plains. The attached map will give the names of the chief places referred to, and a list is provided with the situations of the less known minor localities.

Climatic.

The climate of the peninsula may be described as typically insular and warm-temperate. It differs somewhat from that of the Canterbury Plains, which is more continental in type.

Thus the plains are much colder on winter nights than the adjacent hills. The temperature of Cashmere Hills on frosty nights is from 3° C. to 5° C. higher than that of Christchurch, and on the hills at Redcliffs and Sumner it is still warmer. There ice is rarely seen. The lowest temperature that may be observed on the Cashmere Hills is about −8° C., but winters pass in which it does not fall below −4° C. or −5° C. Even in midwinter the days are often bright and warm, and the temperature in the lower valleys is as high as 15° C. in the shade. Frosts may occur on the plains in any month of the year, but on the neighbouring hills they are almost unknown between September and April. Thus in the beginning of November, 1918, an unusually severe frost (−7° C.) occurred in Christchurch. This was so slightly felt on the hills that tomatoes and potatoes remained unchecked and almost untouched by it. The conditions on the hilltops have been but little studied, though, of course, the temperatures there must be considerably lower both in summer and winter than those at the foot. The temperature range through the year on the lower portion of the hills is comparatively small, but reliable records are difficult to obtain. Probably the difference of average temperature is not more than 8° C. or 9° C. between a month of winter and one of summer, though the maximum temperature in summer is often comparatively high, and the thermometer may even rise above 33° C. In the warm, sheltered valleys on the north side of the peninsula the conditions must approach the warm-temperate, and this is shown in the fact that many typical North Island plants find here their southernmost limit. (A list is appended, pp. 369–70.)

The rainfall varies in different localities, but as comparatively few records have been taken on the peninsula it is impossible to give detailed results. However, the average probably varies from about 25 in. (Convalescent Home, Cashmere Hills) to about 50 in. or 60 in. (on the top of Mount Herbert). A series of careful observations extending over nineteen years (1899–1918) at Pigeon Bay, taken by Mr. E. Hay, give an average of 29·5 in., with a maximum of 39·5 in. in 1913 and a minimum of 16 in. in 1915. The rainfall in the outer portions of the area between Pigeon Bay and Akaroa is no doubt higher than this. In the latter place the records show an average of 45 in. Between Timutimu Head and Birdling's Flat there is again a reduction in the rainfall, for the Akaroa Hills cut off much of the easterly rain. This district therefore reproduces largely the flora of the Lyttelton Hills, but, having a southerly aspect, no doubt is neither quite so hot nor so dry as they are.

Snow falls every year on the hilltops, and on Mount Herbert usually lies for some weeks, but at the base of the hills it does not often fall, and usually does not lie for more than a few hours. The winter of 1918 was exceptional, when snow fell to a depth of 10 in. even at the foot of the hills, and the conditions above 1,000 ft. were truly alpine. Such falls do much damage in the forest in breaking down trees and branches, though but little permanent harm results if frosts do not follow.

Next to the rainfall and temperature the most important climatic factor is the wind. The prevailing wind is from the north-east. This in summer-time is usually a sea-breeze, and then brings no rain, but when part of a cyclonic system it frequently brings continuous though often light rains lasting over many hours. The north-east wind passes into the north-west wind, which is much less frequent, and is hot and dry. Only on the rarest occasions does it bring a scanty shower of rain. It has, as will be seen later, a most important effect on the distribution of the plants within the area. The south-wester is a cold, wet wind, bringing much rain, and determines largely the vegetation on the cliff-faces exposed to the south. The south-easter is, on the northern side of the peninsula, a somewhat rare wind, of a gusty character—often stormy and occasionally bringing heavy rains. It is often deflected as an easterly or north-east wind. The higher rainfall of the outer portion of the peninsula is largely due to it.

The rainfall is very irregular in its distribution over the year. The months of December to March are usually dry, but exceptions occur. During this period droughts are not uncommon, particularly on the north-west faces of the peninsula, and often affect the vegetation. This has tended to produce a distinctly xerophytic type of vegetation on the Lyttelton Hills, though elsewhere it tends to the mesophytic.

Changes in the Plant Covering.

It has already been stated, and cannot be too strongly insisted on, that here—as in so many other places in New Zealand—we are dealing with a vegetation that has during the last seventy or eighty years undergone, and is still undergoing, immense changes. The greatest of these is, of course, the disappearance of the forest. Captain Thomas, Agent for the Canterbury Association, reporting on the 15th May, 1849, estimated that half of the area of Banks Peninsula—viz., 131,000 acres—was forest; but this probably was an underestimate, as nearly two-thirds of the peninsula must have been forest-covered. Now there is probably nowhere on the peninsula a stand of 300 acres of timber-trees, although there are larger areas of the smaller bush trees, as in the forest at the back of Mount Herbert. The reserves at Peraki Saddle, including some 167 acres, perhaps contain the best specimen of primitive forest now to be seen on the peninsula. Though there are equally fine trees near the Lyttelton–Kaituna saddle, yet here the undergrowth has to a large extent been destroyed by stock. It is unfortunate that what up till recently was the finest forest on the peninsula—viz., the one at Stony Bay—is now being cut out by its owners. Kennedy's Bush Reserve, near Christchurch, unfortunately contains few trees of any magnitude, and its former wealth of tree-ferns has been completely destroyed.

Agents altering Plant-distribution.

The primitive plant covering, then, has largely disappeared, and has been replaced by introduced species, particularly by grasses: the balance in the remaining plant associations has been altered, and the conditions under which many of the species live are quite changed. Probably the grasslands of the Lyttelton Hills have been less altered than the forests of the peninsula, for the tussock form still dominates; yet here certainly many changes have taken place and others are still in progress. The chief destructive agents at work where cultivation has not been employed are continual tussock-fires, bush-fires, drought, sheep, cattle, on the Lyttelton Hills rabbits, and on Banks Peninsula hares.

On the grasslands the tussock-fires make for the extinction of the ferns, for the reduction in the number of the species, for the replacement of certain grasses by others, for the destruction of isolated shrubs, and for the multiplication of a few plants that can to some extent withstand the action of fire—*e.g.*, *Coriaria sarmentosa*.

On the other hand, bush country when burned and allowed to restock itself reproduces the usual fire weeds; but these are seldom or never allowed to remain, being either destroyed by the hand of man or replaced in old burns by *Pteridium esculentum* or species of *Leptospermum*. These changes however, will be considered in greater detail under the various plant formations.

It may, however, be noted here that in all the moister bays of the peninsula—that is to say, from Port Levy eastward and southward to Akaroa—cocksfoot (*Dactylis glomerata*) was sown on the burnt areas, and the result has been the development of an artificial plant association. After the first sowing this grass has replaced itself in a remarkable way, and though reaped for forty or fifty years has continued to produce crops of almost undiminished vigour. Largely owing to the scarcity of casual labour the cocksfoot harvest is now becoming a thing of the past, and dairy-farming is to a large extent replacing it.

The cattle are grazed on the cocksfoot, which is the chief ingredient of the pasture lands, though rye-grass (*Lolium perenne*), timothy (*Phleum pratense*), and crested dogstail (*Cynosurus cristatus*) are also to be met with in smaller quantity. Sheep are to be found chiefly on the tussock areas, though even on the cleared forest areas they are in many places being stocked in increasing numbers, owing to the smaller amount of labour involved in looking after them. Further discussion of these economic matters would, however, be out of place here.

The changes due to the action of animals on the vegetation, though extensive, are not so wide-reaching as those of fire. Sheep crop certain grasses, and thus prevent them seeding. They also attack other species of plants, such as *Angelica montana*, *Carmichaelia subulata*, and even the young spinous leaves of *Aciphylla squarrosa*. On the other hand, their function in the spreading of plants by means of seeds can hardly be over-estimated. The large increase in danthonia (*Danthonia pilosa*) referred to farther on may be cited in this regard. Other species spread by the same means are *Urtica urens*, *Acaena novae-zelandiae*, and *Marrubium vulgare* (white horehound). Cattle, again, are probably entirely destructive. *Phormium* soon disappears in their presence, as also does *Marrubium*. In Pigeon Bay, for example, the upper portions of the hills are in many places grey with horehound, whilst the cattle-country immediately below is perfectly clear. Unfortunately, cattle will not run in the rocky, broken country on the hill-crests, and here *Marrubium* has become the worst pest of the district. It remains to be seen whether with time it will work itself out. Probably in the absence of sheep it is but little distributed. Cattle also, as is well known, rapidly destroy the undergrowth in bush country. Rabbits, also, on the area dealt with are probably almost entirely destructive in their action. They reach many places which are either inaccessible to sheep or at least not usually grazed by them. On some of the rocky points of the Lyttelton Hills, which would otherwise be plant-sanctuaries, scarcely a plant is left untouched by them. Shrubs and grasses are all grazed, and only the inaccessible chasmophytes escape. Hares apparently are much less destructive than rabbits, because they are in smaller numbers, do not burrow, and do not frequent cliffs and rocks. The tendency of these agents is not only to reduce the number of indigenous species, but also, as a rule, to limit the numbers of the individuals in the remaining species.

Certain species, however, are apparently on the increase as the result of changed conditions. Such are *Danthonia pilosa*, *D. semiannularis*, *Acaena novae-zelandiae*, *Coriaria sarmentosa*, *Cotula squalida*, *Dichondra brevisepala*, and *Oxalis corniculata*. The two last-mentioned invade even cultivated ground, and I have seen *O. corniculata* growing about the steps of the public buildings of Christchurch.

During a succession of dry seasons the grasses mentioned become common in garden lawns on the hills, and replace temporarily or permanently the shallow-rooted lawn-grasses. In dry seasons, too, rabbits attack the bark of trees, and thus assist the drought in its attack upon the vegetation. *Melicytus ramiflorus*, *Schefflera digitata*, and *Nothopanax arboreum* are amongst the first to suffer, particularly when standing in the open.

The Plant Associations.

Further discussion of such changes may be postponed for the present, and taken when we come to consider shortly the chief of the indigenous plant societies. They may be roughly classified as follows:

(1.) Salt marsh
(2.) Salt meadow
(3.) Coastal rocks } Coastal.
(4. Sand-dunes
(5.) Coastal scrub
(6.) Tussock-grasslands.
(7.) Inland cliff and rock.
(8.) Forest.
(9.) Lowland scrub and heath.
(10.) Subalpine scrub.
(11.) Subalpine grasslands.

(1) (2) *The Salt Marsh and the Salt Meadow.*

These are developed at the head of the tidal flats, and are well seen at Teddington in Lyttelton Harbour, also on the Sumner Estuary and in a few other places on the peninsula. At Lake Ellesmere there are vast extents of brackish marsh and meadow; but these scarcely come within the scope of this paper. Though some of the species occurring in the portion of the lake adjacent to Kaituna have been listed, no attempt has been made to explore the lake and its borders as a whole. It would undoubtedly form an interesting field for the botanist, and one as yet imperfectly known. The conditions there are somewhat unusual in New Zealand. However, the ordinary salt marsh and meadow of the Banks Peninsula district do not differ much from those found in adjacent parts of New Zealand, and they have already been described for the Sumner Estuary by Mrs. Jennings (Miss B. D. Cross).* At Teddington the association is very similar to that at Heathcote, except that I have seen neither *Carex litorosa* nor *Scirpus maritimus* there, though *Scirpus maritimus* occurs at Ohinitahi, at the head of the bay. The first plant to be met with in coming in from the seaward is *Salicornia australis*, in dense cushions, with a small grass (*Atropis stricta*) growing through the cushions. At a level several inches higher appear *Samolus repens* and *Selliera radicans*, followed by the seaside form of *Cotula dioica*. By the side of the tidal guts are *Juncus maritimus* and *Leptocarpus simplex*, the latter in comparatively small quantity. The only shrub present is *Plagianthus divaricatus*, which is plentiful on the tidal flat and close to the coastal rocks where the shallow tidal flat approaches them.

(3) (4) *Sand-dunes and Coastal Rocks.*

There are scarcely any sand-dunes on the peninsula, except those at Sumner, and only small areas of sandy beaches; consequently there are few sand-plants to be noted. So far as I know, *Spinifex* and *Pimelea arenaria* are quite wanting; and *Scirpus frondosus*, *Convolvulus Soldanella*, *Euphorbia glauca*, *Carex pumila*, and other sand-plants by no means common. On the coastal rocks *Mesembryanthemum australe* is abundant, with *Tetragonia expansa* and *T. trigyna*, often trailing downward for many feet. *Rhagodia nutans* occurs less commonly, and more rarely still *Lobelia anceps* and *Lepidium oleraceum*. *Vittadinia australis* and *Tillaea Sieberiana* are abundant here and inland; but I have seen *Tillaea moschata* in only one place. On the wetter rocks *Samolus repens* and *Selliera radicans* reappear, often with the fern usually called *Asplenium obtusatum*, a species which requires further study.

The drier coastal rocks and the adjacent clay banks, as has been pointed out to me by Professor Wall, are the home of certain species of rarer ferns, and produce a little plant association which is as uncommon as it is interesting. In addition to *Asplenium obtusatum* and *A. lucidum* the following ferns, though found elsewhere, particularly haunt such situations: *Cheilanthes Sieberi*, *Nothoclaena distans*, *Polystichum Richardi*, *Polypodium* (*Cyclophorus*) *serpens*, and *Adiantum affine*. The last-mentioned has, of course, been much destroyed by picknickers and pleasure-seekers, and I know only one or two spots at the edge of Lyttelton Harbour where it may be now obtained, though it is common in the less frequented bays of the peninsula.

Professor Wall writes thus to me: "There is a very peculiar and special feature of the bluffs and steep slopes surrounding Lyttelton Harbour, which deserves mention. A hard, barren rim of baked clay occurs between the tussock land above and the rock below, in which grow *Cheilanthes Sieberi* and *Nothoclaena distans*. Potts† describes the formation very exactly, calling the material 'cob.' In many places this rim is now invaded and overshadowed by other vegetation, but the primitive state is still to be seen

* Observations on some New Zealand Halophytes, *Trans. N.Z. Inst.*, vol. 43, p. 545, 1911.

† T. H. POTTS, *Out in the Open*, p. 77, 1882.

here and there. A good example is on the north-eastern side of Quail Island. Practically no plant grows in this sort of place except these two ferns."

(5) *The Coastal Scrub.*

The coastal scrub is characterized by such species as *Olearia Forsteri*, *Dodonaea viscosa*, and *Macropiper excelsum*, though any of these may be found inland. *Angelica geniculata* also occurs in abundance here, and on the peninsula at any rate is not often found in the interior of the forest. Other common species, which, however, have no claim to be considered distinctly coastal, are *Muehlenbeckia complexa*, *Coprosma robusta*, and *C. Cunninghamii* (showing much leaf-variation); whilst both species of *Leptospermum* frequently come down almost to the water's edge. At one time also there were groves of karaka, which apparently were to be found from Decanter Bay round to Okain's, and possibly farther. On the open flats, as at Birdling's Flat, *Muehlenbeckia complexa* in rounded clumps, *Discaria toumatou*, and *Carmichaelia subulata* frequently become prominent features in the landscape; but, again, these are not distinctively coastal, though occurring near the sea.

(6) *The Tussock-grasslands.*

These were originally found only where the hills were directly exposed to the action of the drying north-west wind, or where they were sheltered from the moist easterlies but met the full strength of the cold south-wester. The easterly winds—the prevailing winds of the peninsula—are much less arid than the north-wester, and less violent and cold than the south-wester; so they have interfered but little with forest growth. On the other hand, the area of exposure to the north-wester is well defined by the tussock belts of the north-western faces of the peninsula. The examination of such a point as Adderley Head well illustrates this contention. The tussock on the Lyttelton side is often withered, while the herbage on the Port Levy side is quite green; the rainfall on both sides must be the same. Wakaroa Head, the eastern point of Pigeon Bay, equally well if not better proves the same point. Here, no doubt, the rainfall is somewhat higher than at Lyttelton Heads, so that it is well above the minimum required for forest-production; yet the forest extended along the eastern side of Pigeon Bay only so far as it was sheltered from the direct action of the north-west wind. The projecting end of the point reproduces exactly the vegetation of the northern slopes of Mount Pleasant, even down to the occurrence of the rare *Gymnogramme rutaefolia* in both situations, and the less rare but still xerophytic *Clematis afoliata*. Hence we must expect to find tussock-grasslands wherever the slopes of the hills are exposed to the full violence of the north-wester. This plant association is therefore to be found from Godley Head to Birdling's Flat. As far as Dyer's Pass there are tussock pastures, with scrub only in the gullies; to the westward there is tussock on the open hillsides and headlands, while somewhat heavier forest at one time existed in the valleys. Owing to the clearing of the "bush," tussock is now found in many places where once there was forest. Natural tussock-grasslands are again to be found on the northern slopes of Mount Herbert and One Tree Hill, on the far side of Lyttelton Harbour, though in the deeper and more sheltered valleys of Purau and Charteris Bay there was forest. In the latter place it has been removed only during the last ten years. The characteristic herbs of the tussock pasture are *Poa caespitosa*, *Danthonia pilosa*, *Scleranthus biflorus*, *Oxalis corniculata*.

Dichondra brevisepala, Aciphylla Colensoi: and on slopes exposed to sea-breezes *Cotula Haastii* and sometimes *Convolvulus erubescens.* The most characteristic shrubs are *Carmichaelia subulata* and *Discaria toumatou:* whilst amongst rocks *Muehlenbeckia complexa, Coprosma crassifolia, Sophora prostrata,* and a few other species are occasionally found. Particularly towards the hilltops *Hymenanthera crassifolia* and *Corokia Cotoneaster* abound.

In most places these grasslands are burnt annually in the late winter or early spring—as soon, indeed, as there is a day on which they will burn. This burning has been done right up to the top of Mount Herbert, and has been carried on for the last fifty or sixty years. When done in the months of July, August, and September the tops only of the *Poa caespitosa* are burnt; but when fires occur later in the year the tussock is often burnt out and killed. As a result the *Poa* tussocks become less numerous and remain smaller than they were, and in many places a mat of the wiry *Danthonia pilosa* forms between them. This is a distinctly aggressive species, no place short of actual rock being too hard for it to grow in. It even invades the cocksfoot lands and occupies the drier ridges there. It has thus proceeded at least as far eastward as Pigeon Bay, where it now occupies lands once covered with more valuable introduced grasses. In the north-west areas it may be the most suitable grass available; but it certainly ought, if possible, to be kept out of the richer cocksfoot lands.

Poa Colensoi var. *intermedia* now exists in comparatively small quantity, and tends more and more to be confined to the hilltops, ledges on rocky faces, and similar situations. Even there, however, on the Lyttelton Hills it is often eaten down by rabbits. This pest is not prevalent on the peninsula, and a rabbit-proof fence between Teddington and Gebbie's Valley helps to prevent them reaching there in large numbers. *Festuca rubra, Agropyron scabrum,* and *Danthonia semiannularis* also occur, though in smaller quantities.

Between Birdling's Flat and Timutimu Head, on the ridges and flat exposed points, the same tussock formation is repeated. Though the valleys were forested, yet the character of the vegetation is much more xerophytic than on the easterly faces of the peninsula, and the conditions of the Lyttelton Hills, with their vegetation, are closely reproduced.

(7) *Inland Cliff and Rock.*

Owing to the structure of the hills, rocky cliffs and faces are abundant, and there is a well-developed and highly specialized rock-vegetation, varying considerably with the altitude and aspect. It may be readily studied on the Lyttelton Hills up to a height of 1,500 ft. On the drier rocks with a northerly aspect are found *Hymenanthera crassifolia, Corokia Cotoneaster, Sophora prostrata,* and usually near the sea *Clematis afoliata,* as the most characteristic shrubs. Amongst ferns and herbaceous plants the following occur in such situations: *Gymnogramme rutaefolia, Polystichum Richardi, Cheilanthes Sieberi, Chenopodium triandrum, Linum monogynum, Epilobium cinereum, Senecio lautus,* and more rarely *Rhagodia nutans.* A traverse of the hills—a distance perhaps of not more than 50 yards—to the moister rocks on the southern side shows a very different and unique vegetation. The most characteristic shrub is now *Veronica Lavaudiana. Metrosideros hypericifolia* and *Cyathodes acerosa* also occur: whilst the ferns already mentioned are replaced by *Polypodium grammitidis,* and on the highest peaks shrivelled specimens of *Hymenophyllum multifidum* and occasionally other species of *Hymenophyllum* are to be found. The most characteristic plant, however, is a species of *Senecio*, which, as Wall has shown, between Lyttelton Heads and Gebbie's Pass is *S. saxifragoides*, but elsewhere is *Senecio lagopus* in a large and well-developed form. *Veronica Lavaudiana* is found above 800 ft. only, but *Senecio saxifragoides* comes occasionally down to sea-level, though usually found above 800 ft. In places also *Angelica montana*, *Anisotome Enysii* (?), *Earina suaveolens*, *Libertia grandiflora*, and *Raoulia glabra* become members of the rock association; but these species are to be found on all aspects of the hill, and, with the exception of the plant here called *Anisotome Enysii*, can scarcely be called distinctive species. This *Senecio - Veronica Lavaudiana* association is highly characteristic of Banks Peninsula, and is met with nowhere else. Above 1,500 ft. the distinction between the vegetation of rock-faces with northern and southern aspects tends to disappear. *Dracophyllum acicularifolium* var. *uniflorum* now becomes a highly characteristic shrub of the cliffs and rocky faces, and the subalpine species, to be described later, begin to appear.

To see the lower subalpine element at its best one may go to a cliff on the south-west face of a peak—apparently nameless—between Cass Peak and Cooper's Knobs. This hill is under 1,600 ft., but has an unsheltered exposure towards the south-west, and this probably accounts for the great variety of plants to be found on its face. Amongst the smaller forms may be mentioned *Hydrocotyle microphylla*, *Colobanthus Muelleri*, *Myosotis pygmaea*, *Polypodium australe* var. *pumila*, *Polypodium grammitidis* (well developed), *Hymenophyllum multifidum*, *Geranium sessiliflorum*, *Helichrysum bellidioides*. On the Lyttelton Hills these species are not to be met with at the lower levels, though elsewhere on the peninsula, where the rainfall is higher, they come down much lower. *Lycopodium fastigiatum*, *Veronica Lavaudiana*, *Gaultheria antipoda* (the erect form), and *Dracophyllum uniflorum* also occur here in abundance.

(8) *The Forest.*

Distribution of the Forest Areas.—In pre-European times Banks Peninsula was clad with dense forest, except on the hills overlooking the plains and between Timutimu Head and Birdling's Flat, where the forests were chiefly confined to valleys and hilltops. From Lyttelton Heads to Kennedy's Bush there were no large forests, and between Kennedy's Bush and Little River the forests were not continuous. The hills on the southern side of Lyttelton Harbour were also in part bare; from Little River to Akaroa, and from Akaroa along the outer bays to Port Levy, there was an almost continuous sheet of forest. Here and there the bald heads of some of the higher peaks rose above the forest line, as in the case of Mount Herbert and Mounts Sinclair and Fitzgerald; but elsewhere the forest wave swept over the hilltops, and was continuous except where broken by cliffs. Certain trees abundant on the western ranges, which probably require a rainfall of 50 in., are conspicuously absent from the area: such are *Metrosideros lucida*, *Weinmannia racemosa*, and *Phyllocladus alpinus*.

Types of Forest.—The forest is of two main types—(*a*) the podocarp forest, and (*b*) the beech forest.* The podocarp forest can again be subdivided as to altitude into the lower podocarp and the upper podocarp-cedar

* This is not further described here, but see R. M. Laing, *Trans. N.Z. Inst.*, vol. 46, p. 58, 1914.

forest. It is characterized by the presence of certain taxads—viz., *Podocarpus totara*, *Podocarpus spicatus*, and in smaller quantity *Podocarpus dacrydioides*, as chief timber-trees. In the upper podocarp forest, on the tops of the ridges above 2,000 ft. *P. totara* is replaced by *P. Hallii*, *P. dacrydioides* is absent, and *Libocedrus Bidwillii* is found. This upper forest is found chiefly on the tops and sides of the ridges between Kaituna Valley and the Akaroa – Le Bon's dividing ridge. Here it passes into the beech forest.

The Lower Podocarp Forest.—The lower podocarp forest is remarkably uniform throughout, and cannot be further subdivided by reference to the common species. The localization of some of the rarer species suggests, however, a further subdivision into a seaward area lying between Port Levy and Akaroa, and a landward area lying between Lyttelton and Little River. The former of these areas is somewhat warmer and moister than the other. Here are to be found, though not uniformly distributed throughout the area, *Corynocarpus laevigata*, *Rhopalostylis sapida*, *Coprosma lucida* (large-leaved form), *Cyathea medullaris*, and a form of *Sophora tetraptera* approaching to but different from the East Cape *S. grandiflora* With the exception of *Cyathea medullaris,* these are plants which find their southernmost limit here. On the landward side these species are absent, but at one time *Dacrydium cupressinum* seems to have occurred. Certain rare species also occur here more commonly than on the eastern side. Thus both at Mount Pleasant and at Lake Forsyth there occur the following species, which do not reappear again together, so far as I know, elsewhere on the peninsula: *Olearia fragrantissima*, *Teucridium parviflorum*, *Nothopanax anomalum*, and *Microlaena polynoda*. Other localized species no doubt exist in the peninsula lowland forests, though it is difficult now to be sure that they were not at one time more widely distributed. Amongst these may be mentioned *Pseudopanax ferox*, now chiefly confined to the western area: *Australina pusilla*, in both areas; and *Parietaria*, in both areas. The distinctions of areas here made are not intended to be rigidly insisted on; they are, however, suggestive of some differences in primitive vegetation. But it is too late now to endeavour to define them more accurately, as we are not sufficiently well acquainted with the distribution of the species of sixty years ago. Certain species have undoubtedly disappeared since Raoul's time, and others have become very rare. These may be determined from the accompanying list.

The taxads are the only large timber-trees common in the lower podocarp forest. *Griselinia littoralis*, however, often forms short, knotted trunks, sometimes 4 ft. through, but generally hollow. As the altitude increases, the forest-trees become somewhat smaller. *Podocarpus spicatus*, though not confined to the lower portion of the forest, is at its best and most abundant below 1,500 ft. Large trees of *Podocarpus totara* (sometimes in association with *P. Hallii*) are found up to 2,500 ft.; but in the upper parts of the "bush" *Griselinia* tends to replace the pines, and on the ridges and towards the summit *Podocarpus Hallii* and *Libocedrus Bidwillii* appear. The former is known on the peninsula as "mountain-totara," and, though much valued as a timber, is considered inferior to *P. totara*. The white-pine is not, I think, found above 1,500 ft. Towards the upper limit of the forest the number of species is reduced and the specimens are stunted, until it finally gives place to a poorly developed subalpine scrub.

The smaller trees of the forest are the same all over the peninsula to a remarkable extent, and, indeed, most of them are common as far south as the Bluff. *Griselinia littoralis*, *Melicytus ramiflorus*, *Carpodetus serratus*, *Pennantia corymbosa*, *Sophora microphylla*, *Nothopanax arboreum*, *Schefflera digitata*, *Aristotelia racemosa*, *Fuchsia excorticata*, *Pittosporum eugenioides*, *P. tenuifolium*, and *Hedycarya dentata* are amongst the most abundant. These support an abundant growth of climbers, which in some places render the forest almost impenetrable. The most frequent are species of *Rubus*, *Parsonsia*, *Clematis*, and *Muehlenbeckia*; less common are *Rhipogonum*, *Tetrapathaea*, and *Metrosideros hypericifolia*. In the scrub which is found interspersed with the forest-trees are *Drimys colorata*, various species of *Coprosma*, *Myrtus obcordata*, *Melicope simplex*, and a few other plants. On the forest-floor are *Blechnum discolor*, and *Polystichum vestitum* in large quantities. By the side of the forest-streams *Blechnum fluviatile*, *Blechnum lanceolatum*, *Asplenium bulbiferum*, and *Blechnum capense* are the most abundant species of ferns. In the darker creeks *Leptopteris hymenophylloides* and *Blechnum Patersoni* appear. As a tree-parasite *Loranthus micranthus* is abundant, while *Tupeia antarctica* is much less common. There are, too, as in all parts of New Zealand, many epiphytic ferns: *Cyclophorus serpens*, *Asplenium falcatum*, *Asplenium flaccidum*, and *Polypodium diversifolium* are common in such situations. On exposed windy ridges the forest tends to pass out into the heath.

The Upper Podocarp-Cedar Forest.—Through the centre of the peninsula, at an altitude of somewhat over 2,000 ft., runs a narrow belt of forest in which *Podocarpus Hallii* and *Libocedrus Bidwillii* are the predominant species. At its upward edge in places—*e.g.*, Mounts Fitzgerald and Sinclair—this passes into a still narrower belt of subalpine scrub, probably not more than 100 or 200 yards in width, and not well defined. The absence of lowland trees, such as *Myoporum*, *Dodonaea*, and tree-ferns further differentiates this forest from that of the lowland area; otherwise it is very similar. *Griselinia littoralis*, *Drimys colorata*, *Fuchsia excorticata*, *Nothopanax arboreum*, and certain species of *Coprosma* are here in increased abundance, along with several species of *Rubus*.

The Destruction of the Forest.—Unfortunately, however, there are only scraps of the forest left. Most of it has been destroyed with the advance of settlement. Possibly 10 per cent. of the big trees were used for timber, and the rest wastefully burnt. Of the extensive and almost continuous forest that once blanketed the peninsula from Little River round the coast to Pigeon Bay only scraps are left in the valleys and on the tops of the ridges, and practically everywhere these remnants are run through by cattle. This means that all the forest will be destroyed except for a few small and imperfect reserves. The destruction took place in the half-century between 1850 and 1900, and it is now practically complete. The largest area still forested is on the southern side of Mount Herbert. It is some two miles in length, and lies at an altitude of from 1,500 ft. to 2,500 ft. It is in too high and too bleak a situation to show the lower podocarp forest at its best, but it contains well-preserved areas of the podocarp-cedar forest and the subalpine scrub.

Replacement of Vegetation in Forest Areas.—Where the bush land has not been sown with cocksfoot, but natural causes have been allowed to provide a secondary growth, considerable areas of bracken soon appear, and this in its turn is often replaced by heath, consisting chiefly of the two common species of manuka. Such areas are best seen where the bush was early destroyed by Maoris, settlers, or even by accident, as in Barry's Bay, Duvauchelle's Bay, Little River, Kaituna, and Port Levy.

Where the bush was partly burnt, or burnt patches occurred in the middle of the forest, fire weeds such as *Aristotelia racemosa*, *Solanum aviculare*, *Erechtites prenanthoides*, *Plagianthus betulinus*, and other fast-growing plants appeared, but, owing to the complete destruction of the forest, patches containing these second-growth species have now also disappeared.

(9) *The Lowland Scrub and Heath.*

Not all the scrub and heath areas are areas of second growth. There are scrub areas which have not at any recent time been covered with timber-trees, containing shrubs such as *Melicope simplex*, *Corokia Cotoneaster*, *Helichrysum glomeratum*, *Coprosma crassifolia*, *C. areolata*, *C. virescens*, *Myrtus obcordata*, *Teucridium parviflorum*, *Myoporum laetum*; and as climbers *Clematis foetida*, *Rubus cissoides*, *Angelica geniculata*, *Parsonsia heterophylla* var. *rosea*; whilst on the adjacent or interspersed rocks are *Sophora prostrata*, *Libertia ixioides*, and *Clematis afoliata*. Such scrub occurs where the rainfall has been too small or the exposure too great to admit of forest growth. All the species mentioned above occur on Mount Pleasant (behind Lyttelton) and again at Island Bay, and doubtless elsewhere. It constitutes a plant society which is characteristic of Banks Peninsula, and the same combination, so far as I know, does not occur elsewhere. Similar associations are to be found near the wharf at Port Levy, and also at Caton's Bay, though not so fully developed as in the two localities mentioned.

With the scrub area I have associated the heath, which occurs at Governor's Bay, Port Levy, Duvauchelle's Bay, Barry's Bay, and Wainui, and is perhaps as well developed at Wainui as anywhere on the peninsula. Here it consists of *Leptospermum ericoides* (often covered with the parasite *Viscum salicornioides*), smaller quantities of *L. scoparium*, *Gaultheria antipoda* (the erect form), *Cyathodes acerosa*, *Lycopodium volubile*, *Blechnum capense* (a small form), *Pteridium esculentum*, *Pteris scaberula*, and the orchids *Thelymitra longifolia* and *Pterostylis Banksii*. *Pseudopanax crassifolium* occurs in it scantily, and elsewhere *Leucopogon fasciculatum* is a common constituent. Here also *Raoulia subsericea* appears exceptionally, and at an unusually low level of not more than 500 ft. A somewhat similar heath may be seen at the back of Mount Karetu.

(10) *The Subalpine Scrub.*

This consists, in addition to some species from the upper limits of the forest, of *Olearia cymbifolia* (forma), *O. ilicifolia*, with rare specimens of *Aristotelia fruticosa* and *Gaultheria antipoda* (the prostrate form). *Veronica buxifolia* was once found in it. This association is best seen on the old Purau line between Mounts Herbert and Fitzgerald, and again on the upper edge of the Mount Herbert bush. Species that might be expected and do not occur are *Coprosma foetidissima*, *C. cuneata*, and *Veronica propinqua*. *Pentachondra pumila* has been found on one or two hilltops. The poor development of the subalpine scrub may be due to an insufficient supply of moisture and a too high summer temperature. Near Dunedin it is much better developed, and includes two species of *Dacrydium* and *Phyllocladus alpinus*. These taxads are absent from Banks Peninsula.

(11) *The Subalpine Grasslands.*

Above 2,500 ft. there is to be found a distinct subalpine pasture.* It is characterized by the presence in abundance of *Ourisia macrophylla*

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* See also *Trans., N.Z. Inst.*, vol. 46, p. 58, 1914.

(forma), *Drapetes Dieffenbachii*, and *Anisotome aromatica*. *Euphrasia zelandica*, *Forstera tenella*, and *Oreomyrrhis andicola* also occur, but not so abundantly. This formation is found on all the tops from Mount Sinclair to Castle Rock, but for some reason does not occur on French Peak (2,600 ft.) to Saddle Mount (2,700 ft.). It reappears on Mount Bossu (2,500 ft.) and the neighbouring Carew's Peak (2,600 ft.), and traces of it reappear on Brasenose (2,500 ft.) behind Akaroa Township. Other species of the subalpine pasture are *Danthonia Raoulii* var. *rigida*, *Aciphylla Colensoi*, *Raoulia glabra*, and *R. subsericea*. *Danthonia Cunninghamii* and *Gunnera monoica* are also sometimes to be found. This little subalpine florula is, of course, as much isolated as if it stood on an island off the coast, and it is somewhat difficult to account for its presence here. Either it has been brought by birds or winds, or else it is a remnant of a vegetation that in glacial times reached to the sea-coast and extended widely over the country. We have not the data at present to solve the problem, and it can only be considered in connection with the general geological evidence and with the distribution of alpine species throughout New Zealand. It is, of course, to be expected that in this latitude wind-swept mountain-tops should carry some subalpine species above 2,500 ft. Such species are found near Dunedin as low as 1,500 ft., and in Stewart Island at sea-level. In some cases, however (*e.g.*, View Hill, French Peak), the forests were able to maintain themselves on hilltops up to 2,500 ft. This may be due to edaphic conditions, for these peaks are perhaps less rocky than those which are bare.

Vertical Distribution.

We have now considered briefly the general distribution of the indigenous vegetation on the peninsula. By way of brief recapitulation, it may be pointed out that in walking from the edge of Lake Ellesmere to the summit of Mount Herbert one would pass through practically all the plant associations described. Starting with the salt marsh and salt meadow, these follow in succession: the coastal scrub, a heath, a totara-black-pine forest a *Podocarpus Hallii-Libocedrus* forest, and a narrow belt of subalpine scrub, and finally the subalpine pasture. The same series would be passed through in ascending from the beach at Pigeon Bay to the summit of Mount Sinclair, or from the shore of Lake Forsyth to the top of Mount Fitzgerald.

Endemism.

The area is so isolated that it might be expected to show a certain amount of endemism. This is most readily illustrated by the three species *Celmisia Mackaui*, *Veronica Lavaudiana*, and *Senecio saxifragoides*. *Celmisia Mackaui* has been reported from Mount Fyffe by H. B. Kirk, but the report has not been confirmed; and *Veronica Lavaudiana* has been recorded by Lyall, W. T. L. Travers, and J. B. Armstrong from the river-beds of the Canterbury Plains. Now, *V. Lavaudiana* is a true chasmophyte, and I should be very much surprised to see it growing in the shingle-bed of one of our Canterbury rivers. It might perhaps be expected in the mountain gorges of these rivers, but I have not seen it there, and much doubt its occurrence elsewhere than on Banks Peninsula. Travers records it from the Ashley, but though I have been at many points of the Ashley river-system I have seen nothing resembling *V. Lavaudiana* there. A form of *V. Raoulii* certainly occurs at White Rock in small quantity; and

V. Lavaudiana could scarcely, if occurring, have been completely overlooked by Cockayne, Wall, and myself. I must therefore consider the above three species as endemic on the peninsula till more definite evidence is brought to the contrary.

Cotula Haastii is another species which may be endemic on the peninsula; though recorded from the plains by Haast, it has not been found there recently. There are other plants which are here represented by varietal forms—*e.g.*, *Aciphylla squarrosa*, *Angelica montana*, *Anisotome Enysii*, *Myosotis australis*, *Ourisia macrophylla*, *Veronica Lyallii*, &c.: but as it is not my intention to deal with critical species in this paper I am leaving these out of consideration here. Enough has been said to show that there is sufficient endemism in the area to suggest its isolation for a long time from any other portion of the country.

SPECIES AT THEIR SOUTHERNMOST LIMIT.

The following eighteen species probably here reach their southernmost limit on the eastern coast. Some are to be found farther south on the west coast. I give, where possible, some notes on their northward distribution.

Alectryon excelsum.—Abundant to the north of the Hurunui, and probably to be found in coastal valleys as far south as the mouth of the Waipara (Double Corner).

Angelica rosaefolia.—If correctly reported by Raoul from Akaroa this shows a remarkably discontinuous distribution, as it is not otherwise known outside the North Island.

Clematis Colensoi.—Found also on the foothills to the west; local on the peninsula.

Cordyline indivisa.—Does not occur on the coastal hills of North Canterbury, and I have seen no record of it from the Kaikouras, where, however, it may be expected to occur.

Corynocarpus laevigata.—Common on the Kaikoura coast and as far south as Gore Bay; a single tree at Manuka Bay, north of the Hurunui; but does not, I think, occur between the mouth of the Hurunui and Banks Peninsula.

Cyathea Cunninghamii.—If the determination be correct this is a remarkable southern extension of its range on the east of the South Island, but in Westland it extends beyond the Big Wanganui River.

Dodonaea viscosa.—Common along the coast to the north of Pegasus Bay.

Griselinia lucida.—I have not seen this south of Banks Peninsula, and doubt its occurrence, though reported in the *Manual* as not uncommon as far south as the Bluff. To the north of Banks Peninsula I have noted its occurrence at Manuka Bay, where typical specimens are to be seen on rocks, just to the north of the mouth of the Hurunui. It is not reported in the Dunedin Field Club's Catalogue (1916).

Hedycarya arborea.—On the Kaikoura coast, but I have not seen it between the Amuri Bluff and Banks Peninsula. It is curious that on the west coast it should occur as far south as Preservation Inlet, but it does not pass beyond Banks Peninsula here. Possibly the arid Canterbury Plains have proved a barrier to its southward progress.

Leucopogon fasciculatum.—Occurs inland on Mount Grey downs and in the Lee Valley.

Mariscus ustulatus.—Occurs at Gore Bay. It is reported from North Otago by Buchanan, but this requires confirmation.

Macropiper excelsum.—Common on the coastal hills to the north, but not on the plains.

Pittosporum obcordatum.—If Raoul's Akaroa record is correct this disappearing species shows remarkable discontinuity of distribution. Only known elsewhere from near Kaitaia.

Rhopalostylis sapida.—Does not occur on the coastal hills of North Canterbury, but is found on the Kaikoura coast as far south at least as Hundalee.

Rhagodia nutans.—Not uncommon near the coast at least as far south as Banks Peninsula.

Spiranthes australis.—Not known elsewhere on the east coast of this Island.

Tetrapathaea australis.—I do not know the nearest point where this plant is to be found north of Banks Peninsula, but it does not occur in northern Canterbury, nor, I think, at Kaikoura.

Zoysia pungens is found on the beaches immediately to the north, and shows no discontinuity of distribution.

It thus appears that Banks Peninsula is the southern terminus of a large number of northern species. On the other hand, few if any southern species find here their northern limit; *Olearia fragrantissima* is perhaps one. This suggests a southern drift of species; for, of course, most of the northern species could live as well on the Otago coast as in Banks Peninsula. On the west coast, where there has been no such barrier as the long treeless stretch between Banks Peninsula and Timaru, some of these species have drifted much farther south—*e.g.*, *Cordyline indivisa*, *Hedycarya arborea*, and *Rhopalostylis sapida*. Obviously the frosts of the plains tend to inhibit the occurrence of the more tender species.

The Relationships of the Banks Peninsula Florula.

The Forest.—It will be clear from what has been said that the forest of Banks Peninsula is an outlier of Cockayne's North-eastern Botanical District, No. 8 in the map of New Zealand* showing proposed botanical districts. It does not bear any close relationship to the forests of the Canterbury foothills. The nearest hills are those to the north and north-north-west—*e.g.*, Mounts Oxford, Karetu, and Grey. Here all the species finding their southernmost limit on Banks Peninsula are absent, with the exception of *Clematis Colensoi* and *Leucopogon fasciculatum*; and the timber-trees belong chiefly to the genus *Nothofagus*. It is true that *Podocarpus totara* is present in places on the foothills in small quantity, and *P. spicatus* and *P. dacrydioides* in still smaller quantities, but they are nowhere, as on the peninsula, the dominant species.

We get, however, to the westward at Mount Peel a mixed podocarp forest in which the above-mentioned species predominate, but it, too, differs much from the Banks Peninsula forest. This, of course, does not contain the species finding their southernmost limit on Banks Peninsula, but it contains an unusual variety of species, and amongst them several not found on the peninsula, such as *Nothopanax simplex*, *Aristotelia Colensoi*, *Gaya Lyallii* var. *ribifolia*, and *Hoheria lanceolata*. It thus appears that the Banks Peninsula forest must be regarded as an outlier of the Kaikoura coastal forest, which it closely resembles.

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* *Trans. N.Z. Inst.*, vol. 49, p. 63, 1917.

The Subalpine Area.—This area, as might be expected, is related to the subalpine area of Mounts Grey and Karetu, hills of about the same height as Mount Herbert, and little more than thirty miles away to the north. In both localities *Drapetes Dieffenbachii*, *Anisotome aromatica*, and *Olearia cymbifolia* are amongst the first subalpine forms to appear above the forest line. Mount Oxford is higher and has a much more varied alpine vegetation; and even Mount Karetu from 1,500 ft. and upwards shows species not occurring on the peninsula. Amongst them are *Coprosma repens*, *Celmisia spectabilis*, *Anisotome filifolium*, *Exocarpus Bidwillii*, and *Senecio geminatus*. No doubt this is due to the fact that we have here to deal with a much larger subalpine area than on the peninsula. So far as I know, however, *Ourisia macrophylla*, *Forstera tenella*, and *Oreomyrrhis andicola* do not occur in the Mount Grey district. If further search does not reveal their presence, their absence might seem to indicate that the subalpine florula of the peninsula contains species belonging to an older alpine flora, not now existent in the neighbourhood. None of the plants referred to are species likely to have been recently brought there, or to have been brought in the first place by wind or birds. Still, we have not enough evidence here to come to any definite conclusions, and the matter must be left in abeyance. This review of the vegetation of Banks Peninsula must now be concluded, with the hope that before the present remnants of the primitive flora disappear every opportunity will be taken by local students to complete the work here outlined.

Before concluding this section I must thank those New Zealand botanists from whom I have received much kind assistance. Mr. Cheeseman has identified a number of species for me, particularly of ferns; as also has Mr. Petrie, who has given me much help in connection with the genera *Coprosma* and *Uncinia*. I owe much to the kindly suggestions and advice of Dr. Cockayne, who has studied the vegetation of the Port Hills; and Professor Wall, who has during several years closely examined the flora of the peninsula, has kindly revised the distribution of the species, and, as will be seen, made numerous additions to the list of localities given. I am particularly indebted to him for assistance with the ferns and with the genus *Epilobium*. I believe that the list as it now stands is fairly complete, and that the number of subsequent additions will be comparatively small.

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LIST OF INDIGENOUS PLANTS FOUND ON BANKS PENINSULA.

Explanation of Abbreviations and Signs.

1. Plants marked thus ° (*e.g.*, °*Melicytus micranthus*) in the list are those that I have not collected myself or seen in the collections of others, but are introduced on the evidence of previous collectors. It may perhaps be noted that Raoul's list has been very carefully drawn up, and is throughout reliable. Though the identifications of Mr. J. F. Armstrong's list may not always be correct, still some plant can generally be found which the name represents; but in J. B. Armstrong's list there are names of many species which obviously do not occur on Banks Peninsula. Some of these can at once be rejected on external evidence, but in other cases it is manifestly impossible to say that the plant has not been found on the peninsula, though its occurrence there may be highly improbable. It is included in my list if there is any subsidiary evidence to suggest that it may have become extinct or have been overlooked. These *species inquirendae* are marked with a small (¹) before the initial letter of the genus—*e.g.*, (¹)*Eleocharis Cunninghamii*. This is intended to indicate that there is some reason to believe that the plant occurs or has occurred on the peninsula, but that it has not been recently found. Similarly the *species excludendae*—those plants which, though recorded, probably have not been found on the peninsula, or which have been identified in error—are marked with a small (²) before the initial letter of the genus—*e.g.*, (²)*Fimbristylis frondosa*. Of course, the line between *species inquirendae* and *species excludendae* is often very indistinct. It is quite possible that some of the *species excludendae* may subsequently be found on the peninsula, but the evidence in their favour does not justify their inclusion at present. Should they be discovered they can be readily reinstated. Of the *species inquirendae*, some are included in my list, and others, where perhaps the evidence for their occurrence is somewhat weaker, are only noted. In any count of the list, of course, only those which are definitely included should be reckoned.

2. Plants whose names are preceded by an asterisk, thus, *Asperella gracilis*, have not been found on the Lyttelton Hills—*i.e.*, between Gebbie's Pass and Lyttelton North Head. Plants not so marked are to be found or have in the past been found on the Lyttelton Hills. Some are perhaps now extinct there. It will also be noted that some plants recorded from the Lyttelton Hills are not recorded from Banks Peninsula; this in the majority of cases is probably due to the fact that the district nearer Christchurch has been more exhaustively examined than the more remote one. This, however, is not always the case, for *Senecio saxifragoides* and *Myosotis australis* var. seem to be confined to the smaller district.

3. Initials as under, which will be readily recognized, are used to indicate records where no details are given. In many cases such records will appear under synonyms and not under the names now in use.

R.	..	M. E. Raoul.
J. F. A.	..	J. F. Armstrong.
J. B. A.	..	J. B. Armstrong.
T. P.	..	T. H. Potts.
L. C.	..	L. Cockayne.
A. W.	..	Arnold Wall.
T. K.	..	Thomas Kirk.

Where no authority is given for a locality it will be understood that it is recorded from my own observations. Occasionally, to avoid confusion, I have introduced my own initials (R. M. L.). By "*Handbook*" is meant Hooker's *Handbook of the New Zealand Flora*, and by "*Manual*" Cheeseman's *Manual of the New Zealand Flora*.

4. No doubt there are many localities still to be found for some species. Some plants may be comparatively common which are recorded from only one or two places. Where it is not definitely known that the plant is widespread it is probably better to give exact habitats than make a vague statement. The list will, I think, be found practically complete as regards the Lyttelton Hills, but there will doubtless be a few omissions to be filled in for the peninsula, particularly in the Cyperaceae and grasses.

A good many varieties and a few critical species require closer description and identification. It would, however, much increase the length of this paper to deal with them, and it would, further, require comparison with forms in other parts of New Zealand. This work lies outside of the scope of the present article, but it may be hoped that this discussion will be carried on subsequently by myself or some other botanist. Any collector of Banks Peninsula plants should have no difficulty in identifying the plant referred to in my list. References will be found in the list to plants requiring further investigation.

FERNS (FILICES).

Hymenophyllum rarum R. Br. [J. B. A.]

Waikerikikeri: R. M. L. Rapaki: Potts. "Near Christchurch some of the dwarfer forms may be observed near the top of the small patches of bush that dot the Native reserve at Rapaki" (*Out in the Open*, p. 61).

Hymenophyllum sanguinolentum Hook. f.

Mount Pleasant: A. Wall! Banks Peninsula: Potts; J. B. A.

Hymenophyllum villosum Col.

Castle Rock (Con. Cheeseman).

*°(1)*Hymenophyllum australe* Willd.

Banks Peninsula: Potts.

°(1)*Hymenophyllum dilatatum* Swartz.

Lyttelton Hills: Potts. Banks Peninsula: J. B. A. I have searched the most secluded gullies on the peninsula in vain for this and the next species.

*°(1)*Hymenophyllum demissum* Swartz.

Banks Peninsula: Potts; J. B. A.

**Hymenophyllum flabellatum* Labill. [J. B. A.]
Mount Herbert Peak. Peraki Reserve: R. M. L.

*°*Hymenophyllum Malingii* Metten. [J. B. A.]
"On *Libocedrus Doniana* [*i.e.*, *L. Bidwillii*]. Port Levy": Potts (*Out in the Open*, p. 73).

°(1)*Hymenophyllum minimum* A. Rich.
Rapaki: Potts. Banks Peninsula: J. B. A.

Hymenophyllum tunbridgense Smith. [J. B. A.; L. C.]
Lyttelton Hills: Potts. Charteris Bay: A. Wall. Dover Castle and Mount Fitzgerald: R. M. L.

**Hymenophyllum unilaterale* Willd.
Long Bay, behind Akaroa; apparently a new record.

Hymenophyllum multifidum Swartz. [J. B. A.]
Cliff near Cooper's Knobs; Castle Rock, and Mount Fitzgerald above 2,000 ft., on rocky southern faces.

*°(1)*Hymenophyllum bivalve* Swartz.
Banks Peninsula: Potts; J. B. A.

Some of the above species are probably now extinct on the peninsula. J. B. A. records also (2)*H. scabrum*, (2)*H. pulcherrimum*, and (2)*H. subtilissimum*.

**Trichomanes venosum* R. Br. [R.; T. P.; J. B. A.; L. C.]
Balgueri Valley (Akaroa), on tree-fern trunks: R. M. L.

J. B. A. records also (2)*T. humile*, (2)*T. elongatum*, (2)*T.* (*Hymenophyllum*) *Lyallii*, and (2)*T. Colensoi*; but their existence on the peninsula is unconfirmed.

Cyathea dealbata Swartz. [R.; J. F. A.; J. B. A.; T. P.; A. W.; L. C.]
Once abundant; now becoming less common. Tree-ferns have been largely used for Christmas and other decorations in Christchurch, and now are almost extinct on the Lyttelton Hills, where formerly they abounded.

**Cyathea medullaris* Swartz.
Apparently very rare on Banks Peninsula, but a few plants occur in the remnants of the bush at Waikerikikeri: R. M. L. Akaroa: Raoul

Cyathea Cunninghamii Hook. f. (?).
Bush near Cooper's Knobs: A. Wall! The identification is not quite certain as yet; but the fern discovered can scarcely be anything else, though specimens sent to Mr. T. F. Cheeseman are pronounced to be probably *Hemitelia Smithii*.

Hemitelia Smithii Hook. f. [J. B. A.; T. P.; A. W.]
Akaroa; Wainui; Kaituna Valley; Abundant in the last two places, and probably elsewhere. It just crosses Gebbie's Pass to the bush just below Cooper's Knobs.

Dicksonia squarrosa Swartz. [R.; J. F. A.; J. B. A.; T. P.; L. C.; A. W.]
Common on the peninsula, but almost extinct on the Lyttelton Hills.

**Dicksonia fibrosa* Col. (?).
Wainui. As I have no specimens I am somewhat doubtful of the identification.

(1)*D. lanata* is also recorded by J. B. A. and J. F. A., and (1)*Alsophila Colensoi* by J. B. A. and T. P.

**Davallia novae-zealandiae* Col. [J. B. A.: T. P.]

Banks Peninsula: William Martin (*Lyttelton Times*, 17th August, 1918). I believe I collected this species some thirty years ago at Pigeon Bay, but have not seen it recently.

(1)*Cystopteris fragilis* is recorded by J. B. A. and T. P.

Adiantum affine Willd. [R.; J. F. A.; J. B. A.; A. W.]

Becoming rarer, but still growing on the southern faces of the Lyttelton Hills, Governor's Bay; in abundance at Nikau Palm Gully (Akaroa) and Caton's Bay.

**Adiantum fulvum* Raoul.

Akaroa: Raoul. Charteris Bay: R. M. L. Evidently by no means common.

*°(1)*Adiantum aethiopicum* Linn. [J. B. A.]

Akaroa: Raoul. This has not been seen in recent times, and must be regarded as a doubtful species.

(2)*A. hispidulum* has also been reported, but I have not seen it.

Hypolepis tenuifolia Bernh. [J. F. A.; J. B. A.; L. C.]

Ohinitahi: Potts. Common, usually among stones or boulders above the bush line; perhaps extinct on the Lyttelton Hills.

Hypolepis millefolium Hook. [J. B. A.; T. P.]

At one time on the Lyttelton Hills above Kaituna, and no doubt elsewhere.

Hypolepis distans is also reported by J. F. A. and J. B. A.

Cheilanthes Sieberi Kunze. [R.; J. F. A.; T. P.; J. B. A.; L. C.; A. W.]

Abundant in rocky clefts, and under stones, in dry situations.

Cheilanthes tenuifolia Swartz. [R.; J. B. A.; T. P.; T. K.; L. C.; A. W.

Lyttelton Hills and Banks Peninsula, in tussock lands amongst rocks; now very rare.

Pellaea rotundifolia Hook. [R.; J. F. A.; J. B. A.; L. C.; A. W.]

Common in forest and by streams; occasionally under rocks in dry places.

Pteridium esculentum Cockayne. [R.; J. F. A.; J. B. A.; L. C.; A. W.]

Everywhere abundant; often coming up after the burning of the forest.

**Paesia scaberula* Kuhn. [R.; J. F. A.; J. B. A.]

Not common; Mount Bossu, Wainui: R. M. L.

Histiopteris incisa J. Sm. [J. F. A.; J. B. A.; L. C.]

Ohinitahi: Potts. Not common: on the damper hilltops, Pigeon Bay, Lyttelton Hills (probably extinct). Stony Bay.

* (1)*Pteris tremula* R. Br. [J. B. A.]

Near Tikao Bay: Potts.

Cheeseman (*Manual*, p. 793) mentions (2)*P. macilenta* as recorded from Banks Peninsula, but has seen no specimens.

**Blechnum*† *Patersoni* Mett. [J. B. A.; T. P.]

Common in damper forests.

† The species of *Blechnum* appear in the *Manual* under the generic name *Lomaria*.

Blechnum discolor Keys. [R.; J. F. A.; J. B. A.; L. C.; A. W.]
Common on the forest-floor.

Blechnum lanceolatum Sturm. [R.; J. F. A.; L. C.; A. W.]
Common in the forest.

Blechnum penna marinum Kuhn. [R.; J. F. A.; J. B. A.; T. P.]
Abundant above 1,000 ft., but not common on the Lyttelton Hills, and coming down to 300 ft. in Pigeon Bay. Heathcote Valley: A. Wall: R. M. L. Peak between Kennedy's Bush and Cooper's Knobs: R. M. L.

Blechnum capense Schlecht. [R.; J. F. A.; J. B. A.; T. P.; L. C.; A. W.]
Everywhere abundant.

Blechnum fluviatile Lowe. [J. F. A.; J. B. A.; L. C.; A. W.]
Common by bush-streams.

Blechnum membranaceum Mett. [J. B. A.; T. P.; L. C.; A. W.]
Hay's Bush (Pigeon Bay) and behind Governor's Bay, but not common.

(¹)*B. Banksii*, (²)*B. nigrum*, and (¹)*B. durum* are given by J. B. A. (the last probably occurs), and (¹)*B. vulcanicum* by J. F. A. and T. P. (Ohinitahi). Cheeseman (*Illustrations*, pl. 240) refers to (¹)*B. durum* finding its northernmost limit at Banks Peninsula.

Asplenium flabellifolium Cav. (= ? *A. triste* Raoul). [R.; J. B. A.; J. F. A.; T. P.; L. C.; A. W.]
Abundant under stones and rocks.

**Asplenium adiantoides* Raoul. [J. B. A.; T. P.]
Common on peninsula.

Asplenium obtusatum Forst. f. [R.; T. P.; J. B. A.; L. C.]
Abundant on coastal cliffs and rocks; but it is to be noted that Wall identifies the coastal *Asplenium* of Lyttelton Harbour as a form of *A. lucidum*.

Asplenium lucidum Forst. f. [R.; J. F. A.; J. B. A.; A. W.]
Common in most places. Var. *obliquum* is the commonest, and perhaps the type form, but var. *Lyallii* also occurs. [Con. L. C.]

Asplenium Hookerianum Col. [R.; J. F. A.; J. B. A.; T. P.; A. W.; L. C.]
Common in many forms. (Akaroa is the habitat of the type.)

Asplenium bulbiferum Forst. f. [R.; J. F. A.; J. B. A.; L. C.; A. W.]
One of the commonest of bush ferns, but much sought after by tourists and others.

**Asplenium Richardi* Hook. f. [R.; J. B. A.]
Mount Herbert: Potts. Waikerikikeri, and doubtless elsewhere: R. M. L.

Asplenium flaccidum Forst. f. [R.; J. F. A.; J. B. A.; T. P.; L. C.; A. W.]
Abundant on forest-trees.

J. B. A. and Potts add (¹)*A. trichomanes*, which I have not seen.

Polystichum vestitum Presl. (= *Aspidium aculeatum* Swartz var. *vestitum* Hook. f.: *Handbook*, p. 997). [R.; J. F. A.; J. B. A.; T. P.; L. C.; A. W.]
Common on the forest-floor.

Polystichum Richardi J. Sm. (= *Aspidium Richardi* Hook. f.: *Handbook*, p. 999). [J. B. A.: T. P.: L. C.: A. W.]

Akaroa: Raoul. Abundant in open tussock pasture. This includes doubtless the varietal form *P. oculatum* Hook. f.

Polystichum hispidum J. Sm. [J. B. A.: T. P.: L. C.]

Otahuna: A. Wall!

*°(1)*Polystichum capense* J. Sm.

Akaroa: Raoul. Probably an erroneous identification.

Dryopteris glabella C. Chr. [J. B. A.: L. C.]

Allandale: A. Wall! Balgueri Valley: R. M. L. Ohinitahi: Potts.

Dryopteris punctata C. Chr. [J. B. A.: T. P.; L. C.: A. W.]

Common.

Dryopteris pennigera C. Chr. (= *Polypodium pennigerum* Forst. f.: *Manual*, p. 1009). [J. B. A.: T. P.; L. C.: A. W.]

Common by the sides of streams.

J. F. A., J. B. A., and T. P. give also (1)*Dryopteris* (*Nephrodium*) *decomposita*.

*°(1)*Nephrodium velutinum* Raoul. [J. F. A.: J. B. A.: T. P.]

Akaroa.

**Polypodium australe* Mett. [J. B. A.: T. P.]

Common on trees and rocks.

Polypodium australe Mett. var. *pumilum* Cheesm.

Mount Herbert Peak, and doubtless elsewhere: near Cass Peak: R. M. L.

*(1)*Polypodium Cunninghamii* Hook. [J. B. A.]

Akaroa: Raoul. A rather doubtful inhabitant of the peninsula.

**Polypodium pustulatum* Forst. f. [J. B. A.]

Akaroa: Raoul. I was somewhat surprised to find in Caton's Bay (Lake Forsyth), just above the house, on the forest-floor, undoubted specimens of this species, as I had considered it either extinct on the peninsula or wrongly identified.

Polypodium grammitidis R. Br. [R.: J. F. A.: J. B. A.: T. P.: A. W.]

Not uncommon on rocks exposed to the south-west.

Polypodium diversifolium Willd. [R.: J. F. A.: J. B. A.: T. P.: L. C.: A. W.]

Everywhere abundant on rock and forest-tree.

J. B. A. gives also (1)*Arthropteris* (*Polypodium*) *tenella*.

Cyclophorus serpens C. Chr. [R.: J. F. A.: J. B. A.: A. W.]

Cliffs, rocks, and trees; common.

Nothoclaena distans R. Br. [J. B. A.; T. P.: L. C.: A. W.]

Lyttelton Hills, Quail Island, and Lyttelton Harbour generally: A. Wall!

An undescribed *Cheilanthes* or *Nothoclaena* is common about Diamond Harbour, where it has been found by A. Wall. Cheeseman considers it to be probably a *Nothoclaena*.

Gymnogramme rutaefolia Hook. & Grev. [L. C.; A. W.]

Dry rocks, Dover Castle, and north side of Mount Pleasant; also Sumner Valley; Wakeroa Head; Pigeon Bay.

Gymnogramme leptophylla Desv. [J. F. A.; J. B. A.; T. P.; L. C.; A. W.]
In open tussock land; not common. Heathcote Valley: E. Holdsworth! Lyttelton.

**Gleichenia Cunninghamii* Heward. [J. B. A.; T. P.]
Port Levy, about 2,000 ft., on Pigeon Bay side of valley, but now extinct in this locality. Recorded by William Martin behind Le Bon's Bay (*Lyttelton Times*, 17th July, 1918).

Potts records also (²)*Gleichenia dicarpa*, and J. B. A. (²)*G. circinata*. It is unlikely that either occurs.

Leptopteris hymenophylloides Presl. [J. F. A.; J. B. A.; T. P.; L. C.; A. W.]
In the darker forests, Cooper's Knobs, Kaituna, Port Levy, &c.

J. B. A. gives also (²)*Todea superba* and (²)*Schizaea dichotoma*; both are unlikely species.

Ophioglossum coriaceum A. Cunn. [J. B. A.; L. C.]
Lyttelton Hills, near Bridle-path: hills behind Wainui; ridge between Le Bon's and Waikerikikeri; and elsewhere.

Botrychium australe R. Br. [J. F. A.; J. B. A.; T. P.; L. C.]
Mount Herbert; Lyttelton Hills, &c.; but not often found now.

(²)*Phylloglossum Drummondii* is reported by J. B. A., but probably in error.

Lycopodium varium R. Br.
Lyttelton Hills (perhaps now extinct); Governor's Bay, Caton's Bay, Waikerikikeri, and in several other localities, but not now common.

Lycopodium fastigiatum R. Br. [R.]
Common on the mountain-tops in the centre of the peninsula; also on peak between Cass Peak and Cooper's Knobs.

**Lycopodium volubile* Forst. f. [J. B. A.]
Akaroa: Raoul. Wainui hilltops, above Le Bon's Bay: Summit Road, near Hilltop Hotel: R. M. L. Mount Herbert: A. W.

J. B. A. gives also (²)*L. Selago* and (²)*L. Billardieri*.

Lycopodium scariosum Forst. f.
Only noted in the patch of forest beyond Kennedy's Bush.

**Tmesipteris tannensis* Bernh. [J. B. A.]
Akaroa: Raoul. Okute Valley, Little River: R. M. L.

Class CONIFERAE.

Family Taxaceae.

**Libocedrus Bidwillii* Hook. f. [J. B. A.]
Akaroa to Mount Herbert, above 1,500 ft., and chiefly on the southern sides.

(²)*L. Doniana*, recorded by J. B. A., does not occur.

Podocarpus totara D. Don. [J. F. A.; J. B. A.; L. C.]
At one time everywhere abundant: now getting uncommon.

**Podocarpus ferrugineus* D. Don. [J. F. A.; J. B. A.]
At one time there were a few trees on the peninsula. The only ones I have seen recently are in a small group in Port Levy, on the slopes of Mount Herbert, at about 1,200 ft. Mr. E. Hay has informed me that there is one specimen in his reserve at Pigeon Bay.

**Podocarpus Hallii* T. Kirk.
Usually towards the tops of the hills, where it is often rather stunted. Generally known on the peninsula as "mountain-totara." The timber is considered somewhat inferior to that of *P. totara* Apparently not hitherto recorded.

Podocarpus spicatus R. Br. [J. B. A.; L. C.]
With *P. totara* this was at one time the chief timber-tree of the forests, now largely destroyed. Above 2,500 ft. it becomes dwarfed and flattened to the rocks.

Podocarpus dacrydioides A. Rich. [J. B. A.]
Much less common than the preceding, and generally on the flats, though scattered trees were found in most valleys. "The flat was covered [*i.e.*, in Le Bon's Bay] with white and black pines as thick as they could stand; and the sides of the valley grew immense totaras and other timber." (H. C. Jacobson, *Tales of Banks Peninsula*, 1893.)

*(1)*Dacrydium cupressinum* Soland. [J. B. A.]
I introduce this with hesitation, as I have not seen it on the peninsula, and believe it to be now extinct. However, settlers have assured me that it once grew in Little River, near Okain's, and elsewhere in small quantity.

Mr. W. H. Montgomery, of Little River, writes thus: "Rimus used to be common on my land near the Hilltop"; and I have heard from other sources that some 40,000 ft. of this timber was taken from a stand on Harman's Track (Puaha). J. B. A. (*Trans.*, vol. 12, p. 328) states the rimu is "chiefly found on the higher ridges, and is here a far inferior tree in beauty compared to the West Coast variety of the same species." This does not agree with my information; and I certainly would expect to find it rather in the moister valleys amongst the denser bush than on the higher ridges."

CLASS MONOCOTYLEDONEAE.

Family TYPHACEAE.

Typha angustifolia Linn. [J. F. A.; J. B. A.]
In swampy places common, though becoming less abundant as drainage proceeds.

Family NAIADACEAE.

Triglochin striatum Ruiz. & Pav. [J. B. A.]
Kaituna; Heathcote Estuary: R. M. L. Children's Bay, Akaroa: A. W.

**Ruppia maritima* Linn. [J. B. A.]
Kaituna, Lake Ellesmere.

Zostera nana Roth (?). [J. B. A.]
I have not examined this species carefully. Lyttelton Harbour and elsewhere.

*(2)*Potamogeton pectinatus* Linn.
Lake Forsyth: T. Kirk.

*(2)*Potamogeton ochreatus* Raoul. [R.; J. B. A.]
Banks Peninsula is the habitat of the type.

J. B. A. records two other species—(2)*P. natans* and (2)*P. compressus*—but I have not seen them. *P. Cheesemanii* is to be expected, but has not yet been recorded.

Family GRAMINEAE.

°(1)*Zoysia pungens* Willd. [J. B. A.]

Recorded by Cheeseman (*Manual*, p. 844). I have seen it growing at Gore Bay, and have also seen specimens from New Brighton, and consider that it probably still occurs on the peninsula.

Microlaena avenacea Hook. f. [R.; J. B. A.; L. C.]

Abundant on the forest-floor. (Akaroa is the habitat of the type.)

Microlaena polynoda Hook. f. [J. F. A.; J. B. A.; L. C.]

Rare. Redcliffs, Caton's Bay, in scrub; bush beyond Kennedy's: A. W.

Hierochloe redolens R. Br. [J. F. A.; J. B. A.]

Common; usually above 800 ft.

**Stipa arundinacea* Benth. [J. F. A.; J. B. A.]

Pigeon Bay; Long Bay (near Peraki): R. M. L. Akaroa: Lyall; Kirk.

Stipa setacea R. Br.

Sumner; Heathcote Valley; Cashmere Hills. Probably a recent introduction.

Echinopogon ovatus Beauv. [J. B. A.]

Apparently not common. Lyttelton Hills: A. W Caton's Bay; Island Bay: R. M. L.

J. B. A. records (1)*Agrostis canina* and (1)*A. quadriseta*. These should certainly be looked for.

**Deyeuxia filiformis* Petrie. [J. B. A.]

Kaituna; Mount Fitzgerald; Stony Bay.

*°*Deyeuxia filiformis* Petrie var. *pilosa* Cheesem.

Banks Peninsula: T. Kirk.

Dichelachne crinita Hook. f. [J. B. A.; L. C.]

Common on rock-faces and drier hillsides

Deschampsia caespitosa Beauv. [J. F. A.; J. B. A.]

Akaroa: Raoul. Tops of ridges, Lyttelton Hills: R. M. L. And probably elsewhere.

°*Trisetum antarcticum* Trin. [J. B. A.]

Lyttelton Hills: Cockayne.

**Danthonia Cunninghamii* Hook. f.

Mount Herbert and Mount Sinclair, 2,500 ft. Apparently not hitherto recorded.

Danthonia Raoulii Steud.

Akaroa (the habitat of the type); Mount Sinclair, above 1,000 ft.; Cooper's Knobs.

I treated this previously as *D. flavescens* (*Trans.*, vol. 46, p. 58), but as the plant differs somewhat from the form as found elsewhere, and as it is undoubtedly the *D. rigida* of Raoul, it is the type of *D. Raoulii* and may be called var. *rigida*.

Danthonia semiannularis R. Br. [R.; J. B. A.; L. C.]

Common in the tussock meadows, and probably increasing in quantity.

Danthonia pilosa R. Br. [L. C.]

Abundant, and increasing (see introduction, p. 363).

Arundo conspicua Forst. f. [J. F. A.; J. B. A.; L. C.]
Common in gullies with flax.

Poa caespitosa, Forst. f. [J. B. A.: L. C.]
The chief tussock of the hillside, but slowly disappearing owing to fires and cultivation.

Poa Colensoi Hook. f. [J. B. A.; L. C.]
Commoner towards the hilltops, and apparently a disappearing species.

Poa imbecilla Forst. f. var. *Matthewsii* Hack. [J. B. A.; L. C.]
Common in damper and shadier ground near the hilltops.

J. B. A. includes also (²)*P. breviglumis*, (²)*P. foliosa*, (²)*P. anceps*, (²)*P. Lindsayi*, and (²)*P. scoparia*. Two of these are plants of the sub-antarctic islands.

Atropis stricta Hack. var. *suborbicularis* Hack.
Salt meadows, Teddington (det. Petrie). Apparently not hitherto recorded.

Festuca novae-zealandiae Cockayne. [J. B. A.; L. C.]
Not uncommon in the tussock pastures.

°*Festuca multinodis* Petrie.
Lyttelton Hills: Cockayne.

**Festuca littoralis* Labill. [J. B. A.]
Peninsula, near shore.

Agropyron scabrum Beav. var. [L. C.]
Lyttelton Hills: not common. Island Bay: R. M. L. A migrant tussock.

**Agropyron multiflorum* T. Kirk.
Akaroa: T. Kirk. (Specimen in the Canterbury Museum.)

* *Asperella gracilis* T. Kirk. [J. B. A.]
Akaroa: Raoul.

Family CYPERACEAE.

The following species, recorded only by J. B. A., should, I think, be struck off the list: (²)*Cyperus tenellus*, (²)*Schoenus tenax*, (²)*S. pauciflorus*, (²)*S. axillaris*.

**Mariscus ustulatus* C. B. Clarke. [J. B. A.]
Peraki: L. C. Near Long Lookout, Island Bay: R. M. L.

Eleocharis acuta R. Br. [J. B. A.]
In damp places, Cashmere Hills: R. M. L.; A. W.

(¹)*Eleocharis Cunninghamii* Boeck. [J. F. A.: J. B. A.]
Lyttelton Hills: L. C. (Possibly in error for the preceding species, though A. W. has found it in Hagley Park.)

(¹)*E. sphacelata* is also recorded by J. B. A.

Scirpus inundatus Poir. [J. B. A.]
Damp spots on Lyttelton Hills: A. W. Doubtless also on Banks Peninsula.

* *Scirpus antarcticus* Linn.
Mount Herbert: A. Wall.

**Scirpus sulcatus* Thouars var. *distigmatosa* C. B. Clarke.
Waimui, in watercourses.

Scirpus nodosus Rottb. [J. B. A.]
Lyttelton Hills: Pigeon Bay; Akaroa. Common in dry watercourses and near the seashore.

Scirpus cernuus Vahl.
Salt meadows, Teddington, and elsewhere.

Scirpus frondosus Banks & Sol. [J. F. A.]
Sandhills, Sumner and Taylor's Mistake.

Scirpus americanus Pers.
Ohinitahi: Lake Ellesmere: &c.

Scirpus lacustris Linn.
Heathcote: B. D. Cross.

Scirpus maritimus Linn
Akaroa: T. Kirk. Lake Ellesmere; Ohinitahi.

J. B. A. gives also (2)*Fimbristylis dichotoma*, a very improbable inhabitant, being a plant of the warmer portions of the North Island; but (1)*Cladium teretifolium* may possibly occur. Four species of *Gahnia* also appear on his list. I have seen none, and if any occur they are by no means common. J. F. A. records (2)*Lepidosperma tetragona* (= *Cladium Vauthiera*): this may possibly occur, but I have not seen it nearer than Mount Grey.

Cladium glomeratum R. Br. [J. B. A.]
Cashmere Valley: A. W.!

**Uncinia rubra* Boott.
Abundant, 2,000 ft. and upwards, from Mount Sinclair to Castle Rock.

Uncinia uncinata (Linn. f.) T. Kirk. [J. B. A.]
Common in the forests and elsewhere.

Uncinia leptostachya Raoul. [J. B. A.]
Common in the forest, Akaroa (habitat of type).

Uncinia riparia R. Br. var. *Banksii* C. B. Clarke.
Mount Pleasant (det. Petrie). Akaroa: A. W.

J. B. A. gives also (1)*U. rupestris*, which, being one of Raoul's species, is doubtless an inhabitant of the peninsula; but after a close search I am unable to find it. I think it unlikely that there are other forms on the peninsula than those listed above. If this be so, then *U. rupestris* of Raoul may be included in one of the forms above, possibly *U. riparia* var. *Banksii*; though it is to be admitted that none of my specimens coincide exactly with Raoul's illustration.

Carex appressa R. Br.
Near Lyttelton lighthouse: A. Wall! A new record

Carex virgata Sol. [J. B. A.]
Cashmere Valley, below Marley's Road: R. M. L. Stony Bay: J. Andersen!

Carex secta Boott. [J. F. A.; J. B. A.; L. C.]
Not uncommon in swampy places and by the sides of streams—*e.g.*, Teddington: Charteris Bay: Taylor's Mistake (on the shore); Waimui.

Carex breviculmis R. Br. [J. B. A.]

In drier ground, often near the hilltops.

Carex ternaria Forst. f. [J. F. A.; J. B. A.; L. C.]

Common in damper places—indeed, the most abundant species of *Carex* on the peninsula.

*([1])*Carex Colensoi* Boott.

Specimens from Castle Rock were identified by Petrie as probably belonging to this species.

*°*Carex Raoulii* Boott. [J. B. A.]

Akaroa: Raoul.

**Carex Wakatipu* Petrie. (Con. Cheeseman.)

Castle Rock, 2,500 ft.

Carex lucida Boott. [J. B. A.; L. C.]

Common in damper spots on the Cashmere Hills, in the neighbourhood of Governor's Bay and Teddington, and possibly elsewhere.

Carex litorosa Bailey.

Heathcote: B. D. Cross.

Carex dissita Sol. [J. B. A.; L. C.]

In pastures and forest; not very common.

*°*Carex trifida* Cav. [J. B. A.]

Akaroa: Raoul.

**Carex pumila* Thunb. [J. B. A.]

Waimui: R. M. L. Akaroa: Raoul.

**Carex flava* Linn. var. *cataractae* B. Br. [J. B. A.]

Top of Castle Rock.

Carex pseudo-cyperus Linn.

Watercourse, Port Levy.

Carex Forsteri Wahl.

By the side of bush-streams, Kaituna, Port Levy; Summit Track beyond Kennedy's Bush, Governor's Bay. Some of the specimens have rather the character of *C. semi-Forsteri*.

I have paid too little attention to the genus *Carex* to be able to give a complete list, consequently additional species are to be expected here.

J. B. A. gives in addition ([2])*C. pyrenaica*, ([1])*C. teretiuscula*, ([1])*C. stellulata*, ([1])*C. testacea* ([1])*C. inversa*, ([1])*C. vacillans*. Some of these probably occur.

Family PALMEAE.

**Rhopalostylis sapida* Wendl. & Drude. [J. B. A.]

Once not uncommon, now becoming rare—Holmes Bay (probably now extinct); Laverick's; Okain's; Le Bon's; Waikerikikeri; Damon's; Palm Gully, Akaroa. (The southernmost limit on this coast.)

Family LEMNACEAE.

Lemna minor Linn. [J. F. A.; J. B. A.]

In pools.

Family RESTIACEAE.

Leptocarpus simplex A. Rich. [J. B. A.]

Heathcote, in salt marshes: B. D. Cross. Teddington: R. M. L.

Family Juncaceae.

Juncus pallidus R. Br. (?).

(The identification is not quite certain, as my specimens are somewhat immature.)

Port Levy: R. M. L. Probably also on Lyttelton Hills, near Dry Bush: A. W.

Juncus pauciflorus B. Br. [J. B. A.; L. C.]

Abundant in the tussock pastures.

Juncus vaginatus R. Br. [J. F. A.; J. B. A.]

Akaroa: T. Kirk. Lyttelton Hills.

Juncus polyanthemus Buchen. [J. F. A.; J. B. A.; L. C.]

Common in damper pastures.

Juncus maritimus Lam. var. *australiensis* Buchen. [J. B. A.]

Common in salt marshes. (According to B. D. Cross, extends as far south as Timaru.)

Juncus bufonius Linn. [J. B. A.]

Abundant.

**Juncus planifolius* R. Br.

Akaroa: Raoul. Mount Herbert, near top: A. Wall. Kaituna, in the wayside ditches: R. M. L.

Juncus caespiticius E. Mey. var. *bracteatus* Buchen.

Cashmere Valley: A. Wall.

**Juncus novae-zealandiae* Hook. f.

French Peak, and in a slender state on the top of Castle Rock.

J. B. A. gives also (2) *J. scheuchzerioides* and (2) *J. holoschoenus*, neither of which is likely to occur.

Luzula campestris DC. vars. [J. F. A.; J. B. A.; L. C.]

Family Liliaceae.

Rhipogonum scandens Forst. [J. F. A.; J. B. A.; L. C.]

Common in the forest in many places.

Cordyline australis Hook. f. [J. F. A.; J. B. A.; L. C.]

Common on open hillsides.

**Cordyline indivisa* Steud. [J. B. A.]

Apparently the southernmost limit on this coast. Above 1,800 ft. Purau Line, Akaroa Summit Road: not common.

(2)*C. Veitchii* Hort., given as an additional species by J. B. A., is merely a synonym of *C. australis*.

Astelia nervosa Banks & Sol. [J. B. A.; L. C.]

Abundant, chiefly in forest.

(2)*A. Solandri* and (2)*A. linearis* are recorded by J. B. A., but have not been observed by any one else.

Phormium tenax Forst. [J. F. A.; J. B. A.; L. C.]

Common in gullies and at moister spots.

**Phormium Cookianum* Le Jolis. [J. F. A.; J. B. A.]

On cliffs, and often in the open above the bush line. Possibly occurs on the Lyttelton Hills, though not definitely recorded from there.

(1)*Bulbinella Hookeri* is recorded by J. F. A. and J. B. A., and perhaps occurs.

Arthropodium candidum Raoul. [R.: J. F. A.: J. B. A.: L. C.]
Not infrequent in shaded gullies and in bush. Aylmer's Valley, track to lighthouse: A. Wall. Cashmere Hills; Castle Rock; &c.: R. M. L. Akaroa (habitat of type).

J. B. A. records also ([2])*Dianella intermedia*. I do not think it occurs.

*[c]*Iphigenia novae-zelandiae* Baker. [J. F. A.]
Banks Peninsula: Cockayne, in Cheeseman's *Manual*.

Family Amaryllidaceae.

Hypoxis pusilla Hook. f. [L. C.]
Victoria Park, Cashmere Hills, and elsewhere. Difficult to observe unless in flower. Flowers April to June, and again in early spring.

Family Iridaceae.

Libertia grandiflora Sweet (?). [J. F. A.: J. B. A.]
Abundant. The plant is larger in every way than the common forms of *L. ixioides* that I am acquainted with elsewhere, and may be true *L. grandiflora*: but though the capsules are often ½ in. in length I have measured none exceeding that dimension; the leaves, however, are often over ⅓ in. wide. There is, at any rate, only one species to be found here. The bracts are always long narrow-linear or linear-lanceolate and acuminate. Hooker (*Handbook*, p. 274) evidently regards this form as *L. grandiflora*, so I have r tained the name.

J. F. A., J. B. A., and L C. give *L. ixioides*. J. B A. includes also ([2])*L. restioides* Klatt and ([2])*L. micrantha* A. Cunn.

Family Orchidaceae.

Earina mucronata Lindl. [J. F. A.; J. B. A.: L. C.]
I am not certain that I have seen this species. It is certainly less common than the following.

Earina suaveolens Lindl. [J. B. A.]
Not uncommon in rocky clefts.

J. B. A records also ([1])*Dendrobium Cunninghamii*, but I have not seen it.

**Spiranthes australis* Lindl.
Banks Peninsula: J. B. A.!
Several specimens labelled as from Banks Peninsula are in the Canterbury Museum. In the *Lyttelton Times* of the 6th April, 1918, in the column "From Nature's Book"† appears the following: "Mr. J. B. Armstrong . . . reports that *Spiranthes australis* was very common on the Lake Ellesmere flats before they were drained. Both the red and white variety may be found there still"

Thelymitra longifolia Forst. [J. F. A.; L. C.]
Castle Rock; Sugarloaf, &c.; but becoming less common.

J. B. A. includes ([2])*T. uniflora*, which I have not seen.

† Edited by J. Drummond.

Microtis unifolia Reichenb. [J. B. A.; L. C.]
Not uncommon.

Prasophyllum Colensoi Hook. f. [J. F. A.]
Castle Rock, above 2,500 ft.; Lyttelton (?): R. M. L.

Pterostylis Banksii R. Br.
Not uncommon in the forest and heath.

**Pterostylis australis* Hook. f.
Waikerikikeri; Checkley's Bush, Akaroa; and probably elsewhere.

Pterostylis graminea Hook. f.
Waikerikikeri; Castle Rock; Lyttelton.

(1)*Pterostylis foliata* Hook. f. (?).
Heathcote Valley. One specimen only seen, collected by Miss E. Holdsworth, and thus identified by Cheeseman: "I believe, however, that it is *P. foliata*, of which it has the sheathing bracts and short lateral sepals."

(2)*Cyrtostylis oblonga* is recorded by J. B. A.

**Caladenia minor* Hook. f. [J. B. A.]
Akaroa: Miss M. Fyfe!

Corysanthes triloba Hook. f. [J. F. A.; J. B. A.; L. C.]
Not uncommon in damp shady spots.

**Corysanthes macrantha* Hook. f. [J. F. A.; J. B. A.]
Castle Rock.

Gastrodia Cunninghamii Hook. f. [J. B. A.]
Okute Valley, and probably elsewhere. It has been reported to me from Akaroa, and near Tai Tapu, but I have not seen specimens.

Other orchids reported by J. B. A. are (2)*Dendrobium pygmaeum*, (1)*Corysanthes rotundifolia*, (2)*C. rivularis*, (2)*Lyperanthus antarcticus*, (2)*Caladenia Lyallii*; and by J. F. A., (2)*Corysanthes oblonga*.

Class DICOTYLEDONEAE.

Family Piperaceae.

Macropiper excelsum Miq. [J. F. A.; J. B. A.; L. C.]
Not uncommon in the lower forest, particularly near the sea. Here finds its southernmost limit.

Family Fagaceae.

**Nothofagus Solanderi* Oerst.
Summit of Long Bay Ridge, Akaroa, and extending downward for some distance to the eastward. Forms resembling *N. Blairii* are to be found, but require further examination.

**Nothofagus cliffortioides* Oerst.
Forms apparently belonging to this species occur intermingled with *N. Solanderi* on the Long Bay Ridge. J. B. A. records it with a (?).

**Nothofagus fusca* Oerst. [J. B. A.]
Ridges from Stony Bay to Damon's Bay. Some magnificent specimens are found here in the forest.

Family Urticaceae.

Paratrophis microphylla Cockayne. [J. F. A.; J. B. A.; L. C.]
Abundant in the forest.

Urtica incisa Poir. [J. F. A.; J. B. A.; L. C.]
In forest.

Urtica ferox Forst. f. [J. F. A.; J. B. A.; L. C.]
Abundant in forests and in their neighbourhood.

**Parietaria debilis* Forst. f. [J. B. A.]
In scrub near Caton's Bay, Little Akaloa, and elsewhere, but not common.

Australina pusilla Gaud. [J. B. A.]
Mount Pleasant; Cooper's Knobs (perhaps extinct in this locality); Port Levy, on sides of small waterfall; Barry's Bay, in dark creek.

Family Loranthaceae.

Loranthus micranthus Hook. f. [J. F. A.; J. B. A.; L. C.]
Common; becoming a pest in Akaroa, where it attacks fruit-trees and other deciduous trees such as *Robinia pseudacacia*, and even the willow. (See also *Out in the Open*, p. 135.)

Tupeia antarctica Cham. & Schl. [J. F. A.; J. B. A.; T. P.; L. C.]
Lyttelton (*Out in the Open*, p. 138); Stony Bay; Akaroa; Caton's Bay; Port Levy.

Korthalsella Lindsayi Engler. [J. F. A.; J. B. A.; T. P.]
On *Myrsine Urvillei* at Purau, on *Myrtus obcordata* at Stony Bay, and on *Melicope simplex* at Port Levy.

Korthalsella salicornioides Van Tiegh. [J. B. A.; L. C.; T. P.]
Wainui; Caton's Bay, on *Leptospermum*: R. M. L. Lyttelton Hills: Potts; Cockayne. Dover Castle: A. W.

Of this species Potts (*Out in the Open*, p. 139) writes: "The writer only knows one habitat, that amongst a group of rocks just above the sea in Port Cooper. At the spot mentioned it makes use of the small-leaved manuka (*Leptospermum ericoides*) as a fostering plant." Doubtless extinct in locality referred to.

Family Polygonaceae.

Polygonum aviculare Linn. [J. F. A.]
By roadsides, common; probably introduced.

Rumex flexuosus Soland. [J. F. A.; J. B. A.; L. C.]
Common.

Muehlenbeckia australis Meissn. [J. F. A.; J. B. A.; L. C.]
Abundant.

Muehlenbeckia complexa Meissn. [J. F. A.; J. B. A.; L. C.]
Everywhere abundant at the edge of forests and in dry stony ground.

**Muehlenbeckia axillaris.* [J. B. A.]
Top of Saddle Peak. Seen nowhere else by me.

Family Chenopodiaceae.

Rhagodia nutans R. Br. [L. C.]

Lyttelton Hills, amongst stones; Governor's Bay; Pigeon Bay, by seaside: R. M. L. Sleepy Cove, between Long Bay and Stony Bay, and doubtless elsewhere by the sea-coast: A. Wall.

Chenopodium triandrum Forst. f. [J. F. A.; J. B. A.]

Common in dry rocky ground. In specimens from the Lyttelton Hills the perianth-segments numbered five.

Chenopodium glaucum Linn. [J. F. A.; J. B. A.]

Taylor's Mistake.

Chenopodium carinatum R. Br.

Above Heathcote Reservoir. Probably introduced.

Atriplex patula Linn.

Heathcote: B. D. Cross. Ohinitahi: Teddington.

J. F. A. and J. B. A. give also (1)*Chenopodium ambiguum*, which possibly occurs.

Salicornia australis Linn.

Abundant in salt marshes.

Suaeda maritima Dum.

The beach, Le Bon's Bay; Redcliffs: A. W.

Family Aizoaceae.

Tetragonia expansa Murr.

Abundant on coastal banks, but occasionally ascending to 1,000 ft. on cliffs.

Tetragonia trigyna Banks & Sol.

Less common than the preceding. Also ascending to 1,000 ft., but usually on the sea-coast.

Mesembryanthemum australe Sol.

Common on the sea-coast.

Family Caryophyllaceae.

*°*Gypsophila tubulosa* Boiss.

Lake Forsyth: Kirk.

Stellaria parviflora Banks & Sol. [J. B. A.; L. C.]

Common. A much depauperated form with only 3 or 4 stamens occurs at the altitude of about 1,000 ft. on the southern face of Mount Pleasant.

Colobanthus Muelleri Kirk.

Common in similar places to the following species.

Colobanthus Billardieri Fenzl. [J. B. A.; L. C.]

Not uncommon in rocky places near the hilltops.

(1)*C. quitensis* Bartl. is also recorded by J. B. A., and may occur.

Spergularia media Presl.

Not uncommon on rocky coasts. Probably = *S. marina* var. *rubra* of J. B. A.

Scleranthus biflorus Hook. f. [J. B. A.; L. C.]

In dry and rocky ground; common.

Family RANUNCULACEAE.

Clematis indivisa Willd. [J. B. A.; L. C.]

At one time common in the forest; now much less so.

C. hexasepala Forst. is recorded by J. B. A. and T. K., but does not occur. A specimen labelled *C. hexasepala* and collected by T. Kirk at Governor's Bay is in the collection at the Canterbury Museum, but, as pointed out on the sheet by L. C., is merely a well-grown plant of *C. foetida*.

**Clematis Colensoi* Hook. f. [J. B. A.]

Price's Bush, near Birdling's Flat: S. Page! W. Martin.

Clematis foetida Raoul. [R.; J. F. A.; J. B. A.; L. C.]

Everywhere common in the forest, and in Birdling's Bush forming stems which rival those of *C. indivisa* in diameter. (Akaroa is the type-locality.)

([2])*C. parviflora* is also recorded by J. B. A., but I have not seen it, and doubt its occurrence.

Clematis afoliata Buch. [J. B. A.; L. C.]

Not uncommon on the sea-coast, and occasionally on the drier cliffs up to 1,500 ft. At Sumner it is becoming more abundant.

C. marata is not uncommon on the sand-dunes at New Brighton, but is probably not to be found on the peninsula.

Ranunculus hirtus Banks & Sol. [J. B. A.; L. C.]

Common in the tussock country.

Ranunculus lappaceus Smith var. *multiscapus* Hook. f. [J. F. A.; J. B. A.; L. C.]

Common in open country.

Ranunculus rivularis Banks & Sol. var. *subfluitans* Benth.

Pond, Cashmere Hills.

J. F. A. and J. B. A. record also ([2])*R. pinguis*, an Auckland Island plant, and J. F. A. gives ([2])*R. macropus*.

Family MAGNOLIACEAE.

Drimys colorata Raoul. [R.; J. B. A.; L. C.]

Abundant, particularly on the upper edges of the forests. (Akaroa is the type-locality.)

J. F. A. gives ([2])*D. axillaris*, no doubt in place of the above species, and T. Kirk (*Students' Flora*) states the *D. axillaris* goes as far south as Banks Peninsula, but he is, I think, in error.

Family MONIMIACEAE.

Hedycarya arborea Forst.

Common in the forest. Its southernmost limit on this coast, though it extends as far as Preservation Inlet on the west coast.

Family CRUCIFERAE.

Cardamine heterophylla Schulz. [J. F. A.; J. B. A.; L. C.]

Usually weak and decumbent; but a stout, erect variety (perhaps var. *macrantha*) occurs on the cliffs on the northern side of Mount Pleasant, above the Summit Track (not seen in flower). The weak and decumbent form may be var. *leiocarpa*.

**Lepidium oleraceum* Forst. f. var. *acutidentatum* Kirk.

Coastal cliffs, Waikerikikeri.

Family DROSERACEAE.

J. F. A. and J. B. A. record, but probably in error. (²)*Drosera spathulata* and (²)*D. binata*.

Family CRASSULACEAE.

Crassula Sieberiana Schultz. [L. C.]
An annual, abundant in dry, hard ground and on rocks in spring and summer.

**Crassula moschata* DC. [J. B. A.]
Crown Island Run, on the coast.

J. B. A. records also (²)*Tillaea Sinclairii*.

Family SAXIFRAGACEAE.

Carpodetus serratus Forst. [J. F. A.; J. B. A.; L. C.]
A common forest tree.

J. B. A. lists also (²)*Quintinia serrata*, a quite unlikely species.

Family PITTOSPORACEAE.

Pittosporum tenuifolium Banks & Sol. [R.; J. F. A.; J. B. A.; L. C.]
Abundant in forest, and here erroneously called "matipo." The relative proportions of the leaves vary considerably in breadth and length in different specimens.

J. B. A. and J. F. A. record also *P. Colensoi*, but a specimen so named by J. B. A. in the Canterbury Museum is a common form of *P. tenuifolium*.

Pittosporum eugenioides A. Cunn. [J. F. A.; J. B. A.; L. C.]
Common in the forest.

*(¹)*Pittosporum obcordatum* Raoul. [R.; J. B. A.]
Akaroa: R. (type-locality). Does not appear to have been found since the days of Raoul at Akaroa, though it appears in J. B. A.'s list (see Cheeseman, *Trans.*, vol. 39, p. 436).

Family ROSACEAE.

Rubus australis Forst. f. var. *glaber* Hook. f. [J. F. A.; J. B. A.; L. C.]
Abundant in the forest.

Rubus cissoides A. Cunn. [J. B. A.]
In the forests; abundant.

Var. *pauperatus* Kirk, though sometimes found in the forest, is more often found in the open, chiefly on the sites of old forests. [J. B. A.; L. C.]

Rubus schmidelioides A. Cunn. [J. B. A.] var. *coloratus* Kirk [L. C.]
Common on the margin of the forests, and in rocky ground above the forests.

Rubus subpauperatus Cockayne. [L. C.]
Common near the outskirts of the forest.

Potentilla anserina Linn. var. *anserinoides* Raoul. [R.; J. F. A.; J. B. A.; L. C.]
In swampy ground occasionally. (Akaroa is the type-locality.)

°*Geum urbanum* Linn. var. *strictum* Hook. f. [J. F. A.; J. B. A.; L. C.]
Tussock pastures: Cockayne.

Acaena novae-zelandiae Kirk var. *viridissima* Bitter. [J. B. A.; L. C.]
This is the most abundant form of *Acaena* on the peninsula, and is everywhere common up to 1,600 ft., particularly in dry open ground. In the forest it is usually replaced by the following, which, however, is by no means so common.

Acaena Sanguisorbae Vahl. var.
This variety is thus described from my specimens by L. Cockayne in a letter to me: "Plainly to be distinguished by the dark dull green and but slightly hairy upper surface of the leaf, the silvery under-surface with closely appressed hairs, the sepals green edged with purple within and still more hairy and purple without, the frequently trifid stipules, and the rather short stout spines, which vary from pale to rather dark purple." This variety, comparatively rare on the Lyttelton Hills, occurs frequently on the peninsula above 1,500 ft., and at all levels in the forest.

Acaena Sanguisorbae Vahl. var. *pilosa* Kirk.
This form as described by Kirk occurs on the southern slopes of Castle Rock and Mount Herbert above the height of 2,000 ft., probably also at Cooper's Knobs. It is at once distinguished from the preceding by its glaucous bluish coloration, with brown serrations. The under-surface of the leaf, the upper margin, the petiole, peduncles, and stem are all markedly pilose. (I am indebted to Dr. Cockayne, who is making a special study of the New Zealand species of the genus, for this identification).

A fourth form of *Acaena* (*Acaena Sanguisorbae* Vahl. var. *viridior* Cockayne) occurs in a small piece of bush in the Wainui Valley.

J. B. A. gives also (2)*A. adscendens*, but I do not think it occurs.

Family LEGUMINOSAE.

*(1)*Carmichaelia nana* Col. (?). [J. B. A.]
I have seen specimens belonging, I think, to this species near the top of Mount Herbert, on the northern side. Neither flowers nor fruit were present, and I was unable to identify it with certainty. *C. nana* is common on the old river-bed of the Waimakariri, seven miles from Christchurch.

Carmichaelia subulata Kirk. [L. C.]
Abundant in open country from the seashore to upwards of 1,500 ft. This is the only large species on the peninsula.

J. B. A. records (2)*C. australis*, which does not come south of Pelorus Sound, (2)*C. flagelliformis* (probably in error for the above), (2)*C. pilosa* Col. (?), and with J. F. A., in addition, (2)*C. grandiflora*.

Sophora microphylla J. Müll. [J. F. A.; J. B. A.; L. C.]
Common in the forest, and sometimes on the open hillside.

Sophora prostrata J. Müll. [L. C.]
Common in rocky ground, and here a very distinct species.

**Sophora tetraptera* J. Müll var.

A third and very distinct form of this genus occurs between Raupo and Stony Bay, and apparently has no juvenile stage. On submitting a specimen to T. F. Cheeseman he commented on it as follows: "This seems to be nearer to *S. grandiflora* than to *S. microphylla*, but does not match the East Cape plant, which must be taken as the type." The leaves are about 10 cm. long with 15–20 pairs of linear-oblong leaflets, the standard about $\frac{5}{6}$ the length of the wings, and not reflexed.

J. B. A. records (²)*S. grandiflora*.

Family Geraniaceae.

Geranium microphyllum Hook. f. [J. F. A.; J. B. A.; L. C.]
Common in grasslands.

Geranium sessiliflorum Cav. var. *glabrum* Knuth. [J. B. A.]
Peak between Cass Peak and Cooper's Knobs; Barry's Bay; Castle Rock (2,500 ft.).

Geranium dissectum Linn. var. *australe* Benth. [J. F. A.; J. B. A.]
Not common, and usually in cultivated places.

Pelargonium inodorum Willd. [J. F. A.; L. C.]
Cashmere Hills and elsewhere, chiefly in cultivated ground.

Family Oxalidaceae.

Oxalis corniculata Linn. [J. F. A.; J. B. A.; L. C.]
Everywhere abundant in open country.

Oxalis magellanica Forst.
Old Purau Road, Mount Fitzgerald (2,500 ft.).

Family Linaceae.

Linum monogynum Forst. f. [J. F. A.; J. B. A.; L. C.]
Everywhere common on the coastal cliffs, and sometimes also found on rocky crests and summits.

The introduced *L. marginale* is sporadic and adventive. It was at one time common near the foot of Dyer's Pass Road.

Family Rutaceae.

Melicope simplex A. Cunn. [J. B. A.; L. C.]
Everywhere abundant in the forest.

Family Euphorbiaceae.

Euphorbia glauca Forst. f. [J. F. A.; J. B. A.]
The beach, Le Bon's; R. M. L. The beach, Wainui; A. W.; R. M. L.

Family Callitrichaceae.

Callitriche verna Linn.
Wainui; common in streams. Apparently a new record.

Family Coriariaceae.

Coriaria sarmentosa Forst. f. [J. B. A.: L. C.]

Common in the tree form in the forest, and in the dwarf form in the open. The small form is considered to be more deadly to stock.

Family Corynocarpaceae.

Corynocarpus laevigata Forst. [J. B. A.]

At one time a few scattered specimens probably existed along the coast from Dampier's Bay, Lyttelton, to Long Lookout Point It has been suggested by J. B. A. that it is an escape from cultivation; but there is nothing in its distribution at Long Lookout Point, the only place where it now occurs, to suggest this. It there extends to a distance of a mile and a half inland from the beach, and has been comparatively abundant over this area. It is said that a grove existing at Macintosh Bay was felled by the owner in order to discourage the Maoris from visiting the place. One plant in Aylmer's Valley, Akaroa, found by Miss Fyfe! (See introduction for further account of its distribution.)

Family Icacinaceae.

Pennantia corymbosa Forst. [J. F. A.; J. B. A.; L. C.]

Common in the forest.

Family Sapindaceae.

Dodonaea viscosa Jacq. [J. B. A.; L. C.]

Common in the coastal forest *e.g.*, Gollan's Bay; Rapaki: Lake Forsyth: Akaroa.

Alectryon excelsum Gaertn. [J. F. A.; J. B. A.; L. C.]

Gollan's Bay; Port Levy; Birdling's Bush, where it forms a considerable proportion of the forest; and elsewhere. Its southernmost limit on this coast.

Family Rhamnaceae.

Discaria toumatou Raoul. [R.; J. F. A.; J. B. A.; L. C.]

Abundant in open country. (Akaroa is the type-locality.)

Family Elaeocarpaceae.

Aristotelia racemosa Hook. f. [J. F. A.; J. B. A.; L. C.]

Abundant in the forest.

**Aristotelia fruticosa* Hook. f. [J. B. A.]

Forest on southern side of Mount Herbert (2,500 ft.): only several specimens seen.

**Elaeocarpus Hookerianus* Raoul. [R.; J. B. A.]

Caton's Bay; Tikao Bay: S. Page. Aylmer's Valley; Waikerikikeri; Port Levy. In most places only a solitary specimen or two. (Akaroa is the type-locality.)

*(1)*Elaeocarpus dentatus* Vahl. [J. F. A.: J. B. A.]

I have not certainly seen this on Banks Peninsula. It occurs in Deans's Bush, near Christchurch: and a specimen of *Elaeocarpus* at Pigeon Bay probably belongs to this species, but I have not seen it in flower.

Family Malvaceae.

Plagianthus divaricatus Forst. [J. F. A.; J. B. A.]
Common in salt-water marshes, as at Teddington; or on stony beaches—*e.g.*, Port Levy.

(1)*Plagianthus cymosus* T. Kirk.
A specimen apparently belonging to this species was found on Mount Pleasant, behind Lyttelton, by Cockayne and Petrie; but in spite of numerous searches I have been unable to rediscover the plant. Cockayne now thinks it may have been a flowering plant of the juvenile form of *P. betulinus*.

Plagianthus betulinus A. Cunn. [J. F. A.; J. B. A.; L. C.]
Abundant in the forest.

Hoheria angustifolia Raoul. [R.; J. F. A.; J. B. A.; L. C.]
Common in the opener forest and by roadsides. (Akaroa is the type-locality.)

Family Guttiferae.

Hypericum gramineum Forst. f. [J. F. A.; J. B. A.; L. C.]
Tussock-grasslands.

Hypericum japonicum Thunb. [J. F. A.; J. B. A.; L. C.]
Tussock-grasslands.

Family Violaceae.

Viola filicaulis Hook. f. [J. B. A.]
Hilltops chiefly.

Viola Cunninghamii Hook. f. [J. F. A.; J. B. A.; L. C.]
Tussock-grassland and swamps.

Melicytus ramiflorus Forst. [J. F. A.; J. B. A.; L. C.]
Everywhere common. Known on the peninsula as "cow-leaf" or "whity-wood." The North Island Maori name, "mahoe," is quite unknown here, as is also the Otago "ini-ini."

(2) *Melicytus lanceolatus* is recorded only by J. B. A. I have not seen it nearer than Peel Forest.

°(1)*Melicytus micranthus* Hook. f. var. *microphyllus* Cheesm. [J. B. A.; L. C.]

Hymenanthera crassifolia Hook. f. [J. B. A.; L. C.]
Abundant in rocky places, particularly near the hilltops. A rigid shrub with spinous divaricating interlacing branches, forming a mat closely appressed to stones and cliff-faces. The berries are found on the underside of the mat, and remain white when not exposed to light, but thereafter become dark blue—almost black. It has been regarded as a coastal plant, but is not so here.

The species is extremely plastic, probably as much so as *Discaria toumatou* has been shown to be by Cockayne. In caves and moist forests it loses its thorny and divaricating character, forms long pliant branchlets pubescent towards the tips, and becomes clothed with somewhat larger leaves. In this form it is perhaps not different from *H. dentata*.

Family PASSIFLORACEAE.

Tetrapathaea australis Raoul. [R.; J. F. A.; J. B. A.; L. C.]
Becoming extinct on the Lyttelton Hills. Maori Pa, Port Levy; Pigeon Bay; Aylmer's Valley; Checkley's Bush, Akaroa, common; Barry's Bay; Caton's Bay. Here at its southernmost limit on this coast.

Family THYMELAEACEAE.

**Drapetes Dieffenbachii* Hook.
Common above 2,000 ft. Leaves hairy at the tip but not on the margin. In specimens from Mount Brasenose the perianth-lobes are as long as the tube and externally villous. Dr. Berggren has identified this with the Tasmanian *D. tasmanica*, which it resembles,† but in the absence of specimens of the latter it must be left as it is.

I have seen no pimeleas on the peninsula; but J. B. A. lists (²)*P. prostrata*, though J. F. A. gives it merely as an inhabitant of Canterbury swamps.

Family MYRTACEAE.

Leptospermum scoparium Forst. [J. F. A.; J. B. A.; L. C.]
Everywhere common in heaths.

Leptospermum ericoides A. Rich. [J. F. A.; J. B. A.; L. C.]
Abundant, and in the Kaituna Valley growing into trees more than 2 ft. in diameter at the bole and 50 ft. high.

Metrosideros hypericifolia A. Cunn. [J. B. A.; L. C.]
Not common on the Lyttelton Hills, but plentiful in the forest elsewhere on the peninsula.

According to J. B. A., (²)*M. scandens* and (²)*M. Colensoi* also occur on the peninsula, but these records are almost certainly erroneous.

Myrtus obcordata (Raoul) Hook. f. [R.; J. F. A.; J. B. A.; L. C.]
Common in forest and scrub. (Akaroa is the type-locality.)

**Myrtus pedunculata* Hook. f. [J. B. A.]
Kaituna Valley and elsewhere; but not nearly so common as the preceding. I do not think it occurs on the Lyttelton Hills.

Family ONAGRACEAE.

**Epilobium Billardierianum* Ser. [J. B. A.]
"At sea-level in Sleepy Cove, between Long Bay and Stony Bay": A. Wall.

Epilobium junceum Sol. var. *cinereum* Haussk. [J. B. A.; L. C.]
Lyttelton Hills, and elsewhere; common.

Epilobium junceum Sol. var. *macrophyllum* Haussk.
Waimui Cashmere Valley: R. M. L. Between Little River and Port Levy Saddle, in damp places: A. Wall.

Epilobium pubens A. Rich. [J. B. A.; L. C.]
In many places; common.

† CHEESEMAN, *Manual*, p. 165.

**Epilobium pictum* Petrie.

"On steep banks by the roadside in Balgueri Valley (Akaroa) and Pigeon Bay Peak": A. Wall.

**Epilobium alsinoides* A. Cunn.

Common on the summits from Mount Bossu to Mount Herbert; Waikerikikeri: Stony Bay Peak.

**Epilobium tenuipes* Hook. f.

Mount Herbert, 2,000 ft.: A. Wall.

**Epilobium insulare* Haussk.

On swampy hillsides from sea-level to nearly 3,000 ft., common—*e.g.*, on the south side of Rocky Peak above the hilltop, and on the northern and eastern sides of Mount Herbert near the summit: A. Wall.

Epilobium rotundifolium Forst. f. [J. F. A.; J. B. A.; L. C.]

Common in moist places.

Epilobium linnaeoides Hook. f.

Not common. Heathcote Valley; Wainui: R. M. L. "In damp stony places. Bush at the head of Stony Bay; southern face of Mount Herbert, at about 2,500 ft.; Dan Rogers Gully": A. Wall.

Epilobium nummularifolium R. Cunn. [J. F. A.; L. C.]

Abundant on damp rocks and banks.

Epilobium nerterioides A. Cunn. [L. C.]

Abundant in tussock-grasslands.

**Epilobium macropus* Hook. [J. B. A.]

Southern side of Mount Herbert, near the top: A. Wall.

Epilobium novae-zealandiae Haussk.

Akaroa Summit Road, and elsewhere near the hilltops, and sometimes down to 500 ft. Very variable in form, and occasionally approaching *E. glabellum*.

J. B. A. and J. F. A. record several other species which have been seen by no other observers on the peninsula—*e.g.*, (²)*E. purpuratum*, (²)*E. microphyllum*, (²)*E. crassum*.

Fuchsia excorticata Linn. [J. F. A.; J. B. A.; L. C.]

Everywhere common in the forest.

Fuchsia Colensoi Hook. f. [J. F. A.; J. B. A.; L. C.]

Common in the forest and by the wayside.

Family HALORRHAGIDACEAE.

Halorrhagis erecta Schindler. [J. F. A.; J. B. A.; L. C.]

Common in the open country and in scrub.

**Halorrhagis depressa* Walp.

Common along the summits; everywhere above 1,500 ft.

Myriophyllum intermedium DC. [J. F. A.]

Cashmere Valley; Lake Ellesmere; Kaituna; Wainui.

**Gunnera monoica* Raoul. [R.; J. B. A.]

On the ridge between Akaroa and Flea Bay; Saddle Hill; near summit of Mount Herbert; and in many other localities facing south and south-west, usually above 1,500 ft., but coming down in Wainui to less than 500 ft. (Akaroa is the type-locality.)

The *Gunnera monoica* recorded by J. F. A. from the sandhills is doubtless (²)*G. arenaria*.

Family ARALIACEAE.

Nothopanax arboreum Seem. [J. B. A.; L. C.]

One of the most abundant of forest-trees. Sometimes called "fig-wood" by the settlers, or "New Zealand fig." The surveyors' ugly name of the North is here unknown.

**Nothopanax Colensoi* Seem. [J. B. A.]

Long Bay, in the beech forest, not common; Mount Herbert, in the subalpine scrub.

Nothopanax anomalum Seem.

Mount Pleasant (a few specimens only), and Caton's Bay.

J. F. A. and J. B. A. record (²)*P. simplex*, but the record does not seem to have been confirmed.

Schefflera digitata Forst. [J. F. A.; J. B. A.; L. C.]

Abundant; called "ohau" at Akaroa.

Pseudopanax crassifolium C. Koch var. *unifoliolatum* Kirk. [J. F. A.; J. B. A.; L. C.]

Not uncommon in the forest.

Pseudopanax ferox T. Kirk. [J. B. A.]

Little Akaloa; Caton's Bay: R. M. L. Lake Forsyth: T. Kirk. Stony Bay: J. Andersen! And elsewhere, but quite uncommon.

Family UMBELLIFERAE.

Hydrocotyle elongata A. Cunn. [J. B. A.; L. C.]

Mount Pleasant; Barry's Bay; not common.

Hydrocotyle americana Linn. [J. B. A.; L. C.]

Lyttelton Hills; Stony Bay; and doubtless elsewhere.

Hydrocotyle americana Linn. var. *heteromeria* Kirk. [J. B. A.; L. C.]

Cashmere Valley.

Hydrocotyle novae-zealandiae DC. [L. C.; J. B. A.]

Lyttelton Hills. I have not seen this on Banks Peninsula, but doubtless it occurs.

Hydrocotyle moschata Forst. f. [J. B. A.; L. C.]

Lyttelton Hills (and doubtless elsewhere), common. The most abundant species of *Hydrocotyle* in the neighbourhood.

Hydrocotyle microphylla A. Cunn. (?).

As Cheeseman points out, this may not be Cunningham's plant: but a small and very distinct form of *Hydrocotyle* agreeing with the description of this species in the *Manual* is found very commonly on the tracks and in the bush, usually above 1,000 ft. I append a brief description: Leaves four- or five-lobed, to the middle or slightly beyond, about 5–7 mm. across, glabrous or occasionally slightly farinose, lobes sometimes again notched. Petioles rather long (15–20 mm.), sometimes with a few isolated hairs. Umbels with 2–5 rays, almost sessile, enclosed at the base by several translucent minute rotundate or broadly oblong bracts. Flowers almost sessile, but peduncle elongating in fruit to length of carpel. Fruit laterally compressed, with a rather prominent rib on each face. Carpels rounded at the back. This differs from *H. americana* in the rounded carpels and uniformly smaller size, and from *H. novae-zealandiae* in the much smaller size and more deeply indented leaves. The species is very distinct in appearance and has a well-defined habitat.

J. B. A. records also (1)*H. asiatica*, (2)*H. muscosa*, and (2)*H. dissecta*. *H. asiatica* is certainly to be expected; but, though I have seen it growing freely as an imported weed in a garden on Cashmere Hills, I have nowhere seen it in a natural habitat.

Schizeilema Hookeri Domin. [L. C.]
Rather rare; usually at an altitude of 1,200 ft. or upwards, on southerly slopes or in forest, but in Checkley's Bush (Akaroa) and Wainui reaching to within several hundred feet of the sea. Also occurs at Mount Pleasant; Castle Rock; near Kennedy's Bush track; and elsewhere.

J. B. A. gives also (2)*Pozoa* (*i.e.*, *Azorella*) *hydrocotyloides*—a very unlikely plant to be found here.

Apium prostratum Labill. [J. B. A.]
Common on coastal rocks.

Apium prostratum Labill. var. *filiforme* Hook.
Purau, Teddington, &c., in salt marshes.

**Oreomyrrhis andicola* Endl. var. *Colensoi* Kirk.
In small quantities on the top of Mount Herbert: A Wall!

Crantzia lineata Nutt. [J. B. A.]
In salt marshes, Heathcote Estuary, Kaituna, &c

Aciphylla Colensoi Hook. f.
Purau line, above 2,000 ft.

Aciphylla squarrosa Forst. f. [J. F. A.; J. B. A.; L. C.]
Once common; now rapidly disappearing, particularly in sheep-country.

Anisotome aromatica Hook. f. [J. B. A.; L. C.]
Banks Peninsula, common above 1,500 ft.; but very rare on Lyttelton Hills, Cooper's Knobs, The Tors.

Anisotome Enysii (Kirk) Laing (?)†.
Dr. Cockayne considers this may not be the same as the Castle Hill plant. Usually above 1,500 ft. Dover Castle; Mount Sinclair; Mount Berard; Purple Peak; One Tree Hill.

J. B. A. records (2)*Ligusticum piliferum*. probably in error.

Angelica montana Cockayne. [J. B. A.; L. C.]
Once common; now only in rocky clefts and on shelves inaccessible to sheep.

Angelica geniculata Hook. f. [J. B. A.; L. C.]
Common, usually near the sea-coast. Lyttelton; Akaroa; Kaituna; Waikerikikeri; &c.

?*Angelica rosaefolia* Hook.
Akaroa: recorded by Raoul, but probably not seen since, though it appears in J. B. A.'s list.

Daucus brachiatus Sieb. [J. B. A.; L. C.]
Lyttelton Hills; Castle Rock.

† *Report on Scenery-preservation*, 1914–15, p. 14.

Family Cornaceae.

Corokia Cotoneaster Raoul. [R.; J. B. A.; L. C.]

Abundant in rocky places near the hilltops, and more rarely on the coast, as at Island Bay. (Akaroa is the type-locality.)

Griselinia littoralis Raoul. [R.; J. F. A.; J. B. A.; L. C.]

Abundant everywhere in the forest. (Akaroa is the type-locality.)

**Griselinia lucida* Forst. f.

Waikerikikeri (rare); Little River (perhaps extinct); Stony Bay; sometimes on black or white pines. Probably its southernmost limit.

Family Ericaceae.

Gaultheria antipoda Forst f. [J. B. A.]

Banks Peninsula, 2,000 ft. and upwards; usually prostrate and creeping, and small-leaved. Identified (probably wrongly) with var. *depressa* (*Trans.*, vol. 46, p. 59). Lyttelton Hills (the erect form), on peak between Cass Peak and Cooper's Knobs; and at a low level in Wainui, in manuka scrub.

J. B. A. gives also (²)*G. rupestris*, which I have not seen.

Family Epacridaceae.

**Pentachondra pumila* R. Br.

Near the top of Brasenose (perhaps extinct): R. M. L. Stony Bay Peak: A. Wall.

Cyathodes acerosa Sol. [J. B. A.; L. C.]

Not uncommon amongst rocks.

Leucopogon Fraseri F. Muell. [R.; J. B. A.; L. C.]

1,500 ft. and upward, not common; but coming down to sea-level at Redcliffs.

Leucopogon fasciculatum A. Rich. (?). [J. B. A.]

Rapaki; Kaituna; Akaroa; and elsewhere.

Dracophyllum acicularifolium Cockayne. [J. B. A.]

Abundant on rocky ledges, 1,600 ft. and upwards; Cooper's Knobs, and peak to eastward.

Family Myrsinaceae.

Myrsine Urvillei A. DC. [J. F. A.; J. B. A.; L. C..]

Everywhere common in the forest.

Myrsine divaricata A. Cunn. [J. B. A.]

Kennedy's Bush (one or two specimens); Le Bon's; Mount Fitzgerald; Kaituna; &c.; usually 1,200 ft. and upward.

J. B. A. gives also (²)*M. nummularia*; but I doubt its occurrence.

Family Primulaceae.

Samolus repens Pers. var. *procumbens* R. Knuth. [J. F. A.]

Coastal cliffs and beaches; common.

Family GENTIANACEAE.

°*Sebaea ovata* R. Br. [J. F. A.; J. B. A.]
Port Cooper: Lyall. Lake Ellesmere: T. Kirk.

**Liparophyllum Gunnii* Hook. f.
Lake Ellesmere.

J. B. A. includes (²)*Gentiana montana* Forst., but almost certainly in error.

Family APOCYNACEAE.

Parsonsia heterophylla A. Cunn. [R.; J. F. A.; J. B. A.; L. C.]
Abundant in the forest.

Parsonsia capsularis R. Br. var. *rosea* Cockayne. [R.; J. F. A.; J. B. A.; L. C.]
Very common in the forest; often more abundant than the preceding. (Akaroa is the type-locality of the variety.)

Family CONVOLVULACEAE.

Calystegia tuguriorum R. Br. [J. F. A.; J. B. A.; L. C.]
Not uncommon in the forest.

C. sepium occurs in abundance by the waysides and in gardens, but is probably introduced.

Calystegia Soldanella R. Br. [J. B. A.]
On sandy beaches.

Convolvulus erubescens Sims.
Common on dry hillsides, particularly those exposed to the sea-wind.

Dichondra repens Forst. [J. F. A.; J. B. A.; L. C.]
Less common than the following.

Dichondra brevifolia Buch.
Abundant in dry open ground, and often found in gardens (Cashmere Hills). The flowers at the tips of the branches are almost sessile.

Family BORAGINACEAE.

(¹)*Myosotis spathulata* Forst. f. [J. B. A.]
A form from Mount Pleasant has been so identified by Petrie; but further specimens are required.

Myosotis pygmea Col. [J. B. A., as *M. antarctica* (?).]
Gollan's Bay; Sugarloaf; behind Governor's Bay; usually above 1,000 ft.

Myosotis australis R. Br. var. [J. B. A.; L. C.]
Lyttelton Hills, southern side, at the foot of cliffs and on rocky ledges, usually about 600–800 ft. This plant has been thus identified by T. F. C. and L. C.; while Petrie has hesitated to identify it with any known species. It is undoubtedly intermediate between *M. australis* and *M. Forsteri*, and where it not for the weight of authority against me I should consider it more closely allied to *M. Forsteri* than to *M. australis*. It differs from *M. australis* in the almost prostrate stems, less hispid stem and leaves, shorter racemes; the newly ripe seeds are polished and shining, dark brown, not black. It differs from *M. Forsteri* in being much stouter, the pedicels are shorter and do not

equal the calyx, the leaves are spathulate rather than orbicular-oblong or oblong, being one and a half to twice as long as broad. The nutlets are ovoid, not orbicular. The colour when dry is not so dark as that of *M. australis*, nor so green as that of *M. Forsteri*. The flowers are invariably white, the calyx tubular in the flower, becoming campanulate in the fruit. I propose, however, to leave the discussion of this and other critical species for a subsequent paper.

**Myosotis Forsteri* Lehm. [J. B. A.]

A more typical form of *M. Forsteri* occurs on the Akaroa – Flea Bay Ridge above 2,000 ft.

J. B. A. has also (2)*M. capitata*.

Family VERBENACEAE.

Teucridium parvifolium Hook. f. [J. F. A.; J. B. A.; L. C.]

Mount Pleasant: Caton's Valley. Perhaps now extinct in the former locality.

Family LABIATAE.

Mentha Cunninghamii Benth. [R.; J. F. A.; J. B. A.]

Hoon Hay Valley; hills behind Tai Tapu.

(2)*Scutellaria* has been recorded by J. A. B., but probably in error.

Family SOLANACEAE.

Solanum aviculare Forst. f. [J. F. A.; J. B. A.; L. C.]

A common weed in country that has been recently cleared of bush, and in the outskirts of the forest; not common elsewhere.

Solanum nigrum Linn. [J. F. A.; L. C.]

An abundant weed in gardens and elsewhere, appearing as an introduction.

Family SCROPHULARIACEAE.

Mimulus repens R. Br.

Heathcote Valley: Kaituna (Lake Ellesmere).

(1)*Mazus pumilio* R. Br. [Lyall; J. B. A.]

A doubtful inhabitant.

(2)*Gratiola nana* is also recorded by J. B. A.

**Limosella tenuifolia* Nutt.

Lake Ellesmere.

Specimens collected by T. Kirk under the name *L. aquatica* are in the Canterbury Museum.

Veronica salicifolia Forst. f. var. *communis* Cockayne. [J. B. A.; L. C.]

Abundant in scrub and near the edge of the forest.

Veronica leiophylla Cheesem. [L. C.]

This is the *V. ligustrifolia* Cunn. of Armstrong's list. It is abundant on the upper fringes of the bush, and is often not found elsewhere. In the Kaituna Valley it occurs all through the forest, reaching from over 2,000 ft. down to sea-level; in other places where it comes down to sea-level (*e.g.* Akaroa, Crown Island, Little Akaloa) the leaves become shorter and broader than in the typical form.

**Veronica buxifolia* Benth (forma).

One plant only seen, on Summit Track in Greenland Bush, Mount Herbert.

(²)*V. pimeleoides*, reported by Lyall from Port Cooper, may possibly, though not probably, be *V. Lavaudiana*. At any rate, nothing resembling *V. pimeleoides* occurs near Lyttelton.

Veronica Lavaudiana Raoul. [R.; J. F. A.; J. B. A.; L. C.]

Everywhere abundant on rocky faces above 800 ft. or 900 ft. I have never seen it on the plains. Travers's record of it from there is probably an error. (Akaroa is the type-locality.)

*(¹)*Veronica Raoulii* Hook. f. [R.; J. B. A.]

I cannot help thinking that there must be some error in the record of a Banks Peninsula habitat for this species. It is said by Hooker to have been received by him from Raoul with specimens of *V. Lavaudiana*: but it seems improbable that such a careful botanist as Raoul should have confused two such different species. J. B. A., no doubt following Hooker, records it as from the peninsula. It is not, however, a plant which is likely to have become extinct. Growing in similar situations to *V. Lavaudiana*, one might have expected it to have been found in conjunction with it; but I have hunted assiduously for it in all likely places and have been unable to find it. The nearest point to the peninsula where I have found it is at White Rock, behind Rangiora, where a reduced form occurs.

**Veronica Lyallii* Hook. f. (forma).†

Mount Fitzgerald on the southern face of the big cliff near the summit.

**Veronica canescens* Kirk.

Lake Forsyth: Kirk.

(²)*V. cupressoides*, (²)*V. lanceolata*, (²)*V. vernicosa*, and (²)*V. stricta* (a variety of *V. salicifolia*) are also recorded by J. B. A. *V. cupressoides* probably does not occur on the peninsula. *V. lanceolata* is a variety of the well-known *V. catarractae*, and is also quite unlikely to occur. Both J. F. A. and J. B. A. list (²)*V. Colensoi*, a very unlikely species.

**Ourisia macrophylla* Hook. f. (forma).† [J. B. A.]

Abundant, often covering the ground with matted patches, from about 2,300 ft. upwards. It occasionally extends into the upper edge of the forest, when it becomes more erect.

**Euphrasia zelandica* Wettst.

Southern side and top of Mount Herbert and Castle Rock, 2,500 ft. and upward. Also found by A. W.

J. B. A. records (²)*E. Monroi*, but it is quite unlikely that it occurs.

Family Lentibulariaceae.

**Utricularia monanthos* Hook. f. [J. B. A.]

Lake Ellesmere: J. B. A. There are specimens from this locality in the herbarium of the Canterbury Museum. At one time it occurred in a bog in the neighbourhood of Christchurch.

† *Trans.*, vol. 46, p. 59.

Family MYOPORACEAE.

Myoporum laetum Banks & Sol. [J. F. A.; J. B. A.; L. C.]
Abundant near the sea-coast, and sometimes inland.

Family PLANTAGINACEAE.

Plantago Raoulii Decaisne. [R.; J. F. A.; J. B. A.]
Seen by me, but exact locality overlooked: R. M. L. (Akaroa is the type-locality.)

**Plantago spathulata* Hook. f.
Summit of Mount Herbert: A. Wall!

Plantago Brownii Rapin. [J. B. A.]
Heathcote Valley.

Family RUBIACEAE.

The genus *Coprosma* has caused me much trouble, and I am not quite satisfied as yet that the list for the peninsula is complete. I have to thank Mr. Petrie for much kind assistance here.

**Coprosma grandifolia* Hook. f. (?).
A few plants which perhaps belong to this species occur on the creek in R. J. Fleming's place at Port Levy, and also on the sides of the main creek at Pigeon Bay. On submitting specimens to Dr. Cockayne he declared them to be typical *C. grandifolia*. This determination, of course, gives a large southerly extension to the range of the species. A very similar form occurs in Caton's Bay, and also at Gore Bay, on the northern side of Pegasus Bay. The leaves are membranous, but little glossy, and range up to 8 in. long; and the peduncles are over 2 in. in length. In spite of this it appears to me probable that these are merely specimens of *C. lucida* of luxuriant growth. Growing in the warm, sheltered valleys of Port Levy and Pigeon Bay, under the shelter of the forest, the leaves have become more membranous, the whole plant has become more elongated, and the leaves are confined to the ends of the twigs. This seems to me to be more particularly so as intermediates may be found as in Caton's Valley and on the back of the Sugarloaf. However, the matter must be left for fuller future discussion. In spite of the fact that Cheeseman considers *C. grandifolia* one of the most distinct species of the genus, it seems to me that *C. lucida* grown under the same conditions would approximate closely to it or become identical with it.

Coprosma lucida Forst. f. [J. F. A.; J. B. A.; L. C.]
Common in the forests and on rocky promontories.

Coprosma robusta Raoul. [R.; J. F. A.; J. B. A.; L. C.]
Akaroa; Stony Bay; Lyttelton; Little River; &c. (Akaroa is the type-locality.)

Coprosma Cunninghamii Hook. f. [J. F. A.; J. B. A.; L. C.]
Common and very variable, extending from seashore to 1,500 ft. or 2,000 ft.; usually in scrub.

Coprosma rotundifolia A. Cunn. [J. F. A.; J. B. A.; L. C.]
Common in forest.

Coprosma areolata Cheesem. [L. C.]
Not uncommon—Lyttelton Hills; Port Levy; Pigeon Bay; and elsewhere. Varies considerably in the amount of pubescence on the leaves.

Coprosma rhamnoides A. Cunn. [J. B. A.; L. C.]
Common in the forest and in scrub.

**Coprosma parviflora* Hook. f. [J. B. A.]
Mount Sinclair; Brasenose; about 2,000 ft. and upwards.

Coprosma crassifolia Col. [L. C.]
Pigeon Bay; Akaroa; Mount Sinclair; Lyttelton; and generally common on open stony hillsides that have once been bushed.

([1])*Coprosma rigida* Cheesem. (?).
Mount Pleasant; Otahuna. Identification perhaps not quite certain

Coprosma rubra Petrie.
Near Cooper's Knobs: R. M. L. Lyttelton: A. W.

Coprosma virescens Petrie. [T. K.]
Pigeon Bay; Mount Pleasant; Lake Forsyth. With yellowish-green branchlets in the forest, but passing out into the open at Lake Forsyth, where it forms matted bushes that in autumn have brilliant red almost leafless twigs.

**Coprosma acerosa* A. Cunn. var. *arenaria* Kirk. [J. F. A.; J. B. A.]
On the coast near Long Lookout Point.

Coprosma propinqua A. Cunn. [J. B. A.; L. C.]
Lyttelton Hills; Kaituna; and elsewhere; in many situations.

Coprosma linariifolia Hook. f. [J. B. A.; L. C.]
Common in the forest, particularly above 1,000 ft., but occasionally coming down to sea-level.

J. F. A. gives also ([2])*C. spathulata*, an Auckland species; ([2])*C. cuneata*, usually an alpine plant; and ([2])*C. foetidissima*, which might be expected, but does not, I think, occur.

**Nertera depressa* Banks & Sol. [J. B. A.]
Castle Rock, boggy ground, 2,000 ft.: R. M. L. Western side of Mount Herbert, near the summit: A. W.

* ([1])*Nertera dichondraefolia* Hook. f.
Akaroa: Raoul (as *N. gracilis* Raoul).

Galium umbrosum Sol. [J. B. A.]
Common in stony ground, usually near the outskirts of the forest.

Galium tenuicaule A. Cunn. [J. B. A.]
Swamp, Cashmere Valley.

Asperula perpusilla Hook. f. [J. B. A.]
Kennedy's Bush track; One Tree Hill.

Family Campanulaceae.

^c^*Pratia angulata* Hook. f. [J. B. A.]
Lyttelton Hills: Cockayne. Between Stony Bay and Flea Bay, damp places: A. W.

**Lobelia anceps* Linn. f. [J. F. A.; J. B. A.]
Island Bay, seashore; coastal cliffs, Waikerikikeri: R. M. L. Children's Bay (Akaroa) and sea-coast generally: A. W.

Wahlenbergia gracilis A. DC. [J. F. A.; J. B. A.; L. C.]
Abundant in tussock-grasslands.

Wahlenbergia albomarginata Hook. (= *W. saxicola* of Cheeseman's *Manual*).
Mount Sinclair; Castle Rock: above 2,500 ft.: R. M. L. Akaroa hilltops, common: A. W. A coastal form is said to exist under the cliffs at Lyttelton Heads, but I have not seen it.

Family GOODENIACEAE.

Selliera radicans Cav. [J. F. A.; J. B. A.]
Salt marshes, Teddington and elsewhere.

Family CANDOLLEACEAE.

Forstera tenella Hook. f.
Abundant on the south and south-west faces at the head of Stony Bay and adjacent heights, western face of Mount Herbert: A. W. This species, found by Professor Wall, must be added to the list of the subalpine inhabitants of the peninsula, together with several other plants found by the same botanist: *e.g.*, *Epilobium tenuipes*, *E. macropus*, *Oreomyrrhis andicola*.

Family COMPOSITAE.

**Lagenophora pumila* Cheeseman. [J. F. A.; J. B. A.]
Checkley's Bush; Akaroa; and probably elsewhere.

Lagenophora petiolata Hook. f. [J. F. A.; J. B. A.; L. C.]
Common in the tussock-grasslands.

**Lagenophora pinnatifida* Hook. f. var. *hirsutissima* Cockayne.
Ridge between Waikerikikeri and Le Bon's, plentiful; a few plants on the top of French Peak and on the Long Bay Ridge.

I have to thank Mr. Cheeseman for the determination. The rays are in more than one series; but I have not seen any ripe achenes. The plant agrees well with the description.

Brachycome Sinclairii Hook. f. [J. F. A.]
One of the forms of this very variable plant is abundant in the district It has been determined as *B. Thomsoni* by Cockayne,† but all the specimens I have examined have radical leaves only. The plants on the Lyttelton Hills are usually small, and the leaves often but little lobulated, though membranous rather than fleshy. It seems to me to be distinct from *B. Thomsoni* as I have seen it in Stewart Island; and it is quite distinct from a subalpine form to be found in south Nelson with fleshy shining green entire leaves and large flowers.

Olearia arborescens Cockayne and Laing. [J. B. A.]
Some flowerless specimens have been seen on Mount Herbert by Professor Wall. It has also been recorded by J. F. A. from the Dry Bush, where it does not now exist.

**Olearia ilicifolia* Hook. f.
Purau line, and occasionally elsewhere on the outer fringes of the bush above 2,000 ft.

**Olearia cymbifolia* Hook. f.
In similar positions to the preceding, but even less common.

Olearia avicenniaefolia Hook. f. [R.; J. B. A.]
Akaroa: Raoul. Coastal scrub, Pigeon Bay: R. M. L. At one time it grew under the hill-crests behind Governor's Bay, but is perhaps now extinct there.

† *Report on Scenery-preservation*, 1914–15, p. 15.

Olearia Forsteri Hook. f. [R.; J. F. A.; J. B. A.]
Abundant, especially near the coast-line.

Olearia fragrantissima Petrie. [L. C.]
Decanter Bay; Mount Pleasant; Crown Island: R. M. L. Lake Forsyth: T. Kirk. Near Sumner–Lyttelton Road: A. W.; L. C.
This plant does not appear to be known north of Banks Peninsula.

**Olearia Hectori* Hook. f. (?).
I obtained specimens of a plant which may belong to this species near Le Bon's, but it was not in flower, and the identification is uncertain.

J. B. A. records ([1])*O. virgata*, and it may occur. It grows, or grew, on the banks of the adjacent Heathcote River, but I have not seen it on the hills.

Celmisia longifolia Cass. var. *gracilenta* (Hook. f.) Kirk. [J. F. A.; J. B. A.; L. C.]
The slender scape and narrow leaves (about 5 mm. broad) probably are sufficient marks of this variety. The upper surface of the leaf is dark, almost black, in colour; and often flat, not revolute, this character probably depending upon the amount of moisture received: and the flowers are often large, being fully 40 mm. in diameter. The lower half of the margin of the leaf is slightly toothed and repand, whilst the upper half is entire. I can scarcely think that the branching of the scapes referred to by Cockayne (*Trans.*, vol. 49, p. 58) is at all common, as it has not been noticed by me. At one time common in the tussock lands, but now, I think, scarcer.

Celmisia Mackaui Raoul. [R.; J. B. A.]
In various places in the neighbourhood of Akaroa, from sea-level to 2,000 ft.; usually growing on a damp cliff or near the side of a stream. (Akaroa is the type-locality.)

J. B. A. records also ([2])*C. coriacea*, ([2])*C. Lyallii*, and ([2])*C. spectabilis*. There is no trace of them now, and I cannot think they have occurred here recently.

Vittadinia australis A. Rich. [J. F. A.; J. B. A.; L. C.]
Abundant.

Vittadinia australis A. Rich. var. *linearis* Kirk, a very distinct form, also occurs between Lyttelton Heads and Heathcote Valley, but is probably an introduction.

Gnaphalium luteo-album Linn. [J. F. A.; J. B. A.; L. C.]
Abundant both as a garden-weed and as an inhabitant of the tussock-grasslands.

Gnaphalium japonicum Thunb. [J. F. A.; J. B. A.; L. C.]
Common.

Gnaphalium collinum Labill. [J. B. A.; L. C.]
Common.

Raoulia glabra Hook. f. [L. C.]
Lyttelton Hills, rare; behind Hoon Hay; and elsewhere abundant above 2,000 ft.

**Raoulia subsericea* Hook. f.
On the higher summits between Akaroa and Castle Rock: R. M. L.; A. W.

Raoulia lutescens Kirk.

One specimen only seen, on the new Lyttelton Sumner Road, about 600 ft.: possibly from seed blown up from some river-bed on the plains.

**Raoulia australis* Hook. f. [R.: J. F. A.: J. B. A.]

A rare and disappearing species: one specimen only seen, on the top of Purple Peak. (Akaroa is the type-locality.)

Raoulia Monroi Hook. f.

Dyer's Pass: R. M. L.: A. W. Mount Herbert and elsewhere: A. W.

J. B. A. also records (²)*R. tenuicaulis*, but I have not seen it.

Helichrysum bellidioides Willd. [J. F. A.: J. B. A.: L. C.]

Lyttelton Hills, rare; but elsewhere not uncommon above 1,500 ft.

Helichrysum filicaule Hook. f. [J. F. A.: J. B. A.: L. C.]

Abundant.

Helichrysum glomeratum Benth. & Hook. [R.: J. F. A.: J. B. A.; L. C.]

**Cassinia Vauvilliersii* Hook. f. [J. F. A.: J. B. A.]

In scrub, Mount Herbert and elsewhere, but not common.

J. B. A. gives also (¹)*C. fulvida*, a probable inhabitant, which may be found on sandy beaches, but I have not noted it. J. F. A. records, no doubt in error, (²)*C. leptophylla*.

Craspedia uniflora Forst. f. (one or more vars.).

Lyttelton Hills, and probably elsewhere, but less common than formerly.

J. F. A. and J. B. A. give also (²)*C. alpina*, but this is a most unlikely inhabitant of the peninsula.

Cotula coronopifolia Linn. [J. F. A.; J. B. A.]

Common in ditches and sluggish streams.

Cotula australis Hook. f.

Abundant, and becoming a pest in gardens. Appears to be introduced.

Cotula minor Hook. f.

Seen only on Mount Pleasant, at the back of Lyttelton, under the drip from overhanging rock or on moist faces.

Cotula Haastii Kirk. [Haast; T. K.; L. C.]

Common on dry banks, particularly near the sea, or on the seaward side of the hills. It is said to have been found on the Canterbury Plains by von Haast, but I have not seen it there. The common species in the neighbourhood of Christchurch amongst the pastures are *C. dioica* and *C. squalida*.

J. B. A.'s records of (²)*C. pectinata* as on the peninsula perhaps refers to *C. Haastii*.

Cotula squalida Hook. f. [J. B. A.]

Common in the tussock-grasslands.

Cotula dioica Hook. f. [J. B. A.; L. C.]

Two forms are common, one of the salt marshes and one of the hills; but it is probably useless to attempt at present to define them.

J. B. A. gives also (²)*C. pyrethrifolia*, an unlikely alpine plant.

Erechtites prenanthoides DC. [L. C.]

Common, especially in burnt bush.

Erechtites quadridentata DC. [J. F. A.; J. B. A.; L. C.]
Common by the wayside and in dry ground.

**Erechtites glabrescens* Kirk.
Stony Bay; Kaituna; and doubtless elsewhere.

**Erechtites arguta* DC. [J. F. A.; J. B. A.]
Little Akaloa.

Senecio saxifragoides Hook. f. [J. B. A.]
Abundant, Lyttelton Hills from Gebbie's Pass to Lyttelton North Head, particularly on the southerly faces of the hills from about 600 ft. and upwards; occasionally coming down to 300 ft.

For a discussion of the characters and distribution of this species see article in *Trans.*, vol. 50, p. 198, by Professor A. Wall

Senecio lagopus Raoul. [R.; J. F. A.; J. B. A.]
On or near the summits almost continuously from Akaroa Heads to Gebbie's Pass. In a few places near Gebbie's Pass it crosses on to the Lyttelton Hills. (Akaroa is the type-locality.)

I am reported by Wall (*loc. cit.*) as stating that *S. saxifragoides* occurs on the peninsula. I now wish to withdraw that statement, as it was due to an imperfect understanding of the differences between the two species. There are several forms of *S. lagopus* to be found on the Canterbury Plains, which differ considerably from the type form at Akaroa, and the inclusion of these in my idea of the type led me into error. Undoubtedly the species *lagopus* as at present constituted contains several subspecies which require differentiation.

J. F. A. records also ([2])*S. bellidioides*. Typical *bellidioides* does not seem to occur on the peninsula, though young forms of *S. lagopus* are often indistinguishable from it.

Senecio lautus Forst. f. [J. F. A.; J. B. A.; L. C.]
Common in fairly constant forms, sea-level to 1,500 ft.

Senecio sciadophilus Raoul. [R.; J. B. A.; L. C.]
Sea-level to 2,000 ft.; not common. I have seen one plant at Kennedy's Bush, and it is fairly common on the Summit Track from behind Robinson's Bay to Mount Sinclair. It occurs more rarely in the lowland forest, as in Hay's Reserve, Pigeon Bay, Balgueri Valley, &c, It was reported from the Dry Bush (Lyttelton Hills), but is probably now extinct there. (Akaroa is the type-locality.)

J. B. A. includes also ([2])*S. odoratus* var. *Banksii*, a most unlikely plant.

Microseris scapigera Sch. Bip. [J. F. A.; J. B. A.; L. C.]
Lyttelton Hills: L. C. Castle Rock: R. M. L. Very uncommon here

**Taraxacum magellanicum* Comm.
Lyttelton Hills: L. C.

J. F. A. records ([2])*Crepis novae-zelandiae*, which probably does not occur.

Sonchus oleraceus Linn.
Abundant, but doubtfully native.

**Sonchus asper* Hill var. *littoralis* Kirk.
Sea-cliffs at Pigeon Bay; coast near Nikau Palm Gully; and doubtless elsewhere. Quite distinct from the British *Sonchus asper*.

J. B. A. records ([1])*S. asper*—the typical form, I presume—which, no doubt, occurs; but I have not as yet identified it here.

Art. XXXV.—*The Pronunciation of Scientific Terms in New Zealand, with Special Reference to the Terms of Botany.*

By Professor A. Wall.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 11th March, 1919; issued separately, 19th August, 1919.*]

The fact that the pronunciation of scientific terms in general and of botanical terms in particular is very variable, not to say chaotic, in New Zealand needs, unfortunately, no demonstration. An attempt is here made to show how this state of affairs might possibly be remedied. The question of the pronunciation of Greek and Latin among modern nations is not here dealt with. Although it would not be easy to draw up in detail a scheme for a "modern" pronunciation which should be satisfactory to all, yet it would not be impossible, and the mode already adopted in the schools of New Zealand comes near enough to the ideal for the purposes of this paper. It would be beyond its scope to deal with the pronunciation of Latin and Greek as it varies in England, Scotland, France, Italy, and Germany, or to go back over the sixteenth-century controversies of Erasmus, Reuchlin, and Sir Thomas Smith. It is assumed throughout that a "modern" mode can be found—approximately such as used in the schools of New Zealand—and that such a system stands opposed to the purely "insular" or "English" system, in which all the foreign words are sounded simply as if they were English, as is recommended in Field's *Ferns of New Zealand*. The details of any such modern mode would be settled, if the proposals here outlined came to anything, by the special committee set up for the purpose. The phonetic system here used is that of the Oxford Dictionary, but it has been found necessary to modify it a little. The sound of *s* in *measure* (ʒ) is represented here by zh. The symbol sh is retained. The symbol o may represent either open or close o. Thus in *Australia* our rendering gives o as the first sound, and this is an open o. The stress or accent is indicated here by an acute accent following the stressed syllable.

The writer hopes to be pardoned for the rather hopeless tone of some of his conclusions. The fact is that the question is the most complicated and difficult with which he has ever been faced, involving as it does the history of the pronunciation of Greek and Latin among the different nations of Europe during the last thousand and especially during the last four hundred years (since the Reformation); the variant "modern" or "reformed" systems, and the degree of success which has attended the attempt to introduce them, or any of them, into the schools of England; the purely scientific question of phonetics; the more practical question of phonetic script; the psychological question of inherited or acquired speech-instincts, and especially the instincts which govern accentuation or stressing of syllables and baffle all scientific inquiry; the partly practical consideration of the exchange of ideas and knowledge between students of New Zealand themselves, and between those students and teachers and those of other countries—*e.g.*, of England, Germany, Japan; the political question—New Zealand's position within the British Empire, and her state of intellectual tutelage; the purely practical question of the vocabulary of the farmer and the gardener, &c., which largely coincides with that of the university and technical instructor; and, lastly, the purely philological or linguistic questions, such as accentuation or stressing, and the relation of the scientific vocabulary to that of common life. Many of these considerations conflict with one another; others demand more knowledge and research than the importance of the subject seems to warrant; and, on the whole, the writer has found the subject exceedingly puzzling. It seemed to him all the more necessary, then, that some attempt should be made to deal with it, and this paper represents such an attempt.

It may be added that the proposals here outlined are calculated to produce their effect only upon the rising generation. We older scientific men (if the author may be allowed to use the first person) are hardened in sin and beyond hope.

The only logical scientific system possible would be got by the adoption of a "Continental" Latin pronunciation, or as near an approximation thereto as circumstances might permit. This would have to be rigidly observed so that no exception or anomaly could occur. The adoption of any such system is, however, rendered difficult or impossible by the following considerations:—

(1.) New Zealand, being a part of the British Empire, should look to Great Britain as its scientific metropolis; but the unreformed "English" or "insular" pronunciation of Latin still obtains largely in England, so that many, if not all, of the older scientific men use this pronunciation of Latin and Greek botanical and other scientific terms. It will easily be seen how this concerns imported professors, visiting English botanists, and New Zealand students continuing their studies in England. An imported professor, for example, using the insular mode and not choosing to alter it might be almost incomprehensible to his students, all of whom are familiar only with a "reformed" mode.

(2.) Numbers of words, or parts of words, in the botanical vocabulary appear also in ordinary speech, perfectly anglicized:—

(*a*.) *Geranium*, *Viola*, *Gentian*, *Calceolaria*, *Gypsophila*, *Geum*, *Angelica*, and other generic names tend naturally to be pronounced in the English manner, especially by farmer and gardener; so also *Pinus* in forestry.

(*b*.) Names of native plants which have become familiar to the general public of New Zealand through cultivation or otherwise have been anglicized beyond recall, such as *Celmisia* or *Senecio*.

(*c*.) Parts of terms like *micro-*, *uni-*, *bi-*, *hydro-*, *austral-*, occurring commonly in such words as *microscope*, *universal*, *bivalve*, *hydrophobia*, *Australia*, and thoroughly anglicized, tend to be sounded *anglice* when used scientifically. Thus *hydrocotyle* is usually pronounced haidrocot'ile; but the two *y*'s in it equally represent a Greek υ, so that the word ought to be either hai'drokotai'le or hi'drokot'ile. Again, it feels uncomfortable to speak of "vittadinia australis" as growing in "ostreiliə."

(*d*.) Special difficulties occur where these words have to be inflected. If they be kept Latin in sound they should have a Latin plural: Thus geum should have plural gea; the English dzhīəm should have dzhīəmz. But words like *hydrocotyle*, as noticed above, are neither Latin nor English, as usually pronounced; and such plurals as *genera* (= dzhenera) are established though *genus* is pronounced as English dzhīnəs.

(3.) The vocabulary consists largely of personal names, more or less successfully latinized, from many languages—*e.g.*, English, Scotch, Irish, French, German, Dutch, Scandinavian languages. In any perfectly logical, scientific scheme these must be remorselessly latinized in sound—*e.g.*, all *r*'s must be trilled; the *ch* in *Gaudichaudiana, Deschampsia, Grisebachii, Dieffenbachii, Chapmani, Chathamica, Cheesemanii, Archeria*, must be consistently sounded as k only; the *ie* of *Petrie* and *Guthrie* as i + e; the *th* of *Smith, Guthrie*, &c., as t only; the *ay* and *ai* of *Cockayniana, Blairii, Claytonia*, as ai; the *oo* of *Hooker, Doodia*, as ō. The *J* of any *Johnsoni* must be *J* = y, not *J* = dzh; *au* in *Gaudichaudi, Vauthiera, Gaultheria, australe, Mackaui*, must be au, not ō close or open; *Raoulia* must be raovlia; *Youngii* becomes jovngii; *Roughii*, rovgii.

Examples of terms which would have to be altered greatly if consistently latinized:—

> *Guthrie-Smithiana*, gutrie-smitiana, not gaþri-smiþiana; *Hookeri* (*Bulbinella*), hōkerī, not hukerai; *Fairchildii* (*Pittosporum*), fairkildii, not fērtshaildiai; *Cheesemanii* (*Luzula*), kēsemanii, not tshizməniai; *Campbellensis* (*Celmisia*), kampbellensis, not kambelensis; *Petriei* (*Carex*), pētriei, not pītriai; *Menziesii* (*Fagus*), menziezii, not menzīziai; *Matthewsii* (*Ranunculus*), mattevzii, not mæþiuziai; *Stewartiae* (*Senecio*), stevartie (or -ai), not stiuātiai; *Stackhousia*, stakhovzia (or -sia), not stækhauziə; *Featherstonii* (*Cotula*), featerstonii, not feðestəniai; *Walkeri* (*Celmisia*), valkeri, not wōkərai.

This leads to impossibilities, as some combinations of sounds in such words are impossible in Latin—*e.g.*, *ow* in *Townsoni, Brownii*; *dg* in *Edgerleyi* and *Tunbridgense*; *iea* in *Petrieana*, &c.; *ew* in *Matthewsii*; *ou* in *Youngii*; *ough* in *Roughii*. All double consonants must be sounded double: *Huttoniana, Dallii*, &c. Our present terminology is full of partly latinized pronunciations like mackauai, cunninghamiai, and in fact nearly all the terms in *-i*. The alternative is to pronounce such names according to the usage of the language from which they come, and this if logically and rigidly observed leads to difficulties almost as great; barbarous compromises and approximations result. The French or German botanist visitor may find the British names just as hard and puzzling (*e.g.*, *Buchanani, Youngii*) as the German terms are to those who know no German. All botanists cannot be also trained linguists. Where an orthographical device like the German *ue* or *oe* (as in *Muehlenbeckia, Koeleria*) or our own *ea* (as in *Pearsoni*) or *ie* (as in *Petrie*) or final *e* occurs, it seems absurd to latinize the symbol and pronounce it phonetically (*e.g.*, to sound the second *e* in *Petrieana* or *Field* and the third in *Cheeseman*); yet to do otherwise undoubtedly introduces an anomaly into any logical or perfectly scientific scheme. The same is true of symbols which have become silent (*l* in *Walkeri*) or now stand for a sound quite other than that originally signified (*ow* in *Brownii*, *ew* in *Matthewsii*); and these again offer puzzles and pitfalls for the foreigner. There is no reason why we should not have a New Zealand species "*Cholmondeleyi*," which, with us, if we had only ourselves to consider would be tshamliai; while to the foreigner, guided by the spelling alone, it would be kolmondeleii.

(4.) Even where a uniform "reformed" pronunciation has been introduced, as in the schools of New Zealand, there remains room for inconsistencies and local variations, and it proves most difficult or impossible to persuade, force, or wheedle the young into use of certain sounds, especially the true short *u* as in *sub*, and the long *e* as in *-es* (*Erechtites*), which is universally sounded in New Zealand like *a* in *same* (= ei). Again, *ae* in some schools = ai, in others e or ei.

(5.) Accentuation or stressing offers innumerable and often insuperable difficulties. The English rule of accentuation, which the genius of the language absolutely demands, draws the stress as far back as possible, often placing it in situations most awkward for any tongue other than an English one; and English stresses or emphasizes one or two syllables in a polysyllable at the expense of the rest to a degree unknown in any other language, so that, even if every vowel be given its correct Latin (Continental) value, the word may yet be pronounced in such a way as to be completely delatinized and to seem unintelligible to any but a Briton (*Pittos'porum*, *Meli'cytus*, *macroph'ylla*, *Orthoc'eras*), especially as the vowel-values themselves alter enormously according to the incidence of the stress—*e.g.*, *o* in *macroph'ylla* and *o* in *nobile*. This linguistic instinct is most profound, and amounts to a physical compulsion which can be resisted only by a very few specially constituted persons. It also appears to work inconsistently, as it does in ordinary English; thus we tend to place the stress in the "English position" in pronouncing, say, *Pteros'tylis*, *Hypol'epis*, *multif'idum*, *Gypsoph'ila*, *Hype'ricum* (and in most words which are in general or everyday use, *e.g.*, by gardeners), but not in *Gloss'ostig'ma*, *He'lichry'sum*, *Leu'copo'gon*, *mac'roca'lyx*, &c., where the weight of the first or the third syllable, or the nature of the consonantal bridges, renders the "English" pronunciation difficult or impossible. And there is here no line to be drawn; individual practice varies largely. These difficulties are far greater than those, so much discussed in the past, which depend upon the quantity of the vowel (as in the case of *Clemātis* or *Clemătis*, and *Gladiōlus* or *Gladiŏlus*). However hard it may be to learn, an even or nearly even distribution of the stresses must be acquired if anything like a Latin pronunciation is to be achieved, and this point will have to be specially attended to in the teaching of Latin in the schools. We must learn, that is, to say brachycome, not brachy'come; cyperaceae, not sai'perei'siī; himenofilum, not hai'menofi'lum or haimenof'ilum; abrotanella, not ab'rotanel'la; bukanani, not biukan'ənai; ligustikum, not ligus'tikum; aromatikum, not ar'omat'ikum.

(6.) A great part of the technical vocabulary of botany is the same, in its elements, as that of the other sciences—biology, chemistry, palaeontology, &c.—and whatever system is adopted for any one of these must also be adopted for all. The very names *zoology*, *biology*, and *palaeontology*, in their usual anglicized pronunciation, serve to illustrate and emphasize the great difficulties involved in any such scheme, since it would seem absurd to call a science biology (baiolodzhi) and to speak, within the science, of biogenesis instead of baiodzhenisis. The problem is thus further complicated, for it is essential that there should be complete unanimity and agreement in practice among all the members, for instance, of the staffs of the University colleges and of all technical institutions, agricultural and experimental colleges where the sciences are taught. The question is thus seen to be only a part of a very much bigger one.

(7.) Though this paper deals specially with the names of New Zealand plants, the whole vocabulary of botanical science is, of course, involved. In this case, as in that of any other science, a certain part of this vocabulary has already passed into ordinary speech and is anglicized in sound. This is no constant quantity; at any time, for any out of very many reasons, terms of any science pass over from the technical to the everyday usage, and there is usually a fairly large number of terms, at any given moment of time, in the vocabulary of any science which are indeterminate in this respect—some speakers treating them as scientific terms and pronouncing them accordingly, others using them as "everyday" English. Thus *genus* and *species* are pronounced as English—dzhīnəs, spīshīs, not genus, spekiēs; *chloride* is English (-aid, not -id), while *chlorine* is indeterminate (both -in and -ain). An excellent example is the geological term *stratum*, pronounced by different speakers as strātum and streitum. If the pl. is *strata*, then the *a* is ā, not ei (*cf. Lycopodium*, and genitives and plurals in -*i*). *Fungi* should be either fangai or fungi. Again, *Bacillus* should be bakilus, pl. bakilī; or basilus, pl. basilusiz.

As against these objections, we have in New Zealand a decided advantage over the Old Country if any attempt be made to establish a Continental Latin or Greek pronunciation. We all are familiar with the Maori names at least, and are accustomed to pronounce long *a* and *i* in something like the true Latin manner; we mispronounce the Maori shockingly, no doubt, especially in the stressing of the syllables, but we have not to travel quite so far as a home-bred Englishman if we wish to adopt a reasonable system. This alone, however, can hardly be thought to counterbalance all the difficulties already mentioned.

Supposing that, for the reasons above mentioned, or for others, it be found impossible to establish any reformed Latin system, the question arises, What is the alternative?

There are two alternatives. One is to pronounce all the Latin and Greek terms as English, in respect of both the value of the vowels and the position of the stressed syllables. The other is a compromise.

Consider the two alternatives briefly.

(1.) The average New Zealand student has learned Latin at school and is familiar with that pronunciation which passes for "modern" and with that only. If an "English" scheme of pronunciation be adopted he must unlearn his Latin pronunciation, just as the average Englishman must unlearn his "English" Latin if he is to be understood here. This would seem fatal to any such system. It is certain that a homogeneous and possibly defensible "English" system could be used here, however, as it is in England. There would be variations, inconsistencies of the minor kind, and individual solecisms, no doubt, as there are in England; but such things will always be, whatever system be nominally "adopted." And no doubt it would be a good thing if the farmer and the gardener could be allowed to pronounce the Latin terms as they see them, supposing that they know little or no Latin, and yet be in line with the university-bred student or teacher of the subject; they could then say "ōstreilis" as they say "ōstreilio," and not be troubled by hearing others say "australis."

Yet no scientific man could, I think, bring himself to recommend the adoption of the "English" or "insular" mode. The case of the student who has learned the "new" mode at school would alone block it; no such scheme could be scientifically defended; and this alternative is here dismissed.

(2.) With regard to the other alternative: At first sight it would seem that compromise is the only way, and it may prove that in spite of the best endeavours of scientific men compromise will eventually win. The present chaotic "no system" may be gradually regularized and organized as botanical students and teachers increase in numbers and as those from different centres meet oftener and discuss their subject. And so also with the terminology of science in general: the present comparative isolation of the teachers and students in separate areas tends to encourage the development of variations and local idiosyncrasies; but all that will pass.

Yet, again, the spirit of compromise is an alien in the world of science. If we adopt a policy of *laissez-faire* and allow something to develop somehow in the usual British manner of "muddle through and hope for the best," then the ultimate result will have been partly at least determined by unguided and unenlightened forces working more or less blindly (and in this case deafly), and it will be an unscientific, inconsistent, and unsatisfactory result, encouraging yet more inconsistency, and individual, capricious variation; it will be unstable, illogical, and absurd, and may yet have, we suppose, the sole merit of "pronounceability."

Conclusions.

1. In spite of the difficulties and apparently insuperable barriers with which the practical carrying-out of such a scheme is beset, it is advisable that an attempt be made to establish in New Zealand a uniform mode of pronouncing all scientific terms of Latin and Greek origin upon the basis of such a modern or reformed pronunciation as is used in the schools.

2. It is advisable that a committee of the New Zealand Institute be set up to go into the details and draw up a logical, uniform, scientific system of pronunciation of scientific terms; that the scheme when complete should be adopted by the Institute; and that every possible effort should be made to introduce and explain it in all the University colleges and all institutions where science (even elementary science) is taught, with a view to establishing such uniformity as may prove possible.

3. In order to give practical effect to this idea it would be necessary to draw up a fairly complete glossary of scientific terminology, and to assign to each word a definite phonetic form indicating the sound of each vowel and the incidence of the stress or stresses.

4. It is essential that all students intending to specialize in science should learn Latin: that in the teaching of Latin in the schools the pronunciation should be made as uniform as possible; and that the pupil should be taught to accentuate the syllables of Latin words in as level a manner as possible, and to break himself of the English habit of "preferential accentuation" (if such a term may be used). This is counsel of perfection, and the writer of this paper knows only too well by long and bitter experience how hard it is to induce British boys and girls to modify in the least degree any of those profoundly seated speech-instincts which are a part of their heritage.

5. Even though such an attempt be foredoomed to failure, and even though ultimately a compromise only can be attained (and this is much to be feared), yet the attempt will undoubtedly have some effect for good if only by giving such an advantage to the enlightened and organized forces in the battle as may tend to make the inevitable compromise a better thing—a thing nearer to the "scientific" than to the "popular" result. It is to be hoped also that an attempt of this kind may tend to hasten the arrival of the desirable end—*i.e.*, uniformity of practice—even if that practice be based upon no sound or logical theory. If any such effect should hereby be produced this paper will not have been written in vain.

ART. XXXVI.—*Some Notes on the Language of the Chatham Islands.*

By Archdeacon H. W. WILLIAMS.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 11th March, 1919; issued separately, 19th August, 1919.*]

CHATHAM ISLAND, called by the Maori Wharekauri, and by the earlier inhabitants Rēkohū, was peopled by a branch of the Polynesian race known variously as Maioriori, Mouriuri, and Mooriori (generally spelled "Moriori").* Accounts of the early history of the island and its inhabitants are meagre in the extreme. Toi (*c.* 1125), making for New Zealand in search of his grandson Whatonga, is reported to have sighted an island "like a cloud in the distance." It does not appear that he touched there, and no further information has been preserved. On reaching New Zealand Toi found portions of the North Island† occupied by a people now referred to as "Maruiwi," the name of a former chief. Trouble soon arose between Toi's party and the Maruiwi, and a war of extermination was raged against such of the latter as had not intermarried with the new-comers, and a small remnant of them escaped in six canoes, sailing towards the south from Cook Strait. It is said that some of these reached Chatham Island, but actual proof of this fact is wanting. Moriori genealogies certainly contain the names of Toi, his son and grandson, among the demigods, but a knowledge of them may conceivably have come through another channel.

Some little time later (*c.* 1200) one Kāhu, in a spirit of adventure, fitted out a canoe at the mouth of the Rangitikei River and set out to find the island reported by Toi. He reached Wharekauri, where he found inhabitants who are supposed to have been the Maruiwi refugees from New Zealand. But it must be borne in mind that the Moriori traditions claim that their ancestors had resided on the island for many generations before Kahu's arrival, a statement supported by notes to two Moriori genealogies (Shand, pp. 53, 55); though it is difficult to assess accurately the chronological value of these genealogies, seeing that according to them 1,750 years intervened between Kahu's arrival and the coming of the Rangimata canoe, a period which upon other data is estimated to be about 150 years. The Moriori claim that his ancestors antedated Kahu by a considerable period receives, perhaps, more support from the statement of Matorohanga that four canoes are known to have reached Wharekauri from Rarotonga—one of them, Te Ririno, "long before the visit of Kahu." The names of two of the occupants of this canoe are given. One of them, Kapohau, had a son, Te Ao-marama, a name which occurs in both the Moriori genealogies as that of the father of Rongomai-whenua, who is stated to have been the first ancestor who resided on the island. But this was, according to the genealogies, some 128 generations before the beginning of this century—say, about 1300 B.C., or fifty-five years before the siege of Troy.

Reverting to Kahu, it is said that he, with some of his companions, set out to return to New Zealand, but nothing is known of their fate. Others of the crew married on the island, and some of their descendants have since returned here.

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* This is probably not a tribal or race name, but, like the word "Maori," an adjective meaning "native." Bishop Selwyn, who visited the island in 1848, says that they called themselves "tangata maoriori."

† Recent investigations indicate that this previous occupation probably covered both the Islands of New Zealand.

The Moriori traditions also mention the arrival (*c.* 1350) of three canoes—Rangimata, Rangihoua, and Oropuke—from "Hawaiki," which we may fairly assume to be Rarotonga.

Lastly, in 1835 a body of Taranaki Maoris occupied the island, completely dominating the Moriori inhabitants, many of whom they murdered, while the survivors were reduced to a condition of slavery. Under this treatment the Moriori dwindled rapidly. It is believed that at that date there were about two thousand: Dieffenbach estimated their numbers at ninety in 1840,* and Mr. Shand gave the number as twenty-five in 1898.

So far, then, as history is concerned, the inhabitants of the Chathams would appear to have come from "Hawaiki" (possibly Rarotonga): some may have been Maruiwi from New Zealand: those who came with Kahu were probably of mixed Maruiwi descent; while all would be much influenced by the later-arrived Maori tyrants.

Matorohanga has preserved some descriptive notes of the Maruiwi, which conform in many respects with what is known of the Moriori. At the same time, many of the characteristics recorded appear also in the descriptions of the mixed dwellers on the island of Rangiatea, on which Whatonga was cast away. But this fact is not very helpful, for though we may identify Rangiatea with Raiatea, near Tahiti, we know nothing of the inhabitants of that island eight hundred years ago, or of whence they came.

We may now turn to the language. For our knowledge of this we are indebted almost entirely to the patient and sympathetic investigations of the late Mr. Alexander Shand, who resided on the island for many years. A vocabulary by Mr. Deighton (*Appendix to the Journals of the House of Representatives*, G.-5, 1889) contains equivalents for nearly nine hundred English words. About sixty of his Moriori words are not recorded by Shand.

Mr. Shand collected a number of traditions and legends during the years 1868–1869, when, as he says, "the old people could speak their own language." The information thus obtained formed the basis of a series of articles in the *Journal of the Polynesian Society* (vols. 3–7),† in which Mr. Shand included original Moriori matter enough to fill about forty-four pages of the *Journal*.

Moriori has been described as "a corrupt subdialect of New Zealand Maori": and when the writer began work upon the recent edition of the Maori Dictionary it was suggested that Mr. Shand should be invited to contribute a list of Moriori words with a view to their incorporation in the dictionary. To this he readily agreed, and, though much hampered by ill-health, he compiled a vocabulary of some 2,500 words, many of which are illustrated by examples. He completed the work in 1910, the MS. reaching New Zealand by the mail immediately preceding that which brought the news of his tragic death. With him, unfortunately, perished a considerable amount of additional matter which he had hoped to publish: and we were deprived of his help in elucidating questions arising out of the vocabulary he had compiled. An examination of the vocabulary forced the conclusion that the opinion making Moriori merely a subdialect of Maori requires revision, and it was decided to hold it back for independent publication.‡

As a matter of fact, Moriori appears to be farther removed from Maori than the dialects of many of the islands of the Pacific. Peculiarities of

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* E. Dieffenbach. *Journ. Roy. Geog. Soc.*, vol. 11, p. 207, 1841. Bishop Selwyn took a careful census, and found 268, including children.

† These articles have been republished, and form vol. 2 of the *Memoirs of the Polynesian Society*. References herein are to the pages of this volume.

‡ The copy is now almost ready for the press.

both grammar and vocabulary make the language more difficult for one conversant with Maori to read than Rarotongan, and not less so than that of Tahiti, Uvea, or Niuē.

Structurally the dialect is exceedingly plastic, and affords examples of letter change in bewildering variety. In some cases the metamorphosed word has wholly displaced the form with which we are familar in Maori; in others the Maori form is used concurrently with one or more variant forms. This appearance of Maori forms may in some cases be a survival, while in others it may be due to adoption from the speech of the more recently arrived Maori overlords.

In the matter of letter change we may, in comparing with Maori,* note the occurrence of—

A for *E* : †‡ *ta* (*te*, art.), *a* (*e*, prep.), *tikamata* (*tukemata*).
A for *EI* : *ka* (*kei*).
A for *I* : *ka* (*ki*, prep.).
A for *O* : † *takato* (*takoto*), *kotau* (*koutou*).
A for *OA* : *mana* (*moana*).
A for *U* : *oata* (*hoatu*), *mari* (*muri*).
AI for *I* : *hokai* (*hoki*).
E for *A* : § *heu* (*hau*), *kei* (*kai*), *etu* (*atu*), *eriki* (*ariki*), *tinane* (*tinana*).
E for *I* : *nape* (*napi*).
E for *O* : *reimata* (*roimata*), *tike* (*tiko*), *mohewao* (*mohowao*), *heme* (*hemo*), *konehi* (*kanohi*).
E for *U* : *ange* (*aku*).
E frequently inserted before *H* : *ehau* (*hau*), *ehē* (*hae*), *maehanga* (*māhanga*), *maehara* (*mahara*), *aeho* (*aho*), *poeho* (*poho*); and sometimes (as printed) after *H* : *heanga* (*hanga*) but this last may be only a case of the modified *H*, which will be dealt with below.
EI for *A* : *eitū* (*atua*).
I for *A* : *puti* (*puta*), *eringi* (*erangi*), *iki* (*ika*), *mehori* (*mahora*), *wihine* (*wahine*).
I for *E* : *mi* (*me*, conj.), *ti* (*te*, art.).
I for *O* : *rari* (*raro*), *korihiti* (*korohiti*), *tiri* (*tiro*).
I for *U* : † *matī* (*matū*), *tikamata* (*tukemata*).
I inserted between two vowels : *kaiore* (*kaore*).
I inserted before or after *H* : *puiha* (*puha*), *hiaka* (*haka*)—but the latter may be a case of modified *H*.
O for *A* : † *mahoro* and *mohoro* (*mahora*), *tokoto* (*takoto*), *mōū* (*māoa*).
O for *E* : † *to* (*te*, art.).
O for *I* : *toki* (*tiki*), *tango* (*tangi*), *pororo* (*porori*).
O for *U* : ‡ *tongo* (*toku*).
O for *OU* : *kotau* (*koutou*).
O for *UA* : † *akonei* (*akuanei*), *aoreka* (*ahuareka*).
O for *WA* : *rao* (*rawa*), *manao* (*manawa*).
O for *WE* : *wao* (*wawe*), *kao* (*kawe*), *makao* (*makawe*).
U for *A* : *ur* (*ara*), *hunau* (*whanau*).
U for *E* : *tu* (*te*, art.), *hunū* (*whenua*).
U for *I* : † *ku* (*ki*, prep.), *muru* (*muri*).
U for *O* : *kunei* (*konei*).
U for *OA* : *mōū* (*māoa*).

* The Maori form is given in brackets.
† Cases of this occur in some dialects of Maori.
‡ This occurs in Marquisan.
§ This occurs also in Rarotongan and Mangarevan.

It will be noticed that in the case of many of these changes the vowel appears to have been attracted, so to speak, to the vowel in the preceding or following syllable (though in not a few instances the vowel change has disturbed a previously existing symmetry), and the same rule may be observed operating loosely in the choice of alternative forms in a sentence: thus *ku muru* will generally be used for *ki muri*, *ko ru kupu* and *ki ri kupu* for *ko ra kupu* and *ki ra kupu* respectively (*ru* and *ri* representing the article *te*), *no ro mē* for *no te mea*. A good illustration occurs on page 77: Kitē ko Tu i rari i ri papa o ro waka, *Tu was found beneath the flooring of the canoe.* (*In Maori*, I kitea ko Tu i raro i te papa o te waka.)

In addition to these changes a vowel is sometimes dropped (i) before a consonant, as *na* (*ena*), *ha* (*aha*); (ii) after a consonant, leaving a closed syllable, as *rangat* (*rangata*), *nawen* (*nawene*), *hok* (*hoki*), *or* (*oro*), *mot* (*motu*)*; (iii) after a vowel, in which case the preceding vowel is lengthened by way of compensation, as *ahē* (*ahea*), *mē* (*mea*), *ī* (*ia*), and the passive terminations *hī*, *rī*, *tī* (*hia*, *ria*, *tia*), *ingō* (*ingoa*), *nō* (*noa*), *ahū* (*ahua*), *tā* (*tae*), *marī* (*marie*), *kō* (*koe*), *ēnē* (*ēnei*), *nū* (*nui*), *rē* (*reo*); and (iv) before a vowel, the remaining vowel, as in the last case, being lengthened, as *pē* (*pae*), *tē* (*tae*), *wēwē* (*waewae*), *hēre* (*haere*), and, apparently, *kā* (*koa*). Examples similar to the group (iv) occur in Tikopia, where we find *fē*, *kē*, *mē* for *foe*, *koe*, *moe*.

In a number of words a vowel has become long where in Maori we have a short vowel, as *ihē*, *tihē*, *īka*, *tāki*, *tirā*, *apaāpā*, *tupōko*. But I speak with some diffidence on this point, as I find that Mr. Shand has, in the MS. in my hands, corrected the quantity in several passages quoted from the articles which were printed some ten years previously. It is possible that in reciting the legends a rhythmical diction may have been adopted which placed on certain vowels a stress which did not accord with that of the normal pronunciation.

The consonants are not quite so pliable as the vowels, but still offer no inconsiderable variety. In the cases of *H*, *K*, and *T* a peculiar method of pronunciation is sometimes adopted, in which the tongue appears to be somewhat arched into the palate and the letter uttered with a slight emission of breath which not infrequently produces the effect of a suppressed *I*, or sometimes *E*, sound before the proper vowel of the word. This stressed pronunciation is used with *K* only when followed by *A*, possibly only in the case of the particle *ka*; with *H* only when followed by *A* or *O*; but with *T* it occurs much more frequently, and with any vowel except *O*. Mr. Shand represented this peculiarity of utterance variously in the case of each of the letters named, using the combinations *HHI*, *HI*, or *HE* for *H*; *KH*, *KHI*, or *KKHI* for *K*; and *TCH*, *TCHI*, *TCHE*, or *TC* for *T*. He states in a note that it is difficult to represent the pronunciation in writing, and mentions that it appears to be used in some cases for the sake of emphasis. It is of interest to note that a somewhat similar usage with respect to *H* was observed in the north of New Zealand in the early days, and led the missionaries to write *Shunghie* and *Shauraki* for *Hongi* and *Hauraki*. In Tonga, too, the method of pronouncing *T* when followed by *I* leads to its being represented variously by *J* or *S*.

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* *Ka* is thus sometimes clipped to *k'*, and *ta* to *t'*.

As examples of change in consonants we may note—

H for *WH* :* *huti* (*whati*), *hi* (*whi*), *hunū* (*whenua*).
H dropped : † *eke* (*heke*), *oeha* (*hoha*), *iki* (*hiki*).
K for *NG* : *ka* (*nga*, art.). (No other cases noticed.)
K for *T* : *ka* and *ki* (*te*, art.), *kihorei* (*tihore*).
M for *W* : *imi* (*iwi*), *pakihimi* (*pakihiwi*), *mahine* (*wahine*).
M for *K* : *matahi* (*katahi*).
N for *R* : ‡ *manino* (*marino*). (Uvean has *nana*, *naton* ; *rana*, *raton*.)
NG for *K* : *ngonei* (*konei*).
P for *K* : *harapepe* (*harakeke*), *tupe* (*tuke*).
P for *M* : ‡ *tupuaki* (*tumuaki*).
R for *N* : ‡ *irokonei* (*inakuanei*), *hiringaro* (*hinengaro*).
R for *T* : *rika* (*tika*), *rangat* (*tangata*), *rupuna* (*tupuna*).
W inserted : *warero* (*arero*), *arowaro* (*aroaro*). This sometimes indicates a *U* lost by substitution : *hiwaki* and *hiwiki* (*huaki*). *Awainei* for *aianei* involves more than the mere insertion of *W*.

A further step in the transformation of words is taken in the dropping of a complete syllable at the end of a word, as *hi* for *hine* or for *hinga*, *ma* for *mate*, *mo* for *motu*.

The effect of these letter changes is to introduce a certain amount of ambiguity in the interpretation of our texts: for, on the one hand, a single form may take on the functions of a number of others, while, on the other, the same word may assume a multiplicity of shapes. Thus *a*, which has seven distinct functions of its own, acquires in addition those of *ae*, *āna*, *ana*, and *e* : *e* has three functions of its own and those also of *ae*, *he*, *hei*, *nge*, and is said further to be inserted sometimes into a sentence with no other purpose than that of euphony—a very refuge of the destitute for a grammarian ; *i* has two uses of its own and represents also *ae*, *ai*, *e*, *he* (sing. and pl.), *hei*, *ia*, *ki*, *te* (sing. and pl.), and *wai*, and also perhaps a euphonic use : *hi*, besides its own duties, has those of *he*, *hia*, *hine*, *hinga*, and *whiwhi* : *ka* does duty for *kahore*, *kei*, *koa*, *ki*, *nga*, and *te*, besides retaining two previous meanings. Conversely, the particle *atu* appears also in the forms *ati*, *etu*, *eti*, *whatu*, *wha*, *at*, and *et* ; *whano* may become *whani*, *hano*, *hana*, or *hane* : for the singular definite article we have the choice of *ta*, *t'a*, *te*, *t'e*, *t'ei*, *ti*, *t'i*, *to*, *tu*, *t'*, *ne*, *re*, *ri*, *ro*, *ru* , *i*, *h'a*, *ka*, *ki*, and *ko*, and three of these forms, *i*, *ka*, and *ro*, may also be used in the plural.§

Metathesis is by no means uncommon in Maori and cognate languages, but some examples in Moriori are interesting : *euwha* for *ehua*, pass. of *ehu*, leads to *eueuwha* for *ehuehua* ; *huanui* appears as *uwhanui*, and *hiwiki* (*huaki*) as *hikui* ; *whine* for *wahine* would certainly seem to connect closely with the *fine* in Samoa, Tahiti, Tonga, &c., were it not paralleled as a case of modified metathesis by the occurrence of *kawhai* for *kahawai*.

The last structural peculiarity remaining to be noticed is connected with reduplication. It was noted in dealing with the interchange of vowels that a principle of attraction seemed occasionally to be operating. In not a few cases, however, of reduplicated words, a vowel in one element of the word has been altered. Thus we have *hinihina* for *hinahina*, *ateata* for *ataata*, *okihakehaka* for *hokohakahaka*, and *iarehara* for *harahara*. This variation of vowels occurs very frequently in reduplicated words in Tongan.

* Cases of this occur sometimes in Maori.
† *H* is completely discarded by Whanganui and neighbouring tribes.
‡ This occurs in Marquisan.
§ The forms *t'* and *h'* are here used for the modified *t* and *h* referred to above.

It is not very surprising to find that many words have in Moriori a meaning differing in greater or less degree from that in Maori. We may notice of few of these*: *Anga*, front, intestines (aspect): *hua*, keel of a canoe (hand-spike, lever): *kamo*, beckon, wave to (wink): *kopa*, veer, turn (bent, folded); *mapuna*, ripple, v. (well up); *moteatea*, shine (fearful, apprehensive); *ngoi*, weak (strength): *oti*, death, as well as (in Maori) finished: *pao*, open, a. (strike): *ro*, *roto* has extended its meaning beyond merely "the inside," and we have such expressions as *ko ro ta pari*, "over the cliff": *ko ro to wai*, "above the water"; *tango*, work (take, attempt): *toke*, small (out of sight, gone).

Of all the words recorded by Shand about 10 per cent. appear to be from roots no longer preserved in Maori. It is possible that some of these may, on further investigation, prove to be familiar roots disguised by some of the letter changes discussed above.

Mr. Shand remarks that "The language . . . retains many words more peculiar to the Rarotongan dialect"; but he unfortunately left no list of these,† and I have only succeeded in noticing one. A study of these non-Maori words reveals in the case of about 12 per cent. identity or close approximation with words in one or more of the leading Polynesian languages. Thus we have *ha*, sacred (*sa*, Sa., Uv.); *maramara*, nausea (*malamala*, Sa., Ta.): *puni*, many (Marq.): *tau*, reef (Ta.): *topa*, fall (E.I., Mang., Marq., Ta.): *tohua*, public place (Mang., Marq.): *wharia*, turn (*fariu*, Ta.); *pehe*, sing (Ta.; *pese*, Sa., Tik.). Among the approximations the more interesting are *hakana*, coffin (Marq., hide): *murumuru*, singe (Fut., warm oneself); *nono*, taut (Niue, bind; *no*, bind, Uv.); *po*, troubled (Sa., have war); *poi*, leap (Niue, run: Tik., go): *ro*, go (Tik., *oro*, go); *t'iei*, not (Marq., *tie*; Tik., *sīe*; Nuguria, *teai*; Sikiana, *seai*); *toro*, shoal, ridge (Sa., *tolo*, promontory): *oko*, many (Mang., Marq., strong; and apparently used to give a plural signification almost equivalent to "many"): *nuno*, of no account (E.I., *nunu*, thin).

This would seem to be the place to notice the causative prefix. The usual form is *hoko*, but this varies to *hoka*, *hoke*, *hoki*, *hok*, *ho*, *oko*, *oka*, *oke*, *oki*, *ok*, and *o*. In some cases in the vocabulary Shand uses *whaka*; but this does not, I think, occur anywhere in the published narrative matter, and appears to be an adoption due to Maori influence. This inference is supported by the fact that under the head *hoko* Shand mentions *whaka* only as the Maori equivalent. The normal form *hoko* suggests comparison with *ho'o*, *ho*, in Hawaiian, which seems to be the only other language in which the vowel is normally *o*, though in a few Tongan words *foko* replaces *faka*.

In the affinities thus disclosed the Marquisan dialect figures most frequently; then follow those of Tahiti, Samoa, Hawaii, and Tikopia: Easter Island, Mangarewa, Tonga, Uvea, and Futuna falling a little behind. Rarotonga falls in the last group: but it must be pointed out that the opportunities for a comparison with this dialect were somewhat restricted; and, in any case, it is a mistake to stress heavily numerical values in a comparison of this nature, particularly when the numbers are small and the available vocabularies far from complete.‡

* The meaning of the word in Maori is given in brackets.

† One, which he mentions in a note, is open to doubt.

‡ Mr. Best gives (*Trans. N.Z. Inst.*, vol. 48, pp. 435–36) thirteen Maruiwi words, of which one, *kohi*, appears in Moriori with a slight modification in sense, *hasten* for *come*.

It now remains to notice a few of the grammatical peculiarities of this language. With the limited material in our hands it is not possible to formulate a complete scheme of the grammar; but we are much helped by the fact that Mr. Shand has given a careful, and often literal, translation of what he published. Where he was unable to translate he had to content himself with the sense of the passage as obtained from the narrators.

There is a tendency to clip sentences by the omission of—

(i.) The definite article, as No / taenga ki / tuatoru k'' akina i tao o Whakatau. *When it came to the third time Whakatau's spear was thrust forward* (80); Ka oti / tarei. *The adzing was finished* (35): Pena mai i titike o / tupapaku, ti te hope to hohonu o / toto tangat, *Such was the heap of the corpses that the depth of human blood reached to the loins* (98); Ko roto i ri pu hamama o / totara, *In the gaping trunk of a totara* (97).

(ii.) A verbal particle, as— / Ru mānga a Kura, / toru mānga a Kura, *Kura took two mouthfuls, Kura took three mouthfuls* (41); E kore / tē, *He will not get there;* Ko maru / horo, *Maru swallowed it* (63).

(iii.) A preposition, as—Ka ra waihe ī / wahine mana, *She became a wife for him* (65).

(iv.) The nominal particle, *a*, as—Ka whai mai Nunuku, *Nunuku replied* (132).

The distinction between the active and passive of verbs is not always clearly preserved, and the preposition *e*, which in Maori indicates the agent after a passive verb, is in Moriori used with either an active or a passive: Potehi etu e Maui, *It was discovered by Maui* (29): Tē potehitī mai kō e o hunau, *Lest you be discovered by your relatives* (35).

Similarly, what may be called the transitive preposition *i* is inserted also after intransitive or passive verbs: Ka tak i te rau, *The feather fell* (63); Ka hapa i te hei, *There was one necklet over* (77): Ka pau i te hunu o tana kei i a Rohe, *Part of his food was consumed by Rohe* (29): Ti reira pea i te kiato o ta imi, *Perhaps the bulk of the people were there* (132): A te huna e ratau i te rangat o ratau, *They were hiding one of their number* (77). This usage may perhaps explain away the supposed euphonic use of *i* mentioned by Shand.

The use of the particle *e* after personal pronouns and some adverbs is more frequent than that of its Maori equivalent *nge*, and may reduce slightly the number of cases of the euphonic use of the letter.

In the narratives as edited the definitive particle, *ko*, is used with the subject to a verb more freely than in Maori: Ka puta ko Kura i t'' ata, *Kura went out in the morning* (42). But in many apparent cases of this use it is preferable to regard the *ko* as another form of the definite article, though it is not so recorded by Shand: Ka ki mai ko tupuna ki a i, *His grandfather said to him* (129).

The pronoun *ena*, *those* (near the person addressed), is used adjectively with the signification *other:* Ki te hunga ena ko Tamahine matua, *With other people (she was known as) the senior daughter* (76): K' huihui mai ko Te Wheteina me na ka imi, *There assembled the Wheteina and the other tribes* (94). An additional indefinite pronoun, *a*, is used to obviate the repetition of a noun, somewhat as *nga mea* would be used in Maori: Kimi mei ki ka rakau, i a tika, *Fetch some poles, let them be straight ones* (40).

The expression "hunaunga no ko," *a relative of thine*, which occurs more than once, is peculiar; but we are unfortunately not in a position to say whether this use of the personal pronoun in place of the pronominal suffix had a wider currency. Another anomalous use occurs in the phrase "ta imi na ratou e kai," *the people who ate him* (132). The Maori idiom would be "nana i kai."

A curious inverted construction is found occasionally in which the direct object of the sentence is treated as if it were the indirect object: Ko ta imi t'iei haramai i tangat, ka pang etu ki ri ngakau. *As for the tribes from which no men went with him, he threw them the entrails* (80); Ri oro mai au nei ki t' opeope. *He threw me a scrap.*

The phrase "no ro mē," *because* (Maori, "no te mea"), takes also the peculiar forms "ka ro a mē" and "ka ra wa mē," which it is difficult to explain grammatically. A similar difficulty is raised by the sentence "E mē wa mē meheki naku" (132). Shand's translation, *They are things belonging to me*, no doubt gives the sense, but fails to explain the syntax.

The points reviewed in this paper do not, in the opinion of the writer, make for any special theory as to the identity or origin of the Moriori race. In fact, it is well that we were pledged to no theory, for it seems that the only conclusion we have succeeded in establishing is the entirely negative one that the Moriori tongue is not correctly described as "a subdialect of New Zealand Maori." So far from that being the case, it has as much right to be considered independent as any of the known dialects of the Polynesian language.

ART. XXXVII.—*Report on the Natural Features of the Arthur's Pass Tunnel.*

By a Committee of the Philosophical Institute of Canterbury: C. C. FARR, E. G. HOGG, S. PAGE, L. J. WILD, and F. W. HILGENDORF (Convener).

[*Read before the New Zealand Institute at Christchurch, 4th–8th February, 1919; received by Editor, 21st May, 1919; issued separately, 19th August, 1919.*]

IN 1907, when the railway-tunnel from Otira to Arthur's Pass was about to be commenced, the Philosophical Institute of Canterbury arranged to make a series of records of the phenomena of natural and physical science that were revealed by the piercing of the tunnel.

It was designed to pay special attention to (1) the rock-formation exposed by the section; (2) the temperature of the rock in the bore as compared with that of the rock on the surface; and (3) the radio-activity of the rock in the tunnel (to determine whether the temperature gradient in the earth's crust and the radio-activity of the rocks were related in any measureable degree).

The tunnel was to be about 5 miles 25 chains in length; to penetrate the main chain of the Southern Alps from near the headwaters of the Otira, which flows into the Taramakau, to near those of the Bealey, which flows into the Waimakariri; to be in a straight line from portal to portal; and to rise with an even gradient of 1 in 33 from the Otira end.

A Tunnel Committee was appointed by the Council of the Institute, a series of suitable slow-acting thermometers and other apparatus were obtained, and satisfactory arrangements were made with the contractors for the boring of the holes into the rock for the temperature observations—arrangements that were continued when the work was taken over by the Public Works Department. It was desirable that the temperature bores should be as close to the working face as possible, so as to prevent the cooling of the rock by the air of the tunnel, and so it was arranged that the bores should be put in 4 ft. behind the working face of the bottom heading, that they should be 5 ft. deep and 1 in. in diameter, sloping slightly upwards to prevent the accumulation of water in them, and lightly plugged with tow to prevent the circulation of air. For ease of rediscovery they were for most of the distance put in every 10 chains, at a height of 4 ft. from the floor, and on the east side of the tunnel. Different members of the Committee visited the tunnel at various intervals, either to make the observations or to note their progress in the hands of those to whom they were deputed. The tunnel is not yet completed, but, as the bottom headings have met, it is considered that no new phenomena are likely to be disclosed. The results of the observations are almost entirely negative.

ROCK STRUCTURE.

The course of the tunnel is entirely through rocks of the Maitai system. Its direction makes a small angle with the axis of an anticline, and therefore little can be learned of the order of occurrence of the various beds. There are the usual variations from coarse-grained light-coloured to fine-grained dark-coloured beds, and through these run irregular veins of quartz and occasionally of calcite. Some of the rocks, particularly those of the fine-grained type, are distinctly carbonaceous, and are found to contain in places nests and lenticular masses of impure graphite. All the rocks are somewhat calcareous, and contain in one or two places nodular concretions about the size of a hen's egg. A record of the dip and strike of the veins running through the country rock was kept for some miles from the Otira end, and this record is in the hands of the Public Works Department.

Owing to the rocks exposed being in the axis of an anticline they are frequently faulted, and are broken and shattered to a high degree. This has had an important effect on the permeability of the mass to water, as will be noted immediately.

A complete series of specimens of the rocks obtained through the tunnel has been prepared for preservation in the Canterbury Museum.

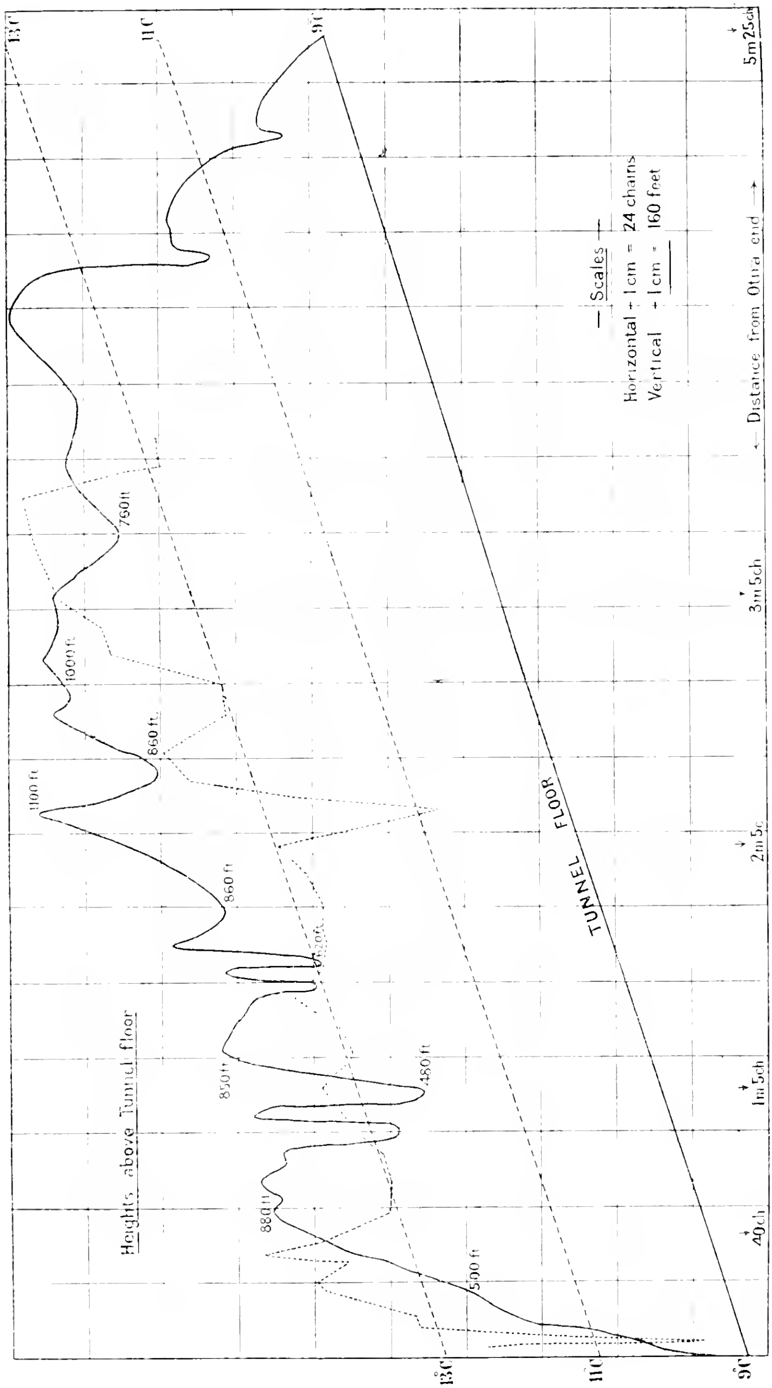
INFLOW OF WATER.

The shattered nature of the rock allowed the ingress of much water, and every time a blast opened up a wet seam streams of water would pour down on the workmen, greatly retarding the progress of the tunnel. When the bore was in 5 chains from the Otira end the influx of water was 0·1 cubic foot per second. The places where the water came in worst were from 10 to 40 chains apart, and these usually occurred where the rock was crushed and broken. In certain places the rock, shattered to pieces the size of a walnut, flowed in with the water, opening up great seams that required much timbering. The occurrence of the wet seams was most capricious. For instance, on one occasion the bottom heading opened up quite dry, but when the tunnel was enlarged to its full size a bad inflow of water was struck. There was no relation between the amount of rock overhead and the inflow of water, one of the worst flows being met with where the overburden was 900 ft. of rock. The course of the tunnel followed very nearly the courses of the Otira and Bealey Rivers, and several times passed under these or their larger tributaries, but there was no relation between the influx of water and the position of the tunnel in respect to these rivers. As a general rule the entering stream dried up considerably in a few weeks or months, but this was not always the case. The remaining flows, with the smaller drips that are practically continuous throughout the length of the tunnel, now produce a considerable stream, discharging 7 cubic feet per second. As the concrete lining is placed in position the water is confined behind the lining, which is pierced with weep-holes at sufficient intervals.

The concrete lining consists of a solid mass up the walls, but the arch is formed of concrete blocks. Between these very small drips occur, and the dripping water, having dissolved in it some of the materials of the concrete, has on evaporation formed stalactites, which are very noticeable objects as they hang from the roof. Their composition is essentially $CaCO_3$, with traces of Fe, Al, organic matter, and NH_3, the last probably from the organic matter. There is no Mg, PO_4, or SO_4. The stalactites are about 1 ft. long, and about $\frac{1}{4}$ in. in diameter. They look solid as they hang, but when broken from the roof are so fragile that they can hardly be held in the hand without breaking, for they have a large hollow down the centre, the solid matter forming the thinnest possible shell. Their rate of growth has been about 2 in. per annum, which is probably a hundred times as fast as stalactites grow in a limestone cave. The difference is due to the fact that in the case of the tunnel it is the soluble calcium hydrate that the water has had to work on, instead of the relatively insoluble calcium carbonate. It is probable that the rate of growth may be temporarily increased by the through draught caused by the opening of the bore from end to end, although the draught is neither so considerable nor so constant as might be expected considering that the tunnel is a mathematically straight line and is 860 ft. higher at one end than at the other. The draught is usually upward, but sometimes is quite absent and sometimes flows downward toward Otira.

Rock Temperatures.

When the tunnel was started it was designed to take at each of many places three simultaneous observations as follows: (1) The rock temperature in the tunnel; (2) the rock temperature at the nearest surface above the temperature-hole in the tunnel; (3) the radio-activity of the rock exposed in the tunnel. By this means it was hoped to contribute to our knowledge of whether, and to what extent, the internal heat of the earth is due to radium emanations as distinct from its residual heat. The conditions were, however, most unfavourable. In the first place, though the tunnel pierces a great mountain-chain, it passes under a low saddle, so that the overburden of rock is at its maximum only 1,100 ft. If the tunnel had been two miles east or west of its actual position the overburden would have been increased to 4,000 ft. or 5,000 ft. In the second place, the great influx of water made it quite clear that the observations would give the temperature not of the rock, but only of the percolating water. Of the temperature-holes bored half were distinctly wet, while the others were so near to wet places that the rock and the thermometer were undoubtedly affected by the water.



Longitudinal Section of Arthur's Pass Tunnel.
Full line, contour of mountains; dotted line, temperature-readings.

The accompanying graph gives the rock-temperature for three miles and a half from the Otira end, the observations being taken every 5 chains for the first 45 chains, and thereafter every 10 chains. No readings were taken at the Bealey end. Since it was desired to correlate the temperature-readings with the overburden of rock, the basal temperature line (9° C.) on the graph has been given the same slope as the tunnel-floor. It will be noted that the temperature graph is roughly parallel to this basal line, and that the minor variations in it, amounting to 3° or 4° C., show no sign of parallelism with the overburden of rock. The capricious variations shown are due chiefly, if not entirely, to the rate at which the water near by percolated from the surface or from the seams in which it was lying. That some heating effect was produced by the passage of this water through the rocks is, however, apparent from the fact that the average temperature of the wet rocks in the tunnel is about 10° C., while the water in the surface streams is about 4·5° C.

Temperatures were read twelve, twenty-four, and forty-eight hours after the insertion of the thermometer, but in only four out of the thirty-five holes put in was there any difference among the three readings of the same hole. The greatest variation shown was at the hole at 1 mile 55 chains, where the readings were 13°, 12·9°, and 12·8° C.

Biology.

The only observation of biological interest was the growth of the fungus known as *Armillaria mellea* on the temporary timbering of the tunnel, where it formed great pendulous bunches of mycelia about 3 ft. long, and somewhat similar in size and appearance to a horse's tail except that the individual strands were coarser. Only the vegetative form of the fungus was found, and this was found only on the pine timbers of the Otira end, being absent from the eucalyptus props of the Bealey end. Probably the fungus occurs in the bush whence the timber was cut and the spores are carried in when the props are placed in position, where the equable temperature, the moisture, and the darkness provide suitable conditions for vigorous growth. The estimated minimum rate of growth is about 3 ft. in a year, but this has been noticeably altered by the completion of the bore, the constant aeration having produced greatly accelerated development.

The Committee wishes to express its sincere thanks to the Right Hon. Sir Joseph Ward, who, as Prime Minister, made a grant in aid of the expenses of the investigation; to the Hon. G. W. Russell for permission to publish the report in the *Transactions of the New Zealand Institute;* to Messrs. McLean Bros. (the original contractors for the tunnel) and to the Public Works Department for facilities for making the observations recorded; and especially to Mr. A. Dinnie, Engineer in Charge, for his unfailing courtesy and willing assistance, and to Mr. Manson, underground foreman, for making most of the temperature observations.

ART. XXXVIII.—*A History of Hagley Park, Christchurch, with Special Reference to its Botany.*

By Miss E. M. HERRIOTT, M.A., Biological Laboratory, Canterbury College.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 7th April, 1919; issued separately, 19th August, 1919.*]

CONTENTS.

INTRODUCTION.

THOSE who gain the summit of the Port Hills by means of the Bridle-path and look across the Canterbury Plains as they appear to-day can have little idea of the appearance they presented to the first Europeans who gazed upon them from a similar vantage-point in the "forties" of last century. They then spread out in a wide stretch of flat country "clothed with abundance of good pasture, singularly deficient in timber."* Isolated patches of forest were to be seen at Riccarton, Papanui, Kaiapoi, and Rangiora. The Papanui Bush has long since disappeared, but the Riccarton Bush still stands, solitary remnant of the famous white-pine (*Podocarpus dacrydioides*) association. The site of the future city was more or less a swamp, interrupted in various parts by shingle-beds and sand-dunes, through which the little river Avon, then variously known as Teonotopo or Potoringamotu, wound its way amidst a thick growth of *Phormium*, niggerheads, and raupo.

The first permanent settlers on the Plains were the Deans brothers, who arrived in 1842 and decided to settle just on the fringe of the now well-known Riccarton Bush. An account of their first journey gives some idea of the general appearance of the early vegetation covering this district. The journey was made up the river from its mouth in a whaleboat as far as "The Bricks," near the present Barbadoes Street Bridge. From that point a Maori canoe conveyed the party to the bend in the river close to the present Riccarton Road. During the whole river journey the canoe had to be forced through a thick growth of vegetation by pulling on the flax and niggerheads. When the little party left the river a path had to be made through the dense "entanglement of fern, tutu, tussock, bramble, spaniards, and other native growth, nearly breast-high."† Such was the virgin state of the land on which the new city was to be built.

* *Handbook for New Zealand*, by a late Magistrate, p. 326, 1848.
† *Canterbury Old and New*, p. 50, 1900.

The Canterbury Association had instructed their surveyors to choose as the site of the capital of their settlement a suitable block of land about 1,000 acres in area, and to lay out lines for the principal streets, squares, sites of public buildings, parks, &c., required for the convenience of the future inhabitants.* After some hesitation as to the respective merits of the seaport and the inland site the latter was selected One of the surveyors protested that the actual site chosen was too swampy, and considered the place on which the suburb of Woolston now stands to be drier and therefore a more desirable situation. He was overruled, however, by his more impetuous colleague, Captain Thomas, and the principal streets, squares, reserves, &c., were laid out as they now stand. As it was to be an ecclesiastical settlement, the principal streets were named after various bishoprics, the names being jumbled up together in a hat and drawn at random as required, so that no undue preference should be given. In this way did the main thoroughfares receive their names. With the large town reserve, however, it was different. This was named out of compliment to Lord Lyttelton, who was chairman of the Canterbury Association, and Hagley Park bears the name of his country seat in Staffordshire.

Size and Boundaries of the Park.

Out of the 1,000 acres an area approximating 500 acres was set aside, vested in the Queen, as a public park. In accordance with the request of the Deans brothers, that the new town should not be placed too near their station, this reserve was placed on the west side of the town, between their station and the town buildings. Roughly speaking, it comprised all the land from the North Town Belt to the South Town Belt for a width of 60 chains. By the Canterbury Association Ordinance of 1855 the land known as Hagley Park was declared to be reserved for ever as a public park, and to be open for the recreation and enjoyment of the public; and it was provided that it should be lawful for the Superintendent to set apart so much of the land as he should think fit for plantations, gardens, and places for public amusement, and to lay out public roads through it. He had power also to let it.

The original reserve includes the grounds now occupied by the Hospital, the Acclimatization Society, and Christ's College. By the year 1855 the 10 acres belonging to Christ's College had already been handed over to the College authorities in exchange for land owned by the College in the centre of Cathedral Square, and it is so specified in the Canterbury Association Ordinance referred to above. In 1863 the Provincial Council by an Ordinance transferred 5 acres 2 roods of the park to the Superintendent for the purpose of a hospital, this being the higher land at the corner of Antigua Street and Riccarton Road. By the Christchurch Hospital Act of 1887 this land and nearly 8 acres more were vested in the North Canterbury Hospital Board in fee-simple, the extra 8 acres being for the purpose of a fever ward, kitchen-garden, and pleasure-grounds, it being especially stipulated that no buildings were to be erected there without the consent of the Domain Board.

Although strictly speaking the original reserve includes this whole area, in this paper only those parts of it now known as "Hagley Park" and the "Botanic Gardens" are dealt with botanically. Hagley Park is divided

* *Handbook for New Zealand*, p. 19.

into North and South Parks, which are separated by Riccarton Road. The North Park is bounded on the south by Riccarton Road, on the west by the West Belt, on the north and east by the River Avon. A small plantation, known as Helmore's Plantation, is cut off on the north of North Park by a public road. The South Park is bounded by the South Belt, the West Belt, Riccarton Road, and Lincoln Road. In the same block of land as the North Park are the Botanic Gardens. On the north these are bounded by a straight line running at right angles to Rolleston Avenue along the College boundary-fence as far as the river, thence by the river itself to the south end of Rolleston Avenue again.

The exact areas of these various portions are rather difficult to determine from the records. In the *Lyttelton Times* of the 20th April, 1852, the Land Office of that day advertises the 445 acres of Hagley Park as available for depasturing, at a rental of 2s. 7d. per acre. The Government Domain, of 64½ acres, is also advertised, at a rental of 1s. 7d. per acre. Whether this Government Domain is part of the original reserve and is the area now occupied by the Botanic Gardens is not quite certain, but, assuming that it is, the total area of the reserve as surveyed in those days would be 509½ acres. This is greater than any later estimate. By the Public Domains Act, 1895, the area of Hagley Park and Domain is described as originally 495 acres This includes the 10 acres vested in the Christ's College authorities, the Hospital ground, and also the areas occupied by the roads through the Park, altogether 35 acres, leaving under the direct control of the Domain Board 460 acres. In 1905 the North Park was surveyed by Mr. N. C. Staveley, of the Canterbury College Physics Department, and in 1906 the South Park by students of the Engineering School, under Mr. W. F. Robinson, and the areas were computed as follows: North Park, 210 acres; South Park, 174 acres 1 rood 4 poles: total, 384 acres 1 rood 4 poles. The accompanying table shows the latest areas recorded for each division of the original reserve:—

	A.	R.	P.
North Park	210	0	0
South Park	174	1	4
Christ's College	10	0	0
Museum	1	0	26
Magnetic Observatory	0	2	13
Domain Garden	51	1	38
Hospital	13	2	18
Acclimatization Society	10	0	0
Total	471	0	19

Subtracting from this total the areas handed over to Christ's College and to the Hospital Board, a total of 447 acres 2 roods 1 pole is left under the control of the Domain Board, thus making a shortage of 22 acres 1 rood 39 poles from the estimated 460 acres of 1895.

EARLY HISTORY.

The administration of the land of the public reserves was at first in the hands of the Land Office. The earliest reference found was in the *Lyttelton Times* of the 3rd April, 1852, where, over Mr. W. G. Brittan's signature, was the advertisement for receiving tenders to depasture "the land known as the Town Reserve surrounding Christchurch, Hagley Park, and the

Government Domain." The Town Reserve and the Government Domain here referred to were later disposed of in other ways, but Hagley Park still remains. In the same issue of the *Lyttelton Times* was an account of a cricket match in Hagley Park between the married and the single men of the settlement. A subscription was taken up during the afternoon to make a proper ground and fence it in, "the present place being rough in the extreme and very difficult to play on." A sum of £30 was collected, which was presumably spent in this way. In a later issue was an advertisement of races to be held in Hagley Park on Easter Monday of the same year. This was accompanied by the statement that the course had been much improved since the last races held there. Again, on the 25th December, 1852, appears an account of the "farewell breakfast" tendered to Mr. and Mrs. Godley on the eve of their departure for England. This took place in Hagley Park in the spacious marquee which had been erected for the Horticultural Exhibition, of which no other mention can be found.

It would seem, therefore, that the Park was early used for one of the purposes for which it had been set aside namely, as a recreation-ground for the townspeople; and to a certain extent the ground must have been prepared for this, cleared of some at least of the thick growth with which it had been covered when the town was first laid out. Details, however, as to this are lacking. Stock of all kinds were freely pastured on this ground, for the action of the Association in charging for the right to pasture on Hagley Park provoked the complaint from one correspondent that the price of milk was high enough as it was without any extra charge in consequence of rents dairymen had to pay. Later on the long grass was cut, and haystacks were a common feature in the parks.

In 1855, by the Canterbury Association Ordinance before referred to, the Superintendent was given power to set aside what land he thought fit for plantations, gardens, &c., but nothing seems to have been done in this direction before 1864. On the 10th May, 1864, a public meeting was held in the Town Hall for the purpose of forming the Canterbury Horticultural and Acclimatization Society, and it was decided that Hagley Park was a suitable site on which to form a botanic garden. The Provincial Government was approached, and a Commission, consisting of Messrs. Hall, Sewell, Miles, and Hill, was appointed "to promote the cultivation and planting of the Government Domain in connection with the objects of the Acclimatization Society."

In early days the Commission (later known as the Board) acted as an advisory committee to the Superintendent, but in 1872 the power of administration was vested in the Board itself. The various Acts of 1872, 1881, 1895, 1908, and 1911 have all dealt with the administration of this Christchurch reserve, and have further defined the extent of the Board's authority over the land.

At the first meeting of the Commission it was unanimously agreed that the ground under control of the Commission should be trenched and planted without delay. The Government Gardener, Mr. Barker, undertook the supervision of the work for the Commission. The portion of the reserve decided on as suitable for acclimatization and horticultural purposes was that lying between Christ's College grounds and the river, and steps were taken to have this fenced off with Van Diemen's Land palings, trenched and dug, while the Provincial Secretary was requested to have the cattle removed which were then depasturing the ground. Due attention was paid to the requirements of the Acclimatization Society as to aviaries and ground for pasturing any animals. Native plants were offered by a gardener at Akaroa at the rate of 6s. to 14s. per hundred, and £30 was voted to be disbursed in the purchase of the same. Dr. von Haast presented seeds he had received from Sir W. J. Hooker, Director of the Kew Gardens, and other private individuals made presents of seeds and plants.

A vote of £1,000 had been granted by the Provincial Government for the carrying-out of the work, and at the outset the finances appeared to be in good condition.

Frequent gaps occur in the minutes of the first few years. In 1867, however, it is recorded that Mr. Barker asked to be relieved of his duties as Government Gardener, and the late Mr. J. F. Armstrong was elected as his successor. Mr. Armstrong acted as curator till 1889, and during the greater part of his twenty-two years' service he was assisted by his son, Mr. J. B. Armstrong, who had charge of the nursery work.

History of the Domain.

The Domain when Mr. J. F. Armstrong took over the management presented a very different appearance from that of to-day with its trim, orderly beds and wide green lawns. A paling fence separated it from Antigua Street, and close to it was a very thick belt of willows and poplars. Over a hundred were taken out from the frontage between Worcester and Hereford Streets. The Museum building and the Gardener's cottage had not then been erected. Three sand-dunes were very conspicuous, one occupying the site of the present Museum, a large one where the first grove of pines (*Pinus Pinaster*) now stands, and a smaller one between these two. Those behind the Museum have since been levelled, but the knoll on which the pines stand still shows something of its original form. All these sand-dunes were covered with fern, amongst which showed an occasional *Discaria*. A huge shingle-pit occupied the greater part of the area now covered by the wide front lawn, and supplied much of the metal for the city streets. There were no flower-beds of any kind. A few of the older trees were there then; the tall *Eucalyptus* on the river-side near the Gardener's cottage was one of these, and the Prince of Wales's oak farther down the path.

It may be of interest to note that the oldest of the trees planted in the Domain and Park, such as the sycamores, oaks, and elms, were imported from England as trees. They came out in big wooden cases, having been removed from the English nurseries during the resting season. On arrival after their six months' journey they were at once put into the river to revive before planting. The stronger of them lived, and grew when planted out, but many died. As soon as it was possible all trees for planting in the Domain were raised in the nursery of the Domain either from seed or from cuttings or layerings. This work, as mentioned above, was in the charge of Mr. J. B. Armstrong, and trees of his raising may be found in all parts of the Park and Gardens. The line of wellingtonias extending from the river to Riccarton Road by the United Tennis and Bowling Club's grounds were all raised from seed in 1873. The beautiful Oriental planes in the avenue leading to Riccarton Road were reared as cuttings, and the limes of the South Park as layerings, in 1873 and 1874. In addition to the work of raising seedlings and trees for the Domain and Park, thousands of young trees were distributed from the Christchurch Gardens to various public bodies in all parts of the colony. In 1881 it was estimated that the number that had thus been gratuitously distributed by the Domain Board during the previous twelve years was 694,972. Later this work had to be discontinued owing to lack of funds.

During the years following 1867 many trees were planted both in the Domain and Parks; flower-beds and lawns were formed in the Domain, and the main paths laid down as they now are. This entailed much hard work, for the whole area was practically uncultivated. The bed just inside the gates which is now so gay with flowers was a deep bed of shingle, all of which had to be removed and replaced by good soil. The College border was amongst those formed, and still contains many trees and shrubs planted at that time; the River border was also formed about the same time, and the Fern border also was prepared for the reception of tree-ferns. A number of these are still to be found there in company with a tangled mass of other native and foreign vegetation, and the whole, as it stands, somewhat resembles a piece of native bush, where the young seedlings of the various trees find a congenial home.

The names of Mr. J. F. Armstrong and of his son will be always connected especially with that portion of the Gardens now known as the "old native section." About 1875 Mr. J. F. Armstrong proposed to lay out the 2 acres hitherto used as a nursery for the cultivation of the New Zealand trees, shrubs, and herbaceous plants, for, as he said, "there are in the colony many beautiful and interesting plants, which it is desirable to preserve from the destruction which is fast overtaking the indigenous flora." He proposed to plant the species in hand in botanical order, and fill up as others should be obtained. A very large collection of valuable plants was brought together here, many of them being collected from their native homes by the son, who took long and arduous journeys for that purpose.

Much of the history of this native section was given many years later by Dr. L. Cockayne in an article entitled "The Native Section, its Value and Possibilities," published in the *Lyttelton Times* of the 12th June, 1911. Dr. Cockayne stated that the function of a native section such as that formed by the Armstrongs was "to form a living museum of botanic material which students could consult; to be a pleasing adjunct to the Gardens; to show that native plants could be cultivated, and were equal to expensive exotics; and, finally, to supply seeds for exchange purposes with horticultural establishments abroad. And right well has it served those purposes." "Through the material collected in this way," the article continues, "Mr. J. B. Armstrong sprang into the front rank of New Zealand botanists by his bold and excellent paper on the New Zealand veronicas, in which he foreshadowed De Vries's mutation theory." Material from this section has been extensively used by Cheeseman, Petrie, and Cockayne, among New Zealand botanists; while seeds collected here have been sent abroad to Edinburgh, Kew, and other great national gardens. This native section is known far and wide throughout the world, and has been visited by many scientific men from all parts of the globe. Since ornamental plants form only a small percentage of the native flora, a native garden cannot be limited to these, or it would give little idea of the New Zealand flora. To be educational it must contain as many plants as can possibly be got to grow there. Farther on in the article the writer states that the native section is one of the horticultural landmarks of the Dominion, and contains abundant material for research, at the same time forming a wonderful object-lesson as to how plants from the most different habitats—swamp, rock, river-bed, forest, scrub, lowland, seashore, and mountain can not only tolerate but enjoy conditions absolutely different; and, in conclusion, he asks that the time-honoured native section should be as religiously preserved and well tended as the new one, and also added to, so that together they may form the most extensive and complete collection of New Zealand plants that has yet been brought together.

During the terms of office of the following two curators—Mr. A. Taylor (1889–1907) and Mr. J. Dawes (1907–8)—very little seems to have been done beyond keeping the grounds in order, owing principally to the want of funds and consequent lack of skilled workmen. Indeed, on several occasions the only assistants the Head Gardener appears to have had were men supplied by the Charitable Aid Board, and these were too infirm for any but the lightest work.

During the years (1908–19) in which the present curator, Mr. James Young, has been in charge many extensive changes have taken place in the Domain and Parks. In the Domain the beds are gay in the different seasons with the various annuals. The new native section, with its luxuriant growth of native plants, is an important addition for the student; the rose-garden, with its wealth of blossoms of every hue, its trim walks and well-kept beds, delights the rose-lover; while the recent addition in the shape of a children's playground, with its paddling-pool and swings, delights the hearts of countless children and is a boon to many a parent. Many other changes are in prospect, and all are possible only by reason of the increased funds at the disposal of the Board. These are obtained by votes from local Boards and Councils, and also from the proceeds of the annual fêtes, instituted on the suggestion of Mr. Young.

The history of all the plants in the Botanic Gardens is beyond the scope of this paper. It will be sufficient for the purpose in view to add a few facts only concerning the planting of the historic trees or plantations.

The Historic Trees of the Domain.

The first tree to be planted in the Domain was the oak still to be found close to the river, to the south-west of the archery-lawn. This was planted on the 9th July, 1863, to commemorate the marriage of the late King Edward, then Prince of Wales. It is known as the Prince Albert Edward oak. On the same day other oaks were planted in different parts of the town: two of these are still to be found in the grounds of the West Christchurch School. The one in the Domain is now a huge tree, with a trunk over 10 ft. in circumference, its branches spreading across the path. It can be easily found and identified by the brass plate fitted into a strong post which stands in front of it. The brass plate dates from the planting of the tree, but for many years it was allowed to become so discoloured as to be almost undecipherable. It has recently been fixed in its present place, and the rubbish cleared away from the tree so that its beauty may be clearly seen.

The next trees of historic interest are those planted by the Duke of Edinburgh on the occasion of his visit to Christchurch, in 1869. It had been arranged that His Royal Highness was to plant the oak near the centre of the first lawn, and four other trees were to be planted in different places later on in the day. When this was made known to the Royal visitor he insisted on planting them all. The oak is known as Prince Alfred's oak, and is still to be seen in the centre of the front lawn. His Royal Highness specially requested that this tree should never be touched with knife or axe, and, though it badly needed it, Mr. Armstrong would not allow it to be touched during his period of office. Since then, however, it has been pruned and has been much improved thereby. Of the other four trees, the *Wellingtonia gigantea* alone remains, and is seen farther to the north of the same lawn; the cedar of Lebanon, the *Cedrus deodora*, and the totara have since died. As Mr. Armstrong quaintly remarked many years ago, the possession of five Royal trees was too much honour for one garden to sustain.

The *Araucaria imbricata* just to the south of the Moorhouse statue was planted in 1871 by Sir George Bowen, then Governor of the colony. He planted four other trees—an oak near the north-west corner of the enclosure near the College grounds, which was cut down in 1893 and replaced by an elm; an ilex oak, which is still standing on the grass plot near the Winter Garden; and two others.

The Marchioness of Normanby's tree is the cedar of Lebanon on the lawn near the Museum path, not the *Cedrus deodora* which is at present labelled with her name. That tree was planted later, in 1880, to celebrate Mr. J. F. Armstrong's sixtieth birthday. It is apparently almost as big as the other cedar, for it has made quicker growth. The Marquess of Normanby planted an oak seedling at the end of the archery-lawn on the same day, and this has since grown into a fine tree. It is to be found just beyond the limes.

On the 6th June, 1893, an oak was planted on the triangular lawn near the Gardener's cottage to commemorate the marriage of Their Royal Highnesses the Duke and Duchess of York. This oak was planted by the chairman of the Domain Board, Mr. H. P. Murray Aynsley, who served for many years in that capacity on the Board and devoted much time and thought to the welfare of the Domain and Parks.

In August, 1902, an oak was planted to commemorate the coronation of King Edward VII. This is now a fine tree, near the north-east corner of the rose-garden, and can be easily distinguished by the stone, suitably inscribed, which has been placed in front of it.

On the 23rd June, 1911, an oak-tree was planted by Mrs. H. J. Beswick near the south bridge to commemorate the coronation of King George V. In 1917 Lord Liverpool planted a Spanish chestnut near the South Domain Bridge. This ceremony was the initial step towards the proposed rock-garden.

There are probably several other trees of historic interest in the Domain which are not properly identified, and it is to be hoped that the Board will act on the proposal made in 1910 to find them out and keep a record of them, making plans of the Domain to show their position, as suggested in the proposal.

On more than one occasion these and other trees and plants have been named and labelled by the various curators, but a section of the public, with a wanton disregard of their privilege in protecting one of the most beautiful assets of their city, constantly destroy these labels either by removing them altogether or throwing them about in other parts of the gardens. Over and over again in the minutes of the Domain Board has this destruction been referred to; it is probably only the more solid nature of the labels in front of some of these memorial trees that has preserved them from the same treatment. This is a serious disgrace to the perpetrators, as is also the deliberate removal of many plants from the beds, which also has been reported from time to time. The public should be made to realize that the beauties of the Domain are theirs to enjoy and to protect in every way.

Buildings in the Domain.

Some mention perhaps should be made of the buildings and other structures of a permanent character found in the Domain. In 1869 the first buildings of the Museum were erected. These faced the front lawn of the Domain. The front rooms and new entrance off Rolleston Avenue were added at a later date. The Board of Governors of Canterbury College, to whom the Museum buildings belong, have no title to the land on which the buildings stand, and this has hindered the erection of additional buildings. In 1872 the Gardener's cottage was built on its present site, and various alterations have been made from time to time, the last being the addition of a Board-room. In 1874 the attempt of the Provincial Council to take another portion of the Domain for the erection of Canterbury College led to the resignation in a body of the Board, who thus protested against the alienation of the reserve from the purpose for which it had been set aside. Public protest also led later to the abandonment of this project.

The sun-dial must have been placed in the Domain quite early in its history, for no mention can be found of it in the minutes. It is said that it was presented by Mr. W. Guise Brittan, who brought it out from England with him. It stood originally where the Moorhouse statue now stands, but was moved to its present position in 1873. The Moorhouse statue was set up in 1885 after some discussion as to the suitability of its being placed in the Domain. In 1902 the Magnetic Observatory was built and a small portion of the grounds fenced off surrounding it. The Rolleston statue was placed in position in front of the Museum and fronting Worcester Street in 1905. In 1908 the Old Colonists' Association applied for and received permission to erect a stone pillar with a brass plate in the Pilgrims' Corner. This led to some discussion as to the actual place which should be known by that name. In 1913, out of the funds bequeathed to the Beautifying Association by the Hon. J. T. Peacock, an elaborate fountain was erected. It was originally right on the path, but was later moved to its present position and the pond then formed round it. The Winter Garden consists of the conservatory and orchid-house from Holly Lea, and was presented to the Domain by Mrs. A. Q. Townend in 1914.

The present nursery grounds and buildings were taken possession of in 1875. Previous to this date the nursery was situated on the ground now occupied by the old native section.

The above gives a very brief history of the Domain, but naturally it cannot be treated exhaustively from a botanical standpoint. The gardens contain much of great interest to the student of plants from his own and foreign lands. In this paper, however, the writer is attempting to trace the changes that have taken place in the vegetation from its virgin state to the present day, with a more particular account of what native plants may be supposed to have maintained their existence from that time. It would be very unlikely that any of our indigenous plants could have managed to exist under the conditions that have prevailed in the Domain since it has been so carefully cultivated, though it is possible that a very few might be able to re-establish themselves if the soil were allowed to lie waste. Nearly all the indigenous plants that are to be found to-day in the original reserve are in that part of it known as the North and South Hagley Parks.

History of the Park.

The various events of historical interest that have taken place in the Park have all had their influence on the vegetation, and will be considered briefly. The first, already referred to, was the "farewell breakfast" tendered to Mr. J. R. Godley in the end of 1852. Thirty years later—that is, in 1882—the South Park was the scene of the Industrial Exhibition. The large entrance-gates, presented by the promoters of the Exhibition, Messrs. Joubert and Twopenny, now form the entrance at Hereford Street, being erected there in 1883. In 1901 there was a great military review in North Park, held on the occasion of the visit of Their Royal Highnesses the Duke and Duchess of York. In Coronation year, 1902, a huge bonfire was made in North Park, between the Armagh Street entrance and the lake. In 1905 the buildings for the International Exhibition were commenced and land enclosed for grounds. These extended from the South Domain Bridge, near the lake, to Carlton Bridge, and in the Park from a point commencing on Helmore Road. This ground consisted of a total of 116 acres—86 acres of free ground, 5 acres of lake, and 25 acres of plantation. In 1910, at the time of Lord Kitchener's visit, a Volunteer camp was held in the North Park. On all these occasions there was of necessity a great disturbance of the soil and destruction of vegetation. One of the conditions laid down in each case by the Board was that the ground should be restored to its natural state when the period of occupation was completed; but this was not possible in every case, and a few of the native plants were lost for ever to the Park on more than one of these occasions.

In 1897, the Diamond Jubilee year of Queen Victoria, the piece of swamp near Armagh Street was formed into a lake and named Victoria Lake after the Queen. It consisted when finished of 5 acres of water, and was 3 ft. deep. The formation of such a lake had been suggested in 1871 by Mr. R. Wilkin, then a member of the Domains Board, but his proposal had not been agreed to. In 1916 the smaller lake to the north was formed as at present, the soil having been removed to improve the border on Rolleston Avenue. There was some trouble at first as regards the water-supply feeding Victoria Lake, but Mr. Young has made use of the 1906 Exhibition deep wells to feed both Victoria Lake and the smaller lakelet beside it.

From a botanical standpoint the destruction of this swamp is much to be regretted, for it contained very many of the indigenous plants which have since that time been lost to the neighbourhood of Christchurch. Such a piece of swamp quite close to the centre of the town would be always easy of access to the student, who now has to go much farther afield in search of bog-plants.

The Park was also used by Volunteer corps as a camping-ground; and, as the first records show, it has been used from the earliest days of the settlement as a sports-ground. The cricket clubs were the first to make use of it, and the South Park has been the scene of their activities from 1867. Later the polo club and the hockey clubs obtained the use of certain portions of the same park. The North Park has been used by various football clubs, golf clubs, and tennis clubs. The latter have laid down permanent courts and erected pavilions of a more or less permanent character. At first, however, the Boards granted the use of the Park only on condition that no buildings of a permanent nature should be erected, and more than one football club was requested to remove the structures it had put up. In every way an effort was made to guard the reserve from any attempt to appropriate any portion of it for the few: it was to be held in trust for the public as a whole. It is to be hoped that the people of Christchurch will in the future be equally as careful to preserve these public grounds which the forethought of the early colonists set aside for their use.

In 1888 four cricket clubs in South Park and eight football clubs in North Park together occupied 49 acres. In 1913 the approximate area of sports-grounds was estimated at 68 acres.

THE SOIL OF HAGLEY PARK.

The nature of the soil on which any plant association is found is always important in the study of the plants forming that association. The soil of Hagley Park is for the most part very sandy, with patches of shingle and smaller areas of swampy ground, though the latter is not now so extensive as it once was. Geologically the Park belongs to the Canterbury Plains, and some account of their formation has been taken from Sir Julius von Haast's report of 1864.*

After describing the probable state of this South Island during the Tertiary and succeeding glacial periods at the close of which the Canterbury Plains began to be formed by the deposits carried down by the glacier torrents, he postulates the formation of a huge lagoon extending from the Rakaia to the Waimakariri. This he considered was formed by a bank composed of deposits of sand and silt carried down by the glacier torrents and so enclosing an arm of the sea. The bank was added to by the drift sand along the coast. Of this lagoon only Lake Ellesmere now remains. The rest has been filled up partly with deposits of silt or glacial mud brought down by the big rivers Rakaia, Selwyn, and Waimakariri (all of which he considered emptied into this huge lagoon), partly by deltas formed by these rivers, and also by the invasion of drift sand from the seashores. By slow upheavals swamps were probably formed, giving rise to extensive beds of peat, by means of which the ground gradually became still higher, so as to offer the necessary conditions for the growth of the kahikatea (white-pine) (*Podocarpus dacrydioides*) and other forest-trees, whilst in the intersecting channels between the dry lands the deposits of silt were still thrown down to form beds of clay and loam (p. 55).

The swampy ground on which *Podocarpus dacrydioides* established itself is farther to the north and west of Hagley Park, but certain small areas within the Park are still swampy, and Victoria Lake marks the site of the largest swamp of more recent years, which for long was an eyesore to the beauty-loving section of the Christchurch public, but, as mentioned above, formed the home of many of our native swamp-plants. The other swampy areas are indicated by the presence of the sedge *Schoenus pauciflorus*. The greater part of the Park, however, is shingly or sandy in character. The shingle has proved a source of revenue to the Domain Boards for many years, while the sand is everywhere present at a greater or less depth from the surface. This sand was a serious trouble to the early Boards. The question of how to stay its inroads or prevent its drifting was at length answered by the happy suggestion of one Board member in 1881 that the City Council be asked to deposit all grass scrapings from the streets on such areas. That apparently settled the difficulty, for no more complaints concerning sand-drifts are heard in the Board meetings. Instead, complaints of a different nature were heard, to the effect that the City Council were exceeding their privilege by depositing more than grass scrapings, and so making of the Park an unsightly dumping-ground for all kinds of city refuse.

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* *Geological Reports to the Provincial Council of Canterbury*: 2. Report on Formation of Canterbury Plains, Session XXII, 1864.

The surface soil of the Park to-day is very different from what it was sixty-nine years ago, when the reserve was first set aside. By 1865, according to Mr. Armstrong's recollections, South Park had been sown down and partially levelled. North Park was much more uneven, the soil much poorer, and drift sand abundant. It was covered by very slight vegetation. Now, by this year 1919, every square inch has been dug or ploughed over more than once. Loads of soil have been carted from the Park to the Gardens for flower-beds and to form the present paths of Rolleston Avenue. Still other loads of city refuse have been deposited in different parts of the Park and covered over with soil, at first for the purpose of settling the drift sand. Deep excavations have been made for the purpose of laying electric cables or in the erection of earthworks for the Volunteer Engineers in days gone by. Certain parts of South Park have been cropped, and in later years extensive areas have been planted in potatoes with the idea of clearing the ground, levelling it, and preparing it for sports-grounds. Other existing sports-grounds have been levelled and sown with grasses. The ground on which the Exhibition buildings were erected has been thoroughly disturbed, and several native plants have been seen no more since that time. The laying-down of tennis-courts, cutting hay, grazing, occasional bonfires—all have had a share in changing the character of the soil and consequently the plant covering.

The Plant Covering.

In considering the plant covering of the Park it will be best to speak first of the trees forming the plantations and avenues, then of the herbaceous plants, paying most attention to the indigenous plants which are still to be found growing here, and which may be considered as having formed part of the original plant covering. It is chiefly to form some printed record of what is known of these plants that this paper was taken in hand.

First, then, some history is given of the planting of the trees.

According to the minutes of March, 1904, Mr. H. P. Murray Aynsley stated that the avenues in the Parks had been planted in the hope that some day a proper drive would be formed round the Park. Some plantations must have been in existence in 1867, for in that year application was made for the use of the grass growing within the plantations, and later in the same year trespassers were reported to be injuring the trees. In 1868 there is a record of the damage caused to the plantations by the turkeys and pigs which had been allowed to run there. The first mention recorded of the actual planting in the Park was in the autumn of 1870, when land was enclosed for an avenue to extend from a plantation (probably the pine plantation west of Victoria Lake) to the entrance near Plough Inn. That is now the avenue of Oriental plane trees which is one of the beauties of the North Park. As stated above, these plane-trees were raised from cuttings by Mr. J. B. Armstrong. A plantation of an acre was made also on the high ground and sandhills north of the footpath. This was of pines, and is still in existence as the pine clump to the north of the lake. That same season instructions were given that "the waste ground north of the road near Carlton Bridge be enclosed and planted with pines." This is what is known now as Helmore's Plantation. The pines in the corner by Carlton Bridge were also planted at this time.

The following year, 1871, saw the plantation at the south-west corner of the South Park formed from trees removed from the avenues along Lincoln and Riccarton Roads, the plantation along Riccarton Road completed, and two small plantations formed on the south side of the road leading to Carlton Bridge. A shingle-pit in the park was also enclosed with a substantial fence and planted with fir-trees.

In 1875 the Head Gardener reported the fencing-off of ground and the planting of a new avenue from the north entrance of the Park along Riccarton and Lincoln Roads, thence along the South and West Belts to Washbourn's Creek, and the continuation of the avenue walk from Lincoln Road along the South to the West Belt. The lime-trees along the north side of the Park were reported to have been destroyed by hares which had escaped from the Acclimatization Society's grounds.

This year (1875) it was also suggested that the avenue in front of the Domain and College should be added to Antigua Street by removing the old fence, the holly fence just within if reinforced with wire netting being sufficient to keep out dogs. Though the completion of this work is not recorded, it probably was carried out during that season, adding greatly to the beauty of what is now known as Rolleston Avenue. This avenue includes some of the oldest trees, planted originally by Mr. Barker. The chestnut-trees from Worcester Street to Gloucester Street are especially beautiful during the flowering season. It is worthy of record that this avenue occupies ground that was originally marked off as a reserve for a mill-race to extend from the river at Armagh Street to the river at the Hospital grounds, and it is occasionally referred to in the early minutes as a "canal reserve." This plan of forming a canal was soon dropped, and on application from the City Council the "canal reserve" was formed into a footpath.

In 1876 it was decided to replace the more common cork-bark elm and ash trees growing in South Park opposite the Saleyards with English elm and *Pinus radiata*, the latter to act as nurses. These latter have been cut down for some years, and the English elms are left.

The grove of trees between the South Bridge and the Riccarton Road was in 1902 named the Harman Grove, in memory of Mr. R. J. S. Harman, who had rendered valuable assistance to the Board for the many years during which he had served as chairman.

In 1904 Mr. M. Murphy suggested the appropriation of 3 acres between Victoria Lake and Armagh Street as a plot for making a collection of hardy trees and shrubs of Australia, but his proposal does not appear to have been acted upon.

Beyond this the minutes make no further record of planting trees in the parks, but much attention has been paid to the proper care of those already planted. These have been pruned or thinned out as need arose, often amid cries of vandalism from the critics who thought they knew better than those whose work it was to attend to these matters. The trees of avenues and plantations to-day, however, are for the most part in a healthy condition, many of them adding greatly to the beauty of the city reserve. The lime avenue of the South Park and the Oriental plane avenue of the North Park and the Rolleston Avenue are especially worthy of mention.

The rest of the area of the Park, excluding the trees and the potato patches, is pasture-land suitable for sheep. The greater proportion of the plants to be found there at the present day are therefore introduced grasses and fodder plants. Chief among the introduced grasses are species of *Agrostis*, *Festuca*, *Lolium*, *Dactylis*, *Cynosurus*, &c., together with many of the more useless grasses, such as species of *Holcus*, *Bromus*, and *Hordeum*. This latter (*H. murinum*) has spread considerably in certain parts, notably in the pine plantation to the north of Victoria Lake. Amongst the leguminous plants can be found several species of *Trifolium* and *Medicago*. The common crucifiers *Capsella* and *Sisymbrium*, the composite *Achillaea millefolium*, and the ordinary composite weeds *Senecio, Cnicus, Taraxacum*, &c., are abundant. *Plantago major, Polygonum Convolvulus*, and *Rumex* spp. are present, while in one portion the lupin is gaining ground.

Most of these weeds belong to the class of plants that occur in any waste land, or in permanent-pasture land that is left to itself for any length of time. Their fruits or seeds are easily carried by wind or animals from one place to another. In some cases they were probably introduced as impurities of the grass-seed sown.

More important for the purpose of this paper is the record of the indigenous plants that have been collected in the Domain or Parks from time to time. Such lists naturally exclude all indigenous plants that may have been planted purposely, such as those that are found in the native sections of the Domain. Only those that from their position now may be considered to have formed part of the original flora of the reserve will be mentioned in these lists. A comparison of their contents will give some idea of the ability of New Zealand plants to hold their own in the face of the European intruders, and of their prospective ultimate fate in the struggle for existence.

The published records are very scanty, but I am deeply indebted to Mr. J. B. Armstrong for permission to use a list he made in 1864 of the indigenous flora of Hagley Park and Domain, a list which has hitherto been in manuscript only. This is given below (list A).

The first reference to the plants is that given above* in the description of the vegetation through which the pioneer party had to force a way, and probably it is descriptive rather of the country lying farther to the west of Hagley Park, though some of the plants would be common in the Park. The "fern" would be the common *Pteridium esculentum*, or bracken, found in all waste places on the Plains. The "tutu," *Coriaria sarmentosa*, used to be found in patches along the river. The "tussock," *Poa caespitosa*, is still to be seen in certain parts of North Park. The "bramble," a term applied usually to the various species of *Rubus*, has not been recorded actually from the Park. The "spaniard," *Aciphylla squarrosa*, has disappeared only recently.

This casual reference dealt only with the more prominent constituents of the flora; the smaller herbaceous plants, not causing any trouble to the pioneers, were not noticed at all.

The next list in point of time is that supplied by Mr. J. B. Armstrong, which gives the names of the plants present in both Park and Domain in 1864. The Domain was at that time in the same uncultivated state as the Park—in fact, it was in a more natural state than the South Park, which had been cropped before that date, with the consequence that it was rather poor in native plants. In some cases where the names given by Mr. Armstrong differ from those in Cheeseman's *Manual* the latter are given also in square brackets, as are also some additions. The species marked with an asterisk are given by Mr. Armstrong, and have therefore been included in the list, though some authorities express a little doubt as to the correctness of the identification.

* *Canterbury Old and New*, p. 50.

List A. Indigenous Flora of Hagley Park and Domain, Christchurch, in 1864.

TREES.—None.

SHRUBS.

	Locality.
Coprosma robusta Raoul	River bank.
Leptospermum scoparium Forst.	A few in the Domain.
Discaria toumatou Raoul	Dry shingly spots.
Coriaria ruscifolia L.	In patches along river.
Olearia virgata Hook. f.	A few in Domain.
Veronica salicifolia Forst.	Common along the river.

HERBACEOUS PLANTS, FERNS, ETC.

Clematis marata Armstrong	Abundant on *Discaria*.
Ranunculus hirtus B. & S.	River-bank.
R. rivularis B. & S.	Swamp (now Victoria Lake).
R. sessiliflorus R. Br. [probably introduced] ..	Sandy spots, North Park.
Cardamine hirsuta DC. var. *a.*	River-bank.
Viola Cunninghamii Hook. f.	Swamp.
Hypericum japonicum Thunb.	Sandy spots, North Park.
Geranium dissectum L. var.	River-bank.
Pelargonium clandestinum L'Herit. [= *P. australe* (Cheeseman)]	Common in Domain and parks.
Carmichaelia nana Col.	Common in shingly places in Domain.
C. flagelliformis Col. [*C. subulata* T. Kirk] ..	Grassy places.
Potentilla anserinoides Raoul [*P. anserina* var. *anserinoides*]	Swamp.
**Geum magellanicum* Comm. [= *G. urbanum* (Cheeseman)]	Swamp.
Acaena Sanguisorbae Vahl.	Sandy spots, North Park.
**Drosera dichotoma* B. & S. [= *D. binata* (Cheeseman)]	Swamp.
Haloragis alata Jacq.	River-bank.
H. depressa Hook. f.	Shingly places, North Park.
Myriophyllum elatinoides Gaud.	In river.
M. variaefolium Hook. f. [= *M. intermedium* DC. (Cheeseman)]	In river.
Callitriche stagnata Scap. [= *C. verna* L. (Cheeseman)]	Swamp.
Epilobium nummularifolium L.	Wet spots.
**E. alsinoides* A. Cunn.	Swamp.
E. microphyllum A. Rich.	Dry sandy spots.
E. junceum Forst.	Dry places.
E. Billardierianum Ser.	River-bank.
Hydrocotyle asiatica L.	Swamp.
H. novae-zealandiae DC.	Wet places.
H. moschata Forst.	Swamp.
**Crantzia lineata* Nutt.	Wet places.
Aciphylla squarrosa Forst.	North Park.
Galium umbrosum Forst.	River-bank.
Celmisia longifolia Cass.	Swamp.
Lagenophora Forsteri DC.	Dry places, North Park.
Cotula dioica Hook. f.	Wet places.
C. squalida Hook. f.	Wet places.
Raoulia Monroi Hook. f.	North Park, near lake.
Gnaphalium filicaule Hook. f. [= *Helichrysum filicaule* (Cheeseman)]	North Park.
G. involucratum Forst. [= *G. japonicum* (Cheeseman)]	Wet spots.
G. collinum Lab.	Dry sandy spots.
Erechtites quadridentata DC.	North Park.

	Locality.
Microseris Forsteri Hook. f.	Common in moist sand.
**Sonchus asper* Hill	River-bank.
Wahlenbergia gracilis DC.	Common in all parts.
Leucopogon Fraseri A. Cunn.	Loose sand, North Park.
Myosotis sp., undescribed, with yellow flowers [probably *M. australis* R. Br.]	..
Solanum nigrum L.	Common; probably not native.
Mentha Cunninghamii Benth.	Wet places.
Plantago Raoulii Decaisne	Dry sandy places.
Scleranthus biflorus Hook. f.	Dry loose sand (Wonderland).
Urtica incisa Poir.	Common on river-bank, Helmore's Plantation.
Microtis porrifolia R. Br.	Common in Domain.
Pterostylis Banksii R. Br.	Swamp only.
Thelymitra longifolia Forst.	Common in dry places.
Lemna minor L.	In water.
**Bulbinella Hookeri* Benth.	Along Washbourn's Creek.
**Anguillaria novae-zealandiae* Hook. f. [= *Iphigenia novae-zealandiae* (Cheeseman)]	Shingly spots.
Juncus australis Hook. f. [= *J. vaginatus* (Cheeseman)]	Wet places.
J. communis L. [= *J. effusus* (Cheeseman)]	Swamp, &c.
J. bufonius L.	Wet places.
**J. planifolius* R. Br.	Swamp.
J. novae-zealandiae Hook. f.	Damp sand.
**Lepidosperma tetragona* Lab. (?) [perhaps *Eleocharis* sp.]	River-bank.
Carex secta Boott.	River-bank.
C. ternaria Forst.	Swamp.
Hierochloe redolens R. Br.	River-bank.
Dichelachne crinita Hook. f.	Both parks.
**Agrostis parviflora* R. Br.	Both parks.
A. aemula R. Br. [= *Deyeuxia Forsteri* Cheeseman]	Both parks.
Arundo conspicua Forst.	River-bank and swamp.
Danthonia semiannularis R. Br.	Both parks.
Deschampsia caespitosa Pal.	Both parks.
Trisetum antarcticum Trin.	North Park.
Poa caespitosa Forst.	Common all over.
Poa n. sp. with purple glumes	Domain only.
Triticum scabrum R. Br. [*Agropyrum scabrum* Beauv.]	Common in both parks.
Ornithopteris esculenta Agardh. [= *Pteris aquilina esculenta* Ch., *Pteridium esculentum*]	Domain.
Lomaria procera Spreng [= *L. capensis* (Cheeseman)]	Along the river.
L. minor Spreng. [a var. of *L. capensis*]	River-bank and swamp.
Ophioglossum lusitanicum Willd.	Domain.
**O. minimum* Col.	Domain only, very rare.
**O. vulgatum* L.	Common throughout.
Botrychium australe R. Br. [= *B. ternatum* (Cheeseman)]	South Park, common.

This list notes the presence in the Parks and Domain of some eighty-eight indigenous plants, and it is interesting to compare it with the list given below of the native plants that have been noticed in the Parks during the last two years. The two areas richest in New Zealand plants at that time were the big swamp, destroyed later with all its indigenous flora to form Victoria Lake, and the stretch of sandy ground on which the Wonderland of the 1906 Exhibition was built. In both cases the plants that once flourished there are gone for ever.

Mr. T. H. Potts (*Out in the Open*, p. 112) records the occurrence of the fern *Botrychium ternatum* from the Hospital grounds: "Very handsome examples have been got from the space lying between the Christchurch Hospital and the River Avon. Old settlers will remember that the situation is, or was, rather, of a moist character: the fronds of the plants from this spot displayed a fine decompound habit." Farther on the same writer records the abundant occurrence in former days of *Ophioglossum vulgatum* about the North Town Belt, and, as seen from Mr. Armstrong's list, it was common throughout the Parks and Domain. It is possible that a close search might reveal its presence even now.

Dr. Chilton has kindly handed over to me a list of some of the native plants growing in North Hagley Park that were noticed by himself and Dr. Cockayne. The list bears the date of the 12th July, 1905. It is as follows: *Poa caespitosa* Forst., *Carex ternaria* Forst., *C. virgata* Sol., *Juncus communis* E. Meyer., *Muehlenbeckia axillaris* Hook. f., *Tillaea verticillaris* DC., *T. Sieberiana* Cheeseman, *Carmichaelia subulata* T. Kirk, *Geranium sessiliflorum* Cav., *Callitriche verna* L., *Aciphylla squarrosa* Forst., *Raoulia Monroi* Hook. f., *Cotula dioica* Hook. f., *Leucopogon Fraseri* A. Cunn.

This does not claim to be a complete list, but is interesting as affording additional evidence of the comparatively recent presence of *Aciphylla squarrosa*, *Raoulia Monroi*, *Muehlenbeckia axillaris*, and *Leucopogon Fraseri*, none of which can be found there now.

Strangely enough, a few patches of *Muehlenbeckia axillaris* are establishing themselves in the front lawn of the Domain. As this was all ploughed up and resown a few years ago, the appearance of this plant must be quite accidental, and cannot be regarded as a survival of the original flora, though it was doubtless present then.

The only other mention I can find of New Zealand plants in Hagley Park occurs in Laing and Blackwell's *Plants of New Zealand*, 1906. On page 216, in connection with the description of *Oxalis corniculata*, a brief list is given, excluding monocotyledons. The list is as follows: *Oxalis corniculata*, *Carmichaelia flagelliformis*, *Ligusticum* (*Aciphylla*) *Colensoi*, *Raoulia Monroi*, *Geranium microphyllum*, *Muehlenbeckia axillaris*, and *Cotula speciosa*. Of these, only *Oxalis corniculata* and *Carmichaelia flagelliformis* are found now, and it is possible, as Mr. J. B. Armstrong says, that the *Oxalis* is the introduced form, not the original New Zealand form of the species. It is, as Mr. Laing states, common in many of the lawns right in the centre of the city, and may have been introduced as an impurity in the grass-seed sown.

Of the other plants which have since been lost, both *Raoulia Monroi* and *Muehlenbeckia axillaris* were present on the sandy ground near the Armagh Street entrance before the 1906 Exhibition, but have not been seen since. *Aciphylla squarrosa* has since disappeared, and *Cotula speciosa* is very evidently a misprint, probably for *Cotula dioica*, which is still to be found in small quantities.

The accompanying list (list B), drawn up in 1918, for which I am indebted to Professor A. Wall, of Canterbury College, includes five species which were not actually found in the Park, but in its immediate vicinity, where freshly turned soil has provided a suitable opportunity for these natives to re-establish themselves, and in each case it is interesting to note that these plants occur in Armstrong's list. They are enclosed in parentheses. The species marked with an asterisk are present in very small numbers, in some cases only one plant being found.

List B.—New Zealand Plants found now in Hagley Park.

MONOCOTYLEDONS.

Gramineae :
Danthonia semiannularis, Poa caespitosa. Alepocurus geniculatus.
Cyperaceae :
Eleocharis acuta, E. Cunninghamii, Schoenus pauciflorus, Carex virgata, C. secta, C. inversa, C. ternaria, C. lucida.
Juncaceae :
Juncus pauciflorus, J. effusus, J. bufonius.
Orchidaceae :
(*Microtis porrifolia.*)
Polygonaceae :
**Muehlenbeckia complexa.*
Crassulaceae :
Tillaea Sieberiana.
Ranunculaceae :
**Ranunculus hirtus.*
Rosaceae :
Acaena novae-zelandiae.
Leguminosae :
**Carmichaelia subulata.*
Oxalidaceae :
Oxalis corniculata.
Callitrichaceae :
Callitriche verna.
Onagraceae :
*(*Epilobium Billardierianum*), **E. rotundifolium, E. nummularifolium,* **E. nerterioides,* (*E. novae-zelandiae*).
Haloragaceae :
**Haloragis erecta* [*H. alata* in Cheeseman's *Manual of N.Z. Flora*].
Umbelliferae :
Hydrocotyle novae-zelandiae, H. moschata, **H. asiatica.*
Convolvulaceae :
Dichondra repens.
Campanulaceae :
*(*Pratia angulata*), **Wahlenbergia gracilis.*
Compositae :
Gnaphalium luteo-album, **G. japonicum, Cotula australis, C. dioica.* **Erechtites prenanthoides.* *(*E. quadridentata*).

A comparison of these two more or less complete lists reveals some rather interesting changes. The only grasses common to the two are the tussock *Poa caespitosa* and *Danthonia semiannularis*: the others of list A are not recorded in list B, though it is possible that the species of *Agrostis* may have escaped notice. The little species *Poa Lindsayi* has established itself on the edges of the old native section. It cannot be definitely stated in this case whether it is reasserting itself or whether it has been introduced with some of the plants that have been transplanted from other parts. It may possibly be the same as the "poa with purple glumes" mentioned in list A. The Cyperaceae are represented in list A by three species, including only two species of *Carex*, against five species in list B. The Juncaceae, again, have five representatives in list A and only three in list B, two of them being common to both. No member of the Orchidaceae is actually found in the Park now, though *Microtis porrifolia* was discovered on the roadside quite near. Mr. Armstrong records that two species, *Microtis porrifolia* and *Thelymitra longifolia*, were common, and that *Pterostylis Banksii* was found in the swamp, which in his description of the localities always refers to that swamp now the site of Victoria Lake. He does not remember ever coming across any species of *Muehlenbeckia complexa*, which, therefore, never formed a prominent member of the primitive vegetation of this district. It is represented now by only one rather sickly-looking specimen on the side of the ditch at the extreme south of South Park, and its presence there may be accidental. All the shrubs given in list A have disappeared, unless a small plant of *Coprosma robusta* is excepted. This was considered to be a garden escape. With the *Discaria* has gone *Clematis marata*, which is usually found in closest association with it. Of the Ranunculaceae only *R. hirtus* is left, and it is found in only one place in South Park and is in danger of extinction. *Carmichaelia subulata*, represented at most by two plants, is also in like danger, its palatability to sheep having proved inimical to its prolonged existence; in fact, it is only very occasionally that it can be found, owing partly to its position amongst the long grass, but chiefly to its being so frequently eaten down. The *Oxalis* has already been mentioned. Mr. Armstrong did not consider the species present in the Park to be the native one. *Epilobium Billardierianum* was found in the Park, according to list A. In list B it is recorded as being found outside the actual boundaries of the Park, but is included in the list as one that probably occurred there originally. The three hydrocotyles occur on both lists. *Dichondra repens* is rather disappointingly absent from list A. It occurs on list B, and is found in great abundance on a waste sandy rise in the Helmore Plantation. It flourishes there to the exclusion of all other plants, introduced and native, its creeping stems enabling it to claim fresh ground in ever-widening rings each year. It is still found on the Port Hills in many parts, and is also found as a rather troublesome weed in many gardens and lawns. Its presence may have been overlooked by Mr. Armstrong when he was compiling his list, or it may have been overshadowed by other larger plants which have since from various causes died out, leaving the territory free for this tenacious little plant. It is hardly likely that it was absent altogether from the original vegetation, seeing that it is so prevalent in other places. It is interesting to see that *Gnaphalium japonicum* was once more abundant than it is now, when it is represented by only one plant, at the side of Washbourn's Creek, and is at different times eaten down and hard to find. *Wahlenbergia gracilis* is now very difficult to find, but was once very common, as it still is on the Port Hills and in other places.

A comparison of these plants with those still found in areas which presumably were covered by similar vegetation reveals the absence of some that might quite pardonably have been expected to persist. For instance, the small grass *Triodia exigua* is found on the Waimakariri River bed, which greatly resembles the soil condition of certain parts of Hagley Park. *Carmichaelia nana* is also common in the same locality, but apparently quite absent from the Park.

The question arises as to the ultimate fate of these few natives that have managed to hold their own through so many vicissitudes. Will they all continue to maintain their existence in the struggle, or are they doomed to extinction? Those that are palatable to the stock grazing in the Park and are also accessible to them are probably doomed: these are the *Carmichaelia*, *Haloragis*, *Gnaphalium japonicum*, and *Erechtites*. Others which fortunately possess some property rendering them distasteful to the grazing-animals, or which are provided with some means of vegetative propagation, or with seeds which are easily distributed, will continue to flourish unless actually uprooted and destroyed. The tussock is proof against most things save fire and cattle: the rushes and sedges flourish where damp conditions prevail, and are safe round the margins of the lakes; the *Acaena* and *Epilobium* are provided with easily distributed seeds: the habit of the cotulas is a useful one in elbowing out competitors: and the acrid juices of the hydrocotyles protect them from the horses which are at present their only enemies.

The fact that our native flora does disappear before European plants has been recorded more than once. In 1875, in his *New Zealand Handbook*, Julius Vogel states that "the lower hills, especially of the Peninsula, were rapidly covered with English grass and clover, which spread of their own accord, rapidly killing the native pastures" (p. 127). The reasons for this are not hard to find. In 1882 Mr. T. F. Cheeseman gave some of them in his paper "On Naturalized Plants of Auckland District" (*Trans. N.Z. Inst.*, vol. 15, pp. 268–98). He points out that the advent of European settlers introduced a set of conditions injurious to the indigenous fauna and flora. They destroyed the vegetation to make room for houses, roads, &c. They introduced herbivorous animals, such as sheep, cattle, horses, which rapidly ate down all plants that they found palatable. These might struggle against such treatment for a longer or shorter time, but in the end they perished from this continual cropping, and their place was taken by plants protected in some way from the attacks of animals, either by the possession of thorns or acrid juices, or by others which were able to exist when eaten. Examples of such plants among the natives would be *Discaria*, *Poa*, *Danthonia*, &c. Then, again, the practice of burning large tracts of vegetation destroyed many of the natives, and the native flora had no plants which could take possession of fresh soil laid bare in any of these ways, whereas the European weeds found here an environment quite suited to them and for which they had been modified for many years.

When this is remembered it is astonishing not that we have so few native plants still remaining in our Park but that we have so many. Grazing-animals were introduced here almost at once: part of the Domain known as the "old pinetum" is the site of an old deer-paddock. Pheasants and hares introduced by the Acclimatization Society worked havoc in Domain and Parks, and much damage was caused in early days by pigs, while sheep have been grazing continuously for sixty-nine years.

An interesting experiment, suggested by Professor Wall, would be the enclosure of a suitable portion of the Park where the native plants should be given every opportunity of living under conditions as similar as could be obtained to those originally existing in the Park. European weeds should be removed, and native plants now no longer found in the Park but originally growing there should be obtained from such places as the Waimakariri River bed and encouraged to grow in this enclosure. The number of plants that could re-establish themselves under these conditions could then be determined. The place need not be an eyesore to the general public, and the horse-paddock now existing would be a very suitable site for such an experimental plot. Needless to say, the scientific value of such an experiment would be very great.

In conclusion, the writer wishes to thank all those who have given assistance in many ways during the preparation of this paper: Dr. Chilton for his advice and encouragement, without which the paper would not have been undertaken: Mr. James Young and Mr. W. F. Hilson for permission to consult the minute-books of the Domain Board; Mr. J. B. Armstrong for much valuable information regarding the past history of the Gardens and Park and for the list of native plants; Professor A. Wall for his painstaking search for the native plants now present in the Park; Messrs. J. C. Andersen, R. Speight, W. D. Andrews, and R. M. Laing for help of other kinds.

ART. XXXIX.—*A New Discoglossoid Frog from New Zealand.*

By ALLAN R. McCULLOCH, Zoologist, Australian Museum.

[*Read before the New Zealand Institute, at Christchurch, 4th–8th February, 1919; received by Editor, 11th February, 1919; issued separately, 26th August, 1919.*]

Plate XXX.

Liopelma hamiltoni n. sp.

General form moderately robust. The width of the head is equal to its length from the tip of the snout to the nuchal constriction. Snout rounded, flattened above; the profile anterior to the nostrils very oblique. Nostril midway between the tip of the snout and the eye. Canthus rostralis moderately distinct; loreal region flat and very oblique. The eye is shorter than the snout, and the diameter of its opening is a little

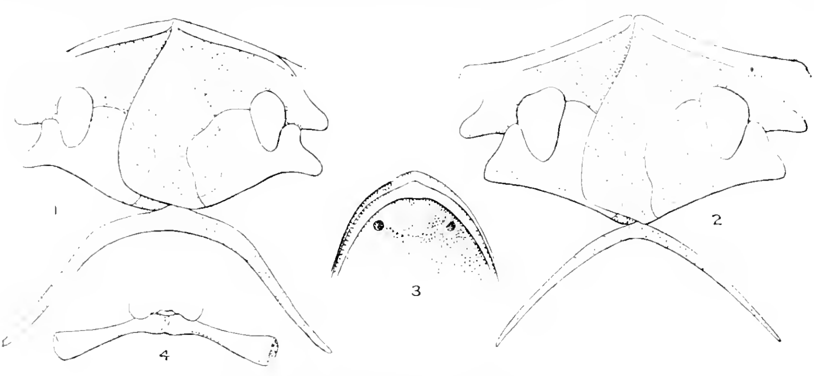


FIG. 1.—*Liopelma hamiltoni*, sternal apparatus.
FIG. 2.—*L. hochstetteri*, sternal apparatus.
FIG. 3.—*L. hamiltoni*, roof of mouth.
FIG. 4.—*L. hamiltoni*, sacral diapophyses.

greater than its distance from the nostril. Narrowest interorbital space about one-third greater than the width of the upper eyelid. No tympanum. A dorso-lateral ridge extends backwards from behind the eye to above the abdomen, and is interrupted above the insertion of the arm. Mandible pointed at the symphysis. Tongue much narrower than in *L. hochstetteri*, its width little more than half that of the mouth; posterior end of the tongue almost completely united with the floor of the mouth. Vomerine teeth consisting of series of about six granules situated upon two ridges: these are separated on the median line of the palate, and are situated between, or slightly behind, the choanae, as in *L. hochstetteri*.

Fingers longer than in *L. hochstetteri*, the first shorter than the second: each palm with a large inner and a small outer metacarpal tubercle. The tibio-tarsal articulation reaches the nostril when the hind leg is carried forward along the side of the body. Toes longer than in *L. hochstetteri*, webbed at the base; a small, flat inner metatarsal tubercle is present.

Subarticular tubercles of fingers and toes distinct. The skin is nearly everywhere smooth, though there are some scattered tubercles on the proximal portions of the thighs and shanks. No omosternum: sternum (fig. 1) two slender diverging cartilaginous styles, and of similar formation to *L. hochstetteri* (fig. 2): the left epicoracoid cartilage overlaps the right in both species. Diapophyses of sacral vertebra (fig. 4) subcylindrical basally, and slightly expanded distally. Short ribs articulate with the anterior diapophyses.

Colour. Light brown in life, with irregular darker and lighter marbling on the upper surfaces. A black band extends from the tip of the snout to the nostril and thence to the eye; it is continued backwards towards the sides below the dorso-lateral ridge. The limbs are marked with oblique black cross bands, which are most prominent on the thighs. Under-surfaces with greyish mottlings.

The foregoing description is based upon a specimen 42 mm. long from the snout to the vent; it is the example figured in Plate XXX, and is selected as the holotype. A second specimen about the same size, and collected with the first, was dissected to examine the internal characters.

Variation.—Two other examples, received in alcohol, differ only in being somewhat more uniformly coloured, their black markings being more or less obscure.

Identity.—This species differs from *L. hochstetteri* not only in its more slender form, but in having much longer fingers and toes, the webs of which are more reduced than in that species. The tongue is narrower and not so free posteriorly.

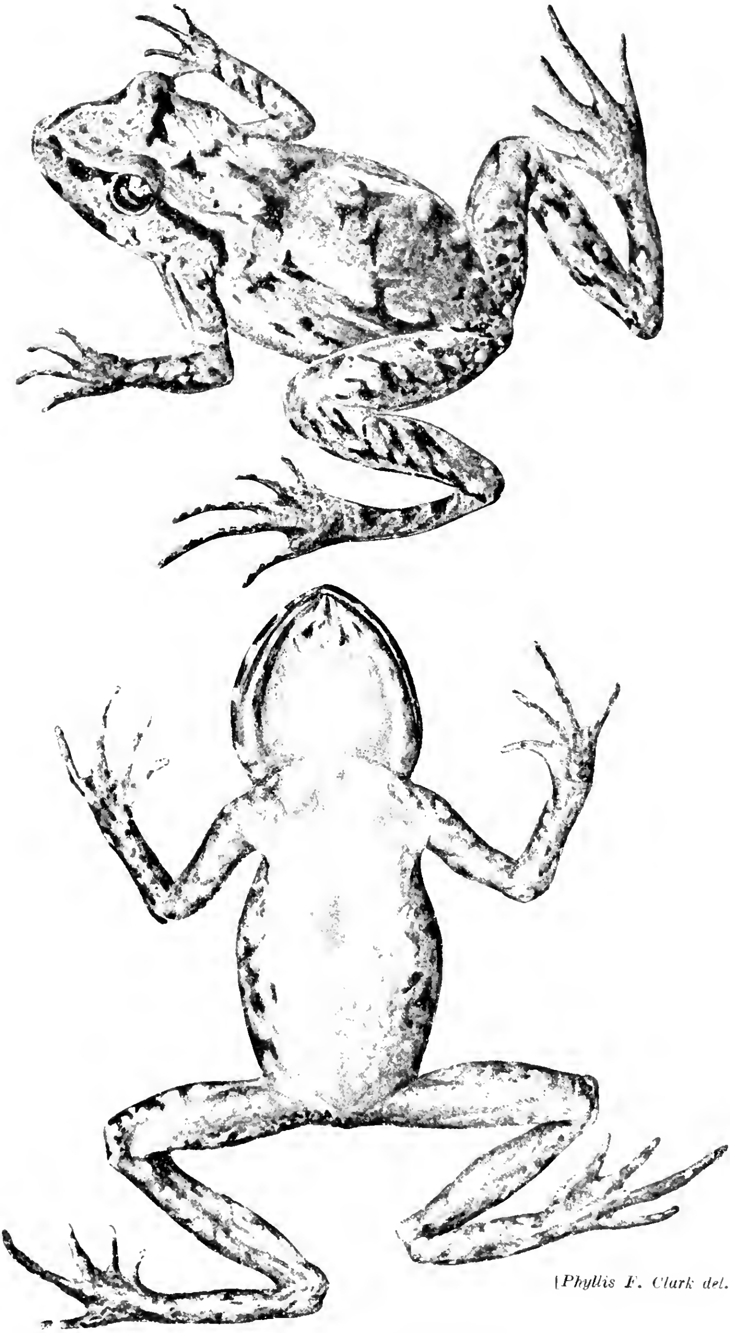
The holotype and paratype are deposited in the Dominion Museum, Wellington.

Habitat. Stephen Island, Cook Strait.

I am indebted to Dr. J. Allan Thomson for the privilege of describing this interesting new species, which is named after its discoverer, Mr. Harold Hamilton.

Supplementary Note by Charles Hedley, F.L.S., Australian Museum.

This interesting addition to the fauna of New Zealand was discovered by Mr. Harold Hamilton on Stephen Island, at the north-west extremity of Cook Strait. This small island is also noteworthy as a refuge of the tuatara, or *Sphenodon*. Dr. J. Allan Thomson subsequently visited the island and obtained further material. After several days of fruitless search, fourteen specimens were found crowded under a large heap of stones. As it was in July, Dr. Thomson suggested that this party may have been hibernating. During the winter there are a few streams on the island, but in summer all the surface water disappears. This suggested to Dr. Thomson that possibly the *Liopelma* is viviparous. On the other hand,



[Phyllis F. Clark del.

Liopelma hamiltoni n. sp.

Face p. 448.]

some interesting modifications in the development of this frog may occur, such as is exhibited by the Australian *Pseudophryne*,* of which the hatching of the ova may be postponed for a period of at least three months when dry conditions prevail.

According to A. S. Thomson,† *L. hochstetteri* also hides under stones. He found that it was so rare and of such retiring (perhaps nocturnal) habits that even the Maoris were not acquainted with it. Possibly this habit of close concealment was engendered by escaping from the voracity of the moas.

The vertebrate fauna of New Zealand has always been regarded as one of fascinating interest. At the first glance the poverty of reptiles and the complete absence of mammals appear to indicate that New Zealand has never held direct intercourse with any continent—that, in biological phrase, New Zealand is "oceanic" rather than "continental." Such a conclusion is, however, vigorously combated both by the fauna as a whole and by the varied and well-developed flora. "No other country on the globe," wrote Wallace, "has such an extraordinary set of birds." And returning to the reptiles, though the brief records enumerate no snakes and only one frog and fourteen lizards, yet the presence of the *Sphenodon* alone confers on the New Zealand fauna a distinction lacking in many with a far longer roll-call.

Thus the quality of the New Zealand reptilian fauna makes amends for its quantity, and establishes the fact that land communication once really did exist between it and the outside world. But the old fashion of those few inhabitants implies that the date of such traffic was a remote one. When large problems depend for their solution upon scanty data, science is athirst for every drop of information, and so the discovery of a second indigenous frog is of special interest.

The discoglossoid frogs form a small, compact group remarkable for their primitive structure and for a disconnected distribution, discordant with usual faunistic associations. Stejneger‡ considers that their original home was to the south-east of the Himalayas, and that in early Cretaceous times the discoglossoids radiated thence to New Zealand, to western America, and to western Europe. But central Asia can have had no relations or direct communication with New Zealand. As the mass of the Australian Amphibia arrived there from South America via Antarctica, it is now suggested that, whether originally Asiatic or Neotropical, *Liopelma* had a similar history. Together both the frog faunas of Australia and of New Zealand might have arisen in South America, both escaped by a southern outlet—the one to New Zealand, the other to Australia—and by the eastern door of "Arch-helenis" both may have been admitted to the Mediterranean region by way of north-west Africa, and thence to Asia. But the difference between the Discoglossidae of New Zealand on the one hand and the Australian Hylidae and Cystignathidae on the other would then imply that the different migrations flowed at different periods and perhaps by different channels to New Zealand and to Tasmania respectively.

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* J. J. Fletcher, *Proc. Linn. Soc. N. S. Wales*, vol. 2, p. 379, 1889.
† A. S. Thomson, *Edinburgh New Philos. Journal*, vol. 55, pp. 66–69, 1853.
‡ L. Stejneger, *Bull. Am. Geogr. Soc.*, vol. 37, p. 9, 1905.

Art. XL.—*Terminology for Beak and Foraminal Development in Brachiopoda.*

By S. S. Buckman, F.G.S.

Communicated by Dr. J. Allan Thomson.

[*Publication authorized by the Publication Committee under Regulation 5, (a), (2); issued separately, 26th August.*]

The previous communication made by me on this subject, entitled "Terminology for Foraminal Development in Terebratuloids (Brachiopoda)," which appeared in the *Transactions of the New Zealand Institute*, vol. 48, 1916, pp. 130–32, seems to have provided terms which are found to be useful and convenient. It has also received commendatory notice in *Revue critique de Paléozoologie*, 1918, pp. 37–39, though the writer of the review has fallen into an error which may be misleading. For these reasons I am tempted to pursue the subject somewhat further.

The error committed by the writer in question is this: He says (p. 38). "M. Buckman a indiqué graphiquement la position du foramen circulaire par rapport à la ligne de séparation des valves." This is a complete misunderstanding of the little diagram in my paper. The position of the foramen is not indicated with regard to "the line of separation of the valves," but in regard to the line of the beak-ridges (*la ligne des carénes laterales du crochet*)—quite a different matter. The line of the beak-ridges is the convenient and necessary datum-line for the purpose, and it is this line which is represented by the horizontal lines in my diagram. This line of the beak-ridges separates a more or less defined area, the pseudo-area or cardinal area of the ventral valve.

There is another little matter for notice in this quotation. The circular foramen is not a necessity in regard to these terms. That the foramen was indicated by a circle was only a matter for convenience in printing. The position of the foramen is one observation; the shape of the foramen is another—quite distinct; and the condition of the foramen is a third. These must be kept separate, for all sorts of combinations are possible.

The shape and some of the developmental phases of the foramen come under the terms "trigonal," "subtrigonal," "elliptical," "circular," and so forth—see my memoir, "The Brachiopoda of the Namyau Beds," *Palaeontologia Indica*, n.s., vol. 3, part 2, 1917 (1918); but other terms, like "obtrigonal,"* "oblong," "trapezoid," &c., will be required. The condition of the foramen I have described by such terms as "telate," "marginate," "auriculate," "attrite," "labiate," "renovate." Some of these conditions are found only with the hypothyrid position, others belong to the mesothyrid in the main or to the epithyrid. Particulars are given in the work above quoted under the headings of "Rhynchonellidae" and "Terebratulidae," but I am unable to cite the page-numbers, as the only copy which has yet reached me is at the binder's.

Returning now to the position of the foramen, it may be desirable to have terms by which to indicate its position in regard to the line of the

* With apex pointing anteriorly.

valve-junction; but before proposing these it is advisable to consider the general course of development which has led to the specialized foramen of the Telotremata: it is to such foramens that the various terms hitherto proposed apply.

(1.) The pedicle-opening or delthyrium is unmodified, and is therefore in area coextensive with what may be called an opening or foramen.

(2.) The pedicle-opening is modified by the growth of various plates, so that the area of the foramen is less than the area of the delthyrium.

(3.) The pedicle-opening moves, as new test is deposited, away from the apex towards the posterior margin, and the abandoned track is closed by a plate called a "listrium" (Discinacea).

(4.) The pedicle-opening moves in the opposite direction, out of the delthyrial area, by the pedicle gradually absorbing the apex. This is the development found in submesothyrid to epithyrid Telotremata.

Now, as the modifications of the foramen take the form of constricting the area or a shifting of position, it may be seen that the terms "Neotremata," and so forth, which suggest something bored out, are not altogether appropriate. Only in the last case, where old test is removed, is there anything like the process of boring. Closing up a space so as to reduce a hole is something quite distinct from boring out. However, that point is not for consideration now.* What has to be dealt with is what may be called the character of the foramen.

When the foramen and the delthyrium correspond the foramen might be said to be *delthyrid* in character. When the foramen is less in area than the delthyrium, by the growth of various plates which modify the delthyrial opening, then the term *constricted foramen* seems appropriate. When the foramen is shifting or has shifted its position more or less out of the delthyrial area, then the foramen is in its character *migrant* or *migrate*, as the case might be. The mesothyrid Telotremata have migrant foramens, and the epithyrid, migrate. When the foramen moves as new territory is developed it may well be called *emigrant*, and when it goes to take up old territory—the Terebratuloids—it could quite well be said to be *immigrant*.

Using the term "foramen," therefore, in the above general sense as the pedicle-opening, which in character may be unmodified, modified, or migratory, it is necessary to define its position with regard to the line of the valve-junction. It is situated in the ventral valve, and the obvious term would be

Gastrothyrid (γαστήρ, belly). All the position-terms, "hypothyrid," "mesothyrid," "epithyrid," relate to and are more precise locations of the foramen in gastrothyrid Brachiopoda.

If the foramen were situated in the dorsal valve, then the term would be

Notothyrid (νῶτος, back). I know no such case; but according to the statement in the review above noticed the hypothyrid position would be notothyrid. It is, however, gastrothyrid, and hypothyrid because under the apex.

Then there are cases in which the foramen is situated at the junction of the two valves, part of the foramen being in each valve. For this it is not so easy to obtain a suitable term, but I would suggest

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* It might be suggested, however, that "Eotremata" would be preferable to "Atremata," understanding τρῆμα in the sense of opening.

Symbolothyrid (from συμβολή, the part that meets, the joining, the end).* Symbolothyrid is the foraminal position in many Atremata, in early forms of the Telotremata, and is also found in *Platystrophia*. "Coenothyrid" (from κοινός, shared in common) also suggests itself, but would have to be rejected to prevent confusion with *Coenothyris*. it would be inadvisable to have to say that *Coenothyris* was not coenothyrid but gastrothyrid. In regard to the symbolothyrid foramen there is the possibility of its greater portion being in one valve and the lesser part in the other. Such cases could be described as symbolothyrid inclining to gastrothyrid or to notothyrid, as the case might be.

Some special developments in the structure and conditions of the foramen now seem to merit distinctive terms. The foramen is in the form of a tube extending into the valve: the shell is therefore

Siphonothyrid (σίφων, a tube), as in the Siphonotretidae and in *Syringothyris*. A siphonothyrid shell is to be distinguished from one in which the whole beak projects forwards as a little tube well separated from the dorsal umbo. This is a case of a *tubular* beak, and is found, for instance, in *Terebratula wrighti* Davidson, of the Bajocian, to which I have given the generic name *Tubithyris*.† A greater development still of the tubular beak is seen in *Lyra meadi* (*Terebrirostra*), where the beak is produced into a long pipe. This may be termed a *fistulate* rostrum or beak (*fistula*, a pipe). It is the whole beak which is under observation, not merely the foramen; that, I expect, is epithyrid attrite, but I have no example of this interesting and rare shell.

Cryptothyrid (κρυπτός, hidden) is a term now suggested to denote a foramen hidden or concealed by the beak, as in the case of *Athyris*, which originally obtained its name (α, not; θυρίς, foramen [window]) because it was supposed that it lacked a foramen. It is quite possible that the pedicle was almost functionless.

In *Productus* the pedicle certainly was functionless, the foramen being more or less sealed up, the animal having no need to use the pedicle, as it could anchor itself by its long spines. For this condition the term

Clistothyrid (κλειστός, shut up) seems suitable. I would prefer to write it "cleistothyrid," to signify that the first *i* is to be pronounced long, but such is not the rule that has been laid down.

I am under the impression that a minute *Rhynchonella* of the Upper Inferior Oolite to which I have given the name *Nannirhynchia*‡ is clistothyrid. The foramen seems to be closed, but observation in regard to this feature of so small a shell is difficult. This tiny shell has a hirsute test, sufficient, perhaps, to anchor so small an object.

A further development of the clistothyrid condition is when the foramen is not only closed with calcareous matter, but the shell is cemented down to the object of attachment. For this the term

Calcithyrid (*calx*, lime) seems obvious. Objections to it as a barbarism are sure to be made; but they neglect the fact that a word is for use first

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* I have already proposed for this position of the foramen the term *amphithyrid* (Brachiopoda, Australian Antarctic Expedition, 1911–14, *Scientific Reports*, ser. C, vol. 4, pt. 3, p. 20, 1918). Mr. Buckman, who has seen the manuscript of my paper, but is apparently unaware that it is published, writes that the name is not as happy as it might be, as the Greek αμφιθυρος means "with door or both sides, a double entrance," suggesting a foramen in each valve. As there is no definite law of priority in such terms, it is preferable to use *symbolothyrid*.—J. Allan Thomson, 25/6/19.

† *Records Geol. Surv. India*, vol. 45, p. 78, 1915.

‡ *Gen. Jur. Brachiopoda*, p. 2, 1914.

and for ornament afterwards. It is sure to be said that one should take the Greek word of similar meaning—χάλιξ—and write "chalicothyrid": but I am not in favour of this far more cumbrous and less obvious word. The Craniidae, Thecidiidae, and Richthofenidae are some of the cemented shells and are therefore calcithyrid. If it is urged that the development in the last-named is so much greater that it deserves distinction, then I make it a present of "chalicothyrid": it does seem rather to suit that family.

The above terms would seem to provide a ready means of describing some important aspects of beak and foraminal development. But there is a further case to be considered—the position of the foramen in shells which have considerable development of the cardinal area or its homologue the false cardinal area. Two terms for what is really the same feature are very unsatisfactory. There is some objection to calling this feature simply "the area," for that term is required for general use; but it might be termed the *interarea*, as being the area lying between the apex and the posterior line of valve-junction—the cardinal margin when there is a hinge, but at any rate the posterior margin. When there is lateral compression posteriorly by which areas are formed each side of the beak—shown, for instance, so well in *Rhynchonella plicatella*—then the term "areola," which is in use, seems unsuitable: for it is larger, not, as its name suggests, smaller, than the cardinal area. The term *planarea* seems advisable. There would thus be the interarea and the planareas; but the presence of the one would, I think, prevent the other appearing in the same shell: at least, the former is merged in the planareas.

With great development of the interarea the term "hypothyrid" for the position of a foramen in the interarea might not be sufficiently precise. It could be modified as "apically," "medianly," or "marginally" hypothyrid, as the case might be.

Mention of the apical position suggests that it is desirable to distinguish the rostrate shells which keep the apex and those which lose it: the former, like the Rhynchonellidae, would be shells with rostrum *apicate*: the latter, like Terebratuloids, with rostrum *truncate*. It has been usual to speak of the foramen as being truncate; but this is mainly from a consideration of the attrite foramen of the Terebratulids. But the attrite condition is expressive of the wearing-away of the tela—the points of the beak-ridges: and so it seems advisable to apply the term "truncate" to the rostrum as soon as the apex is excavated by the pedicle. The angle and the degree of such truncation, especially when combined with attrition, may vary very considerably—obviously through nearly 180 degrees. To meet such cases "subtruncate" or "undercut," "vertically," "obliquely," and "horizontally" truncate might suffice for general purposes. Words compounded of *in* and *re* are to be avoided; for properly the latter should apply to what goes backwards—that is, towards the dorsal valve. Too often the former has been used for such cases—the legacy of old teaching. *Peccavi!*

One other point is for consideration. When the pedicle has eaten through the apex and has attained the epithyrid position, or even before, it seems to have a tendency to return—to move back towards the dorsal valve again: it may be said to be in character *remigrant*. In such case it produces a labiate foramen with some recutting of the dorsal wall of the foramen. In such recutting points might be produced which resemble tela but are not true ends of beak-ridges, only projecting edges of foraminal rim: if so, they should be termed *pseudotela*, and the foramen would be *pseudotelate*. Further investigation of this matter is required, and perhaps may best be undertaken by those who have the opportunity to obtain and study fresh Recent specimens. With such material at hand notice might be taken of the part played by the pedicle in depositing test in the foramen. In the inside of the labium of fossil Terebratulids with labiate foramen may be found a tongue-shaped layer of test which one supposes to have been deposited by the pedicle: if so, this should merit distinction as the *pedicle-plate*, to be looked for in connection with a remigrant foramen. Then the question comes whether similar secretion by the pedicle has played any part in the fusing of the deltidial plates. To the fused deltidial plates as shown by Terebratulids I have given, in the memoir already mentioned, the name of *symphytium*, from the likeness to the closing-up of a wound. In some well-preserved epithyrid Terebratulids the middle area of the symphytium seems to be distinct, with very considerable resemblance to the pedicle-plate. And in some shells the symphytium seems to be composed entirely of this middle piece. Now, there arises the suspicion that this middle piece has been laid down at first in between, and later on the foraminal edge of, the coalescing deltidial plates. For if there was simple coalescence of the deltidial plates, growing together from the edges of the delthyrium, as they certainly do in hypothyrid Rhynchonellids with concrete deltidial plates, then the lines of growth should run longitudinally, more or less parallel with the diverging edges of the delthyrium. But in the piece under consideration the lines of growth appear as transverse rugosities—the transverse direction being what would be expected from deposition by the pedicle, and the rugosities being connected with the swelling and attenuation of the pedicle under muscular stimulus connected possibly with periodical variations of marine conditions.

Now, if such arguments be correct, the symphytium—the final closing of the deltidial plates—in epithyrid shells is to be distinguished altogether from the conjunct or concrete deltidial plates of hypothyrid shells. One should find, perhaps, in mesothyrid shells concrete deltidial plates united near the cardinal margin, but separated medianly (that is, the part nearer the apex), and, lying in this separation, the beginning of the symphytium with its transverse rugosities; and in epithyrid shells, a later development, perhaps only the symphytium, margined possibly by a relic of the deltidial plates.

To observe these details in fossil shells means much excavation, with results not always satisfactory, on account of defective preservation. One may hope that those who have the opportunity to examine Recent epithyrid shells may be able to supply further details.

PROCEEDINGS.

PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE.

MINUTES OF THE SIXTEENTH ANNUAL MEETING OF THE BOARD OF GOVERNORS.

WELLINGTON, 17TH JANUARY, 1919.

THE annual meeting of the Board of Governors was held in the Dominion Museum on Friday, the 17th January, 1919, at 10 a.m.

Present: Professor Kirk (in the chair), Mr. Aston, Mr. C. A. Ewen, and Mr. E. J. Parr.

Poverty Bay Institute. An application from the Poverty Bay Institute for incorporation with the New Zealand Institute, dated the 18th December, 1918, was received; and, on the motion of Mr. Ewen, seconded by Professor Kirk, it was resolved, That the Poverty Bay Institute having complied with the requirements of the New Zealand Institute Act and Regulations, and having applied for incorporation with the New Zealand Institute, their application is hereby granted.

Adjournment to Christchurch. On the motion of Mr. Parr, it was resolved to adjourn the meeting to Christchurch on the 1st February, 1919, at 10 a.m., the place of meeting to be Canterbury College.

CHRISTCHURCH, 1ST AND 3RD FEBRUARY, 1919.

The adjourned annual meeting of the Board of Governors was held in Canterbury College, Christchurch, on Saturday, the 1st February, 1919, at 10 a.m.

Present: Dr. L. Cockayne, President (in the chair); Hon. G. W. Russell (Minister of Internal Affairs), Mr. B. C. Aston, Mr. L. Birks, Professor C. Chilton, Professor T. H. Easterfield, Mr. M. A. Eliott, Dr. F. W Hilgendorf, Mr. H. Hill, Professor H. B. Kirk, Professor H. W. Segar, Professor A. P. W. Thomas, Hon. G. M. Thomson, Dr. J. A. Thomson.

Professor C. C. Farr, Dr. C. Chilton, and Mr. L. Birks on behalf of the Canterbury Philosophical Institute welcomed the members of the Board to Christchurch.

Apologies for non-attendance were read from Mr. C. A. Ewen (Hon. Treasurer), Mr. E. J. Parr, and Dr. P. Marshall.

The Secretary announced that the only change in the representation was that Professor T. H. Easterfield replaced Mr. G. Hogben as a representative of the Wellington Philosophical Society, Mr. Hogben having resigned. The Government representatives, Professor Chilton and Mr. Ewen, who retired this year, had been re-elected.

The minutes of the previous meeting, held on the 17th January, 1919, in Wellington, were read.

Poverty Bay Institute. The application of the Poverty Bay Institute, dated the 18th December, 1918, for incorporation with the New Zealand Institute being granted, on the motion of Professor Kirk, seconded by Mr. H. Hill, it was resolved, That the certificate of incorporation of the Poverty Bay Institute be signed by the President and the Hon. Secretary. It was then sealed and signed.

The Hon. the Minister of Internal Affairs, Mr. G. W. Russell, then addressed the meeting, and promised to increase the annual grant for the current year to the New Zealand Institute by £500, and bring in legislation to increase the statutory grant to £1,000 per annum. Dr. Cockayne thanked the Hon. the Minister, and, on the motion of Dr. J. A. Thomson, seconded by Mr. H. Hill, it was resolved, That a hearty vote of thanks be accorded to the Hon. Mr. Russell for his speech and for his promise of further financial support to the Institute. In order that the Hon. the Minister might take part in the discussion, Professor Kirk's motion was now taken. Professor Kirk moved, and Professor Easterfield seconded, That the Institute express to the Minister of Internal Affairs its regret that he has, in a recent instance, vetoed its well-considered advice in respect to an allocation from the research grant, giving no reason for the veto; that it requests that the right of veto shall in future not be exercised without stated reason, and, if the Institute desire it, without discussion between the Minister and the representatives of the Institute; and that, if this request of the Institute be not granted, the Institute must reluctantly leave it to the Minister to administer the research grant without its advice, unless in some special matter he wishes it for his guidance.

The Hon. the Minister promised that in future, where the veto was exercised, reasons would be given, and the motion was withdrawn.

The meeting adjourned at 12.30 p.m. until 2 p.m.

Incorporated Societies' Reports and Balance-sheets were laid upon the table. No reports had been received from the Nelson Institute, the Wanganui Philosophical Society, or from the Hawke's Bay Philosophical Institute.

Standing Committee's Report. The report of the Standing Committee was read and adopted.

Report of the Standing Committee for 1918.

Nine meetings of the Standing Committee have been held during the year 1918, the attendance being as follows: Dr. Cockayne, 7; Dr. J. A. Thomson, 6; Mr. Ewen, 7; Mr. Hogben, 7; Professor Kirk, 6; Mr. Parr, 3; Hon. G. M. Thomson, 2; Mr. Aston, 9; Messrs. Benham, Hilgendorf, Birks, Eliott, Hill, Marshall, Segar, and Thomas, 1 each.

Hector Memorial Award.—The High Commissioner for New Zealand, under date of 6th August, 1918, notified the Under-Secretary for Internal Affairs that at the request of Sir E. Rutherford, and with the consent of the Standing Committee, the 1916 medal was presented to him privately on the 25th July, 1918.

The 1918 medal, awarded to Mr. T. F. Cheeseman, of Auckland, was presented to him publicly on the 10th June, 1918, by the Mayor of Auckland, Mr. J. H. Gunson, at the opening lecture of the Auckland Institute's session.

Supply of Medals.—A further supply of twelve medals has been received from Messrs. Wyon. These are not quite the same as the old medal, being struck on thicker metal of apparently a different composition.

War Roll of Honour.—The collection of data from the incorporated societies for the preparation of a Roll of Honour has been continued by the Hon. Secretary.

Volume 49, Transactions of the New Zealand Institute, for the year 1916, was laid upon the tables of the House of Representatives and of the Legislative Council on the 15th April, 1918.

Volume 50, Transactions of the New Zealand Institute, for the year 1917, was issued on the 15th July, 1918, and distributed in bulk direct to the incorporated societies by the Government Printer. A copy was laid on the table of the House of Representatives on the 29th October, 1918, and on the table of the Legislative Council on the 30th October, 1918.

Publications.—It has been decided to present as complete a set as possible of the *Transactions of the New Zealand Institute* to the Cawthron Institute, and to place the library on the mailing-list of the Institute.

A number of observatories, at the New Zealand Government Astronomer's request, have been supplied by the New Zealand Institute with volumes of the *Transactions* which contain papers by Professor Bickerton.

The following have been placed on the mailing-list and an exchange of publications arranged :—

Société de Chimie Industrielle.
Athenaeum Subject Index to Periodicals.
Commonwealth Advisory Council of Science and Industry.
University of California (certain departments only).
Lloyd Library, Cincinnati.
Department of Agriculture, Wellington.

Partial sets of *Transactions* have been presented to the Ashburton High School, and to the Department of Agriculture, Wellington.

Resolutions of the Standing Committee not otherwise mentioned in this report are as follows :—

Banking Account : That Dr. J. A. Thomson be authorized to sign cheques in place of Professor Easterfield, who was then no longer a member of the Board.

Carter Bequest : That the Public Trustee be authorized to sell the New Zealand Loan and Mercantile Agency Company's stock.

Science Congress at Christchurch : That it is desirable that the Philosophical Institute of Canterbury should take over the whole management of the Congress.

Date of Annual Meeting : That all Governors be informed that the annual meeting is called for the 17th January, 1919, at Wellington, but that those not living in Wellington need not attend ; and that, in accordance with the agreement amongst the Governors at the last annual meeting, the meeting will be adjourned from Wellington to Christchurch on the 1st February, 1919.

Jubilee of the Institute : That owing to the war the Institute postpone any recognition of the Jubilee until a more convenient season.

National Efficiency.—On the 12th March, 1918, the Standing Committee asked the Hon. the Minister of Internal Affairs for information concerning the report of the New Zealand Institute's Scientific and Industrial Research Committee, which that committee had sent to the National Efficiency Board, and asked whether the committee set up by the New Zealand Institute in conjunction with the Director of the Dominion Museum could now proceed with the proposed census of industries in terms of the resolution sent him on the 11th January, 1918, which was as follows: "That the committee, having heard that the Hon. the Minister is prepared to take steps at an early date to inaugurate a Dominion scheme of scientific and industrial research by making a preliminary census of past research, actual problems of industry awaiting solution, and of available laboratories and research workers, advises that the Director of the Dominion Museum should undertake such census, being supplied by the Minister with specially qualified assistance, and that a committee of the New Zealand Institute should co-operate with him."

The Hon. the Minister, under date 24th April, 1918, replied that Cabinet had considered the report of the National Efficiency Board on the subject, and it had been decided to circulate this report among Ministers for their consideration, and promised to communicate again with the Institute in the matter.

Annual Reports and Balance-sheets of the following incorporated societies have been received and are now laid on the table :—

Auckland Institute, to 20th February, 1918.
Philosophical Institute of Canterbury, to 31st October, 1918.
Otago Institute, to 30th November, 1918.
Manawatu Philosophical Society, to 31st October, 1918.
Wellington Philosophical Society, to 30th September, 1918.

Census of Industries.—On the motion of Professor Kirk, seconded by the Hon. G. M. Thomson, it was resolved, That the Hon. the Minister of Internal Affairs be asked whether he can now make the further communication on the matter of the census of industries, referred to in the Standing Committee's report under the heading "National Efficiency."

On the motion of Professor Kirk, seconded by Mr. Eliott, it was resolved, That the Institute depute the President, Professor Easterfield, and Dr. J. A. Thomson to give evidence before the Parliamentary Committee on Science and Industry.

Hon. Treasurer's Reports.—In the absence of the Hon. Treasurer, the Hon. Secretary moved, and Professor Kirk seconded, That the Hon. Treasurer's reports, duly audited by the Auditor-General, be adopted. Carried.

The Public Trustee's Reports on the Carter Bequest, the Hutton Memorial Fund, and the Hector Memorial Fund for the year ending 31st December, 1918, were adopted.

New Zealand Institute.—Statement of Receipts and Expenditure for the Year ending 31st December, 1918.

Receipts.	£	s.	d.	*Expenditure.*	£	s.	d.
Balance at 31st December, 1917	418	17	10	Government Printer ..	757	8	6
Post Office Savings-bank interest to 31st December, 1918	3	5	4	Expenses, annual meeting ..	38	19	1
Government statutory grant	500	0	0	Fire-insurance premium on library, £1,500	5	0	0
Publications sold	50	1	5	Bank charges and cheque-book	1	0	0
Affiliated societies' levy, 1917	114	3	0	Secretary's expenses, postage, stationery, and clerical work	31	16	6
Affiliated societies' levy, 1918	89	8	3	New Zealand Express Company, Chicago	3	13	6
Government grant for research work	330	0	0	Research grant to Professor Evans	200	0	0
Government grant for research work, 20th December	30	0	0	Research grant to Professor Malcolm	30	0	0
Endowment Fund deposit in Post Office Savings-bank	4	18	1	Research grant to Professor Easterfield	50	0	0
				Research grant to Dr. Chilton	50	0	0
					1,167	17	7
				Balance as under ..	372	16	4
	£1,540	13	11		£1,540	13	11

Balance in—	£	s.	d.
Bank of New Zealand	330	18	4
Post Office Savings-bank	41	18	0
	£372	16	4

New Zealand Institute.—Statement of Liabilities and Assets at 31st December, 1918.

	Liabilities. £	s.	d.	*Assets.* £	s.	d.
Hector Memorial Fund in hands of Public Trustee and *per contra*	1,067	19	9	1,067	19	9
Hutton Memorial Fund in hands of Public Trustee and *per contra*	826	6	11	826	6	11
Carter Bequest in hands of Public Trustee and *per contra*	4,342	5	4	4,342	5	4
Special grants for research work on hand	75	0	0	..		
Government Printer's account	547	12	6	..		
Balance Endowment Fund Account	4	18	1	..		
Levies for 1918 unpaid	..			3	7	6
Authors' copies and books sold	..			4	15	9
Balance at Bank of New Zealand, Wellington ..	..			330	18	4
Balance at Post Office Savings-bank, Wellington ..	..			41	18	0
Balance	..			246	11	0
	£6,864	2	7	£6,864	2	7
To balance	£246	11	0			

Against this debit balance the Institute has a large stock of *Transactions* for sale, and possesses a very valuable library.

Hector Memorial Fund.—Statement of Account for the Year ending 31st December, 1918.

		Dr.	Cr.
		£ s. d.	£ s. d.
By Balance brought forward		..	1,106 13 9
Public Trust Office—			
Interest to 31st December, 1918, at 4½ per cent.	£ s. d. 46 10 1		
Bonus interest to 31st March, 1918 ..	4 15 11		
		..	51 6 0
To New Zealand Institute Account—			
Professor C. Chilton, Hector Prize for 1917	45 0 0		
Mr. T. F. Cheeseman, Hector Prize for 1916	45 0 0	90 0 0	..
To Balance		1,067 19 9	..
		£1,157 19 9	£1,157 19 9
By Balance		..	£1,067 19 9

Hutton Memorial Fund.—Statement of Account for the Year ending 31st December, 1918.

		Dr.	Cr.
		£ s. d.	£ s. d.
By Balance brought forward		..	787 11 5
Public Trust Office—			
Interest to 31st December, 1918, at 4½ per cent.	£ s. d. 35 8 0		
Bonus interest to 31st March, 1918 ..	3 7 6		
		..	38 15 6
To Balance		826 6 11	
		£826 6 11	£826 6 11
By Balance		..	£826 6 11

Carter Bequest.—Statement of Account for the Year ending 31st December, 1918.

Residuary Account.		Dr.	Cr.
		£ s. d.	£ s. d.
By Balance brought forward		..	4,138 5 11
Public Trust Office—			
Interest to 31st December, 1918, at 4½ per cent.	£ s. d. 186 0 7		
Bonus to 31st March, 1918	17 18 10		
		..	203 19 5
To Balance		4,342 5 4	
		£4,342 5 4	£4,342 5 4
By Balance		..	£4,342 5 4

Assets.

		£ s. d.
Balance as per account	..	4,342 5 4
Shares—New Zealand Loan and Mercantile Agency Company (Limited)—	£ s. d.	
First mortgage debenture stock	10 0 0	
Second mortgage debenture stock	4 0 0	
Second preference debentures	3 10 0	
Second ordinary debentures	1 10 0	
		19 0 0

Liability.

		£ s. d.
Legacy—Museum and New Zealand Institute ..	..	50 0 0
Balance Trustee's commission	..	At scale rates

Financial Position of the Institute.—The President detailed the steps he had taken to bring before the Hon. the Minister the state of the Institute's finances. On the motion of Mr. Hill, seconded by Mr. Eliott, it was resolved, That for every copy of volume 51 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.

Hutton Fund Grants. The Hon. G. M. Thomson made a statement concerning the Portobello Fish-hatchery. An account of the work, which was assisted by a grant from the Hutton Fund in 1916, will be published in a pamphlet entitled "A History of the Portobello Fish-hatchery," to appear shortly.

Research Grant Committee's Reports. On the motion of Professor Easterfield, seconded by Mr. Aston, the report was received.

Report of the Research Grant Committee.

(Professor Easterfield, Mr. G. Hogben, and Mr. B. C. Aston.)

(For previous reports see *Trans. N.Z. Inst.*, vol. 49, p. 580, and vol. 50, p. 333.)

Reports from the grantees have been received as follows:—

Mr. L. P. Symes, who was in 1916 granted £50, through the Philosophical Institute of Canterbury, for investigating the decay of apples and other fruits in cold storage, reported on the 23rd December, 1918, that little progress had been made and no portion of the vote had yet been expended. Grantee asks that the grant may be continued for another year.

Mr. L. Birks, to whom £10 had been granted in 1916, through the Philosophical Institute of Canterbury, for investigating the electrical prevention of frosts in orchards, reported on the 4th February, 1918, that none of the grant had then been expended, but suggested that it be increased by £20 from the current year's vote, and subsequently, on the 15th March, he asked for £30 additional. The matter was referred to a referee, and on receiving his report the Standing Committee resolved to ask the Philosophical Institute of Canterbury for further information. This not being forthcoming, the matter is in abeyance. Mr. Birks reported on the 30th December, 1918, that he regretted owing to the shortage of staff it has again been impossible to do anything this year, but hoped to be able to detail an officer for the work next season.

Messrs. R. Speight and L. J. Wild, to whom £50 was granted in 1916, through the Philosophical Institute of Canterbury, for investigation of the phosphatic limestones of Canterbury, on the 16th August, 1918, reported fully on the results of their work. Although this is reasonably complete and not likely to be modified by subsequent research, the grantees proposed to continue the investigation later in the year as occasion offers, and they are therefore retaining some £14, unexpended balance of the grant, reporting additional results when obtained.

Professor H. B. Kirk, to whom £25 was granted in 1917, through the Wellington Philosophical Society, for investigating methods of killing mosquitoes and larvae, reported on the 30th December, 1918, that he had continued this work, and gave a progress report of the results so far obtained. These confirmed the conclusions previously reported as to the value of light tar-oil as a larvicide. His statement of expenses showed that £9 11s. 3d. had been expended in travelling-expenses.

Messrs. La Trobe and Adams, to whom £50 was granted in 1917, through the Wellington Philosophical Society, towards the construction of a tide-predicting machine, reported on the 12th December, 1917, having spent £64 1s. 6d., and applied for a further grant of £75. The Standing Committee referred the matter to a sub-committee consisting of Mr. G. Hogben and Professor Sommerville, and they having reported favourably on the work already accomplished towards the construction of the machine, the Standing Committee granted the application. The Hon. the Minister, under the terms controlling the issue of Government research grants (see *Trans. N.Z. Inst.*, vol. 49, p. 326), however, withheld his sanction, and no payment could therefore be made.

Professor Jack, to whom £25 was granted in 1917, through the Otago Institute, for investigating the electric charge on rain, reported on the 23rd December, 1918, that he had not been able, owing to stress of work caused by war conditions, to take over the grant, and asked that it may be paid to him in February next.

Professor W. P. Evans, to whom £200 was granted in 1918, through the Philosophical Institute of Canterbury, for investigating New Zealand brown coals, reported on the 24th December, 1918, that only preliminary work on a very small scale had been possible owing to the difficulty in obtaining apparatus and assistance. An experienced assistant, at £250 per annum for two years from the 1st February, 1919, had now been secured, who would give his whole time to the work. No payments out of the grant had been made, but fractionating apparatus to cost £58 had been ordered and should shortly arrive from London. The Board of Governors of Canterbury College had added £100 to this grant for the year 1919, and had promised additional £150 for 1920. Grantee requested that the grant of £200 might be carried on to 1919.

Professor C. Chilton, to whom £50 was granted in 1918, through the Philosophical Institute of Canterbury, for investigating New Zealand flax (phormium), on the 31st December, 1918, reported that although the grant had been made in his name the investigations had been carried out by Mrs. B. D. Jennings, who had made considerable progress, more particularly in the direction of starting observations and experiments to test the cause of diseases affecting the flax, improved methods of cultivation, &c. There had been a serious deterioration in the flax crop in some districts, involving losses of such commercial value that further investigation was more necessary than ever. Only £10 of the grant had been spent, but the grantee asked that the grant might be continued for another year.

A more detailed report has since been submitted (30th December, 1918) by Mrs. Jennings, through Dr. Chilton, intimating that she has been engaged by the Flax-millers' Association to investigate the yellow-leaf disease, on which she submits some information.

Professor John Malcolm, to whom £30 was granted in 1918, through the Otago Institute, reported on the 7th December, 1918, that, largely owing to having had this grant at his disposal, he had been enabled to send for publication in the *Transactions of the New Zealand Institute* a short paper on tutu fruit and seed, and had made some further progress with work on pukateine. He asked that the subject of his investigations might be extended to include questions referring to the preservation of meat and dairy produce. Grantee had spent £14 12s. on books, chemicals, experimental material and petty cash.

Professor T. H. Easterfield, to whom £50 was granted in 1918, through the Wellington Philosophical Society, for investigating the wax content of New Zealand brown coals, reported in January, 1919, that, owing to the temporary deprivation of his assistant by illness, and the war, the investigation had not been commenced, neither had any expense been incurred. The grantee asks that the grant may be continued for another year.

It will be noticed that in most cases the sums granted have not been expended. In some cases the amounts have been lodged in a local savings-bank by the grantee to his credit. In future it will be desirable that the sums be retained by the Institute until required, so that any interest may become its property.

One of the grants (for £20) which has been surrendered has been placed to the credit of the New Zealand Institute, and it will be necessary to decide what to do with this sum.

A discussion took place on the final clause of the report, dealing with the disposal of the interest on the unexpended portion of grants. On the motion of Mr. Eliott, seconded by Professor Segar, it was resolved, That in future sums voted be retained by the New Zealand Institute and placed in the Post-office Savings-bank or other approved investment until actually required by the grantee, so that the New Zealand Institute receive the benefit of any interest earned and hold it in trust for future research grants. An amendment by Professor Chilton, seconded by Dr. Hilgendorf, that the grants on allocation should be paid to the Treasurers of the societies through which the applications were made, was lost.

On the motion of Dr. J. A. Thomson, seconded by Professor Thomas, it was resolved, That the Government Research Grant Committee be instructed to amend the regulations for administering the research grant by incorporating resolutions passed by the Board of Governors which affect the administration of the grants.

On the motion of Mr. Eliott, seconded by Professor Kirk, it was resolved, That the unexpended portions of all Government research grants be continued to the grantees for the coming year.

Hutton Research Grant.—An application from Miss Mestayer for a grant of £10 towards work on New Zealand Mollusca was granted on the motion of the Hon. G. M. Thomson, seconded by Professor Easterfield.

Hector Award Committee's Report.—The President then opened the recommendation of the Hector Award Committee, which was to the effect that the award should be made this year to Dr. P. W. Robertson. Professor Easterfield, in moving the adoption of the report, gave the committee's reasons for the selection of Dr. Robertson. The motion was seconded by Professor Segar and carried.

Publication Committee's Report.—The report of the Publication Committee was adopted on the motion of Dr. Cockayne, seconded by Dr. J. A. Thomson. On the motion of Dr. Chilton, seconded by Dr. J. A. Thomson, it was resolved, That the words "for the year ——" be omitted from the title of the *Transactions of the New Zealand Institute.*

Report of Publication Committee.

Thirty-two papers were accepted for publication in vol. 50 of the *Transactions of the New Zealand Institute,* and the volume was issued on the 15th July, 1918. It contains xii + 392 pages (of which 68 are devoted to the Proceedings), 35 plates, and numerous text-figures.

No bulletins were issued during the year.

A circular was sent out by the Editors to the Secretaries of the incorporated societies requesting that the manuscripts of papers intended for publication in the *Transactions* should be sent forward as early as possible. A number of papers for vol. 51, received early as a result of this request, are already in the hands of the Government Printer, and we hope that the publication of the volume will thus be expedited.

As it seems desirable that papers read at the general meeting of the Institute, in February, should be printed in the forthcoming volume (vol. 51), the committee recommends that the volume be described as "for the year 1918–19," instead of "for the year 1918," subsequent volumes to be for 1919–20, &c. Apart from the special circumstance of the inclusion of papers read at the general meeting, this description would be correct, as the volume always contains the report of the annual meeting of the Board of Governors. It might help also to stop the practice of misquoting the dates of volumes of the *Transactions*, which is almost universal in manuscripts submitted for publication.

For the Committee.

Leonard Cockayne,
C. A. Cotton, Hon. Editors.

Catalogue of Fishes.—On the motion of the Hon. G. M. Thomson, seconded by Professor Segar, it was resolved, That this meeting of the Board of Governors re-urges upon the Government the necessity of preparing and publishing a catalogue of New Zealand fishes as a work of national importance, and that this work should be undertaken at as early a date as possible.

Library Committee's Report.—On the motion of Dr. J. A. Thomson, seconded by Dr. Chilton, the report of the Library Committee was adopted.

Report of Library Committee.

As no funds have been available for the purpose, little has been done in the library beyond receiving, registering, and placing on the shelves the incoming periodicals. A list of the serial publications received by the library during 1917 was prepared by a member of the Committee, and was printed in the Appendix to the Proceedings, vol. 50, pp. 381–85.

For the Committee.

C. A. Cotton.

Correspondence.—The President read a letter from Mr. T. F. Cheeseman wishing the Congress success. It was resolved that the President be requested to write to Mr. T. F. Cheeseman congratulating him on his long service with the Institute.

Indexing the Transactions.—A letter from the Philosophical Institute of Canterbury, dated 30th August, 1918, concerning the indexing of the *Transactions* was read, and, on the motion of Professor Easterfield, seconded by Dr. Chilton, it was resolved, That the Standing Committee be instructed to take steps to index the volumes 41 to 50 when funds permit.

British Science Guild.—A letter was read from the British Science Guild (2/3/18) desiring that its objects should be brought under the notice of the Institute. Received.

Resolutions passed at the Last Annual Meeting.—A letter from the Under-Secretary, Internal Affairs Department (7/2/18), acknowledging the resolutions concerning the Government passed at the last annual meeting, and promising that they would receive attention, was received.

Hamilton Prize.—A letter from Mr. C. J. Tunks (30/8/18), making certain suggestions regarding the Hamilton Prize, was, on the motion of Professor Easterfield, seconded by Professor Thomas, referred to the Wellington Philosophical Society.

Method of sending Papers to Editor for Publication.—A letter received from the Canterbury Philosophical Institute (2/10/18), regarding the proper procedure in dealing with papers for publication, was deferred until Dr. Hilgendorf's motion was dealt with.

Fellows of the Institute.—The report of the Committee appointed to consider the question of the proposed Fellowship of the New Zealand Institute was, on the motion of Dr. Thomson, seconded by Dr. Cockayne, received, and was considered clause by clause.

Report of the Committee appointed to report on the Proposed Fellowship of the Institute.

(Dr. Cockayne (convener), Dr. J. A. Thomson, and Mr. Hogben.)

1. The Fellowship of the New Zealand Institute shall be an honorary distinction for the life of the holder.

2. The Original Fellows shall be twenty in number, and shall include the past Presidents and the Hutton and Hector Medallists. The remaining Original Fellows shall be nominated as provided for in Rule 7 (*a*), and shall be elected by the said past Presidents and Hector and Hutton Medallists.

3. The total number of Fellows at any time shall not be more than forty.

4. After the appointment and election of the Original Fellows, as provided in Rule 2, not more than four Fellows shall be elected in any one year.

5. The Fellowship shall be given in general for research or distinction in science, or for eminent service to the nation in any capacity, provided that the total number of Fellows elected under the last-named head shall not exceed one-tenth of the total number of Fellows.

6. No person shall be elected as Fellow unless he is a British subject and has been a member of one of the incorporated societies for three years immediately preceding his election.

7. After the appointment and election of the Original Fellows, as provided in Rule 2, there shall be held an annual election of Fellows at such time as the Board of Governors shall appoint. Such election shall be determined as follows:—

(*a*.) Each of the incorporated societies at Auckland, Wellington, Christchurch, and Dunedin may nominate not more than twice the number of persons as there are vacancies to be filled. Each nomination must be accompanied by a full statement of the qualifications of the candidate for Fellowship.

(*b.*) Out of the persons so nominated the Fellows resident in New Zealand shall select twice as many persons as there are vacancies, if so many be nominated.
(*c.*) The election shall be made by the Board of Governors at the annual meeting.
(*d.*) The methods of election in clause (*b*) and of election in clause (*c*) shall be determined by the Board of Governors.

Clause 1: "The Fellowship of the New Zealand Institute shall be an honorary distinction for the life of the holder." Adopted.

Clause 2: "The Original Fellows shall be twenty in number, and shall include the past Presidents and the Hutton and Hector Medallists. The remaining Original Fellows shall be nominated as provided for in Rule 7 (*a*), and shall be elected by the said past Presidents and Hector and Hutton Medallists." A motion by Professor Thomas, seconded by Professor Segar, that the number of Original Fellows be thirty in number, instead of twenty as proposed, was lost. After the word "Medallists" where it first occurs, it was resolved, on the motion of Professor Segar, seconded by Mr. Eliott, to insert the words "who have held their distinctions and positions prior to the 3rd February, 1919, and who at that date are members of the New Zealand Institute." The clause as amended was adopted.

Clause 3: "The total number of Fellows at any time shall not be more than forty." Adopted.

Clause 4: "After the appointment and election of the Original Fellows, as provided in Rule 2, not more than four Fellows shall be elected in any one year." Adopted.

Clause 5: "The Fellowship shall be given in general for research or distinction in science, or for eminent service to the nation in any capacity, provided that the total number of Fellows elected under the last-named head shall not exceed one-tenth of the total number of Fellows." A motion by the Hon. G. M. Thomson, seconded by Professor Thomas, that the words "in general" and all words after the words "distinction in science" be delected, was carried; an amendment by Mr. L. Birks, seconded by Professor Segar, of the addition thereafter of the words "or of eminent services to the nation in the application of scientific principle" being lost. Adopted as amended.

Clause 6: "No person shall be elected as Fellow unless he is a British subject and has been a member of one of the incorporated societies for three years immediately preceding his election." Adopted.

Clause 7: "After the appointment and election of the original Fellows, as provided in Rule 2, there shall be held an annual election of Fellows at such time as the Board of Governors shall appoint. Such election shall be determined as follows:—

"(*a.*) Each of the incorporated societies at Auckland, Wellington, Christchurch, and Dunedin may nominate not more than twice the number of persons as there as vacancies to be filled. Each nomination must be accompanied by a full statement of the qualifications of the candidate for Fellowship."

It was explained by the President that by an oversight in drafting the report the representation of the smaller societies had been omitted, and therefore he accepted the addition, after the words "twice," of the words "as many persons as there are vacancies, and each of the other incorporated societies may nominate as many persons as there are vacancies." With this addition the clause was adopted.

At this stage the meeting adjourned until Monday morning at 10 a.m.

The Board resumed on Monday, the 3rd February, at 10 a.m., there being present Dr. Cockayne (President), Mr. Aston, Mr. Birks, Professor Chilton, Mr. Eliott, Mr. Hill, Dr. Hilgendorf, Professor Kirk, Professor Segar, Hon. G. M. Thomson, Dr. J. A. Thomson, and Professor Thomas.

Clause 7, subclause (*b*): "Out of the persons so nominated the Fellows resident in New Zealand shall select twice as many persons as there are vacancies, if so many be nominated." Adopted.

Subclause (*c*): "The election shall be made by the Board of Governors at the annual meeting." On the motion of Professor Segar, seconded by Professor Thomas, the words "from the persons selected by the Fellows" was added to the end of subclause (*c*). Adopted as amended.

Subclause (*d*): "The methods of election in clause (*b*) and of election in clause (*c*) shall be determined by the Board of Governors." The word "selection" was on the voices inserted in placed of "election" where it first occurs. Adopted as amended.

New subclause 7 (*e*): On the motion of Dr. Hilgendorf, seconded by Mr. Eliott, it was resolved, That the names of the nominees shall be submitted to the Fellows at least six months, and the names selected by them shall be submitted to the Governors at least three months, before the date fixed for the annual meeting of the Board of Governors at which the election is to take place. Adopted.

New clause 8: On the motion of Professor Chilton, seconded by Professor Easterfield, it was resolved, That the official abbreviation of the title "Fellow of the New Zealand Institute" be "F.N.Z.Inst." Adopted.

The President then put the motion, That the regulations governing the institution of the Fellowship of the Institute as amended be adopted. The motion was carried, Mr. Hill dissenting.

The following are the regulations as adopted:

Regulations governing the Fellowship of the Institute.

1. The Fellowship of the New Zealand Institute shall be an honorary distinction for the life of the holder.

2. The Original Fellows shall be twenty in number, and shall include the past Presidents and the Hutton and Hector Medallists who have held their distinctions and positions prior to the 3rd February, 1919, and who at that date are members of the Institute. The remaining Original Fellows shall be nominated as provided for in regulation 7 (*a*), and shall be elected by the said past Presidents and Hector and Hutton Medallists.

3. The total number of Fellows at any time shall not be more than forty.

4. After the appointment and election of the Original Fellows, as provided in Regulation 2, not more than four Fellows shall be elected in any one year.

5. The Fellowship shall be given for research or distinction in science.

6. No person shall be elected as Fellow unless he is a British subject and has been a member of one of the incorporated societies for three years immediately preceeding his election.

7. After the appointment and election of the Original Fellows, as provided in Regulation 2, there shall be held an annual election of Fellows at such time as the Board of Governors shall appoint. Such election shall be determined as follows:—

(*a*.) Each of the incorporated societies at Auckland, Wellington, Christchurch, and Dunedin may nominate not more than twice as many persons as there are vacancies, and each of the other incorporated societies may nominate as many persons as there are vacancies. Each nomination must be accompanied by a statement of the qualifications of the candidate for fellowship.

(*b*.) Out of the persons so nominated the Fellows resident in New Zealand shall select twice as many persons as there are vacancies, if so many be nominated.

(*c*.) The names of the nominees shall be submitted to the Fellows at least six months, and the names selected by them submitted to the Governors at least three months, before the date fixed for the annual meeting of the Board of Governors at which the election is to take place.

(*d.*) The election shall be made by the Board of Governors at the annual meeting from the persons selected by the Fellows.

(*e.*) The methods of selection in subclause (*b*) and of election in subclause (*d*) shall be determined by the Board of Governors.

8. The official abbreviation of the title "Fellow of the New Zealand Institute" shall be "F.N.Z.Inst."

Dr. J. A. Thomson moved, Mr. Eliott seconded, and it was carried, That Dr. L. Cockayne, Professor T. H. Easterfield, Professor C. Chilton, and the Hon. G. M. Thomson, be a committee, with power to act, to determine the method of election of the remaining Original Fellows and to carry out the election.

On the motion of Mr. Eliott, seconded by Professor Thomas, it was resolved, That the matter of bringing into operation the sections in clause 7 as adopted by the Board be left in the hands of the Standing Committee.

Report on Kapiti Island.—Professor Kirk read the joint report of Mr. Bendall and himself on Kapiti Island, which had been received by the Hon. Secretary too late to circulate. He reported that the work had been done by himself and Mr. Bendall, a member of the Council of the Manawatu Philosophical Society, instead of Mr. Eliott, who was unable to visit the island. On the motion of Mr. Eliott, seconded by Mr. Hill, it was resolved, That the report of Professor Kirk and Mr. W. E. Bendall be adopted, and printed in the *Transactions and Proceedings*, and that the authors be thanked for their services in the matter.

Report on Kapiti Island as a Plant and Animal Sanctuary.

This report takes as a starting-point Dr. Cockayne's "Report on a Botanical Survey of Kapiti Island," presented to Parliament in 1907 by the late Hon. Dr. McNab, Minister of Lands, and it deals especially with the extent to which the recommendations of that report have been given effect to or have apparently been ignored.

Wild Sheep.—By far the most important and far-reaching of the recommendations referred to is that the whole island should be acquired by the Government, that being the only means by which it can be hoped effectively to put a stop to the damage being done by sheep belonging to Native owners. We do not find in Dr. Cockayne's report a statement of the extent of the Native holdings in 1907. At present the Natives hold about 644 acres. But they have far more sheep than their own holdings could support, and the greater number of these are running wild over the island. It is safe to say that not less than eight hundred of these sheep are running on the lands of the Crown. It does not, perhaps, concern the Institute more than it does the community at large that no rent is charged for this privilege, but so far as we can learn that is the fact. Although the Natives have the right to muster over the whole island, the difficulties of mustering on Kapiti are so great that very many of these sheep have never been docked or dagged, and it may be taken for granted that they have never been dipped. Nearly all are carrying long, filthy dags; very many have the wool torn more or less completely from the back by the bushes. It would be hard to find anywhere else in New Zealand sheep that present the marks of neglect more obviously. The point that especially concerns the Institute is that these sheep, with the wild goats, are setting a limit to the life of the forest. Not only do they prevent to a very large extent the growth of young trees, but they open up the forest to the sweep of the wind. They prepare it for invasion by grass, tauhinu, manuka, and other hardy plants. Although the manuka is one of the least objectionable of these invaders, yet in dry situations, such as some of the spurs, where it harbours no moss or liverworts, very little humus is formed, and that little is quickly washed away by rain. On some spurs—for example, on one just south of Waterfall—where manuka has replaced the forest, much soil has been removed, and in no great time the manuka itself will be unable to retain its footing. In such cases the manuka marks a phase in the passage to utter barrenness.

Wild Goats.—As already intimated, wild goats share with the sheep the work of destroying the original plant-covering. The caretaker, Mr. Bennett, has shot great numbers of them, and their remains are to be found all over the Crown lands. The thoroughness with which this work is being done impressed us very much. The extinction of goats on Kapiti will involve still a great deal of work. We estimate that there cannot be less than three hundred of them at the present time, and there may be many more.

Australian Opossums.—In many parts of the bush the damage done by opossums is noticeable. Kohekohe, mahoe, and passion-flower are among the plants that most frequently show the marks of having been attacked. There are several groups of dead *Fuchsia* trees, and these the caretaker is satisfied have been killed by opossums. Systematic trapping has been carried out, and the numbers have evidently been very much reduced; but they are still quite common. The only safe aim is their absolute extinction so far as Kapiti is concerned.

Wild Cats.—We understand that most, perhaps all, of the wild cats have been killed. We neither saw nor heard any. The caretaker exercises unceasing vigilance in the matter.

Deer and Wild Cattle.—All have been killed.

It will be seen that, except in the all-important matter of the wild sheep, there is little cause for disappointment and much cause for satisfaction with what has been done. The achievement is due to the fact that the caretaker is very vigilant and highly capable. Having selected a man with those qualifications, the Government has failed to take the vitally important action that would have resulted in complete success.

Government's Intentions.—In the last estimates there appeared a sum of £1,000 for the purpose of stocking Kapiti Island with sheep. The intention is to fence off the clearing at Rangatira Point and the Taipiro clearing in the middle of the island, and to run two fences across the island, cutting off the open lands at the northern and southern ends. It is intended to make a track from Rangatira to the Taipiro clearing and on to the southern clearing, to enable fences to be erected and to serve as driving-tracks in mustering. Sheep could then be run on the open lands with no damage to the bush. Presumably, all the Native sheep would first have been disposed of. The advantages to be gained, in addition to revenue, would be that danger from fires in long dry grass would be avoided, and that there would be a sufficient staff, maintained without loss, to care properly for the parts of the island that would remain a sanctuary.

The Institute will probably consider whether it should make any representations to the Government with regard to the scheme just referred to. There is, we think, no denying that if sheep are on the island there will always be some danger of the bush being invaded by them, a danger that will be very slight under efficient management, but that if at any time the island passes under careless or otherwise inefficient management will be very serious indeed. In such a case the position of the island as a sanctuary might be worse than at present. If the island is kept as a sanctuary pure and simple, as we suppose it was the first intention of the Government that it should, then New Zealand will best have expressed a sense of its duty to care for a portion of a flora and fauna that are unique, the needless destruction of which could never be excused, and could only be explained on the ground of sordid ignorance. On the other hand, it is to be borne in mind that the danger of fire, already referred to, is a real one, although one that may easily be exaggerated. The danger could be minimized by planting the open lands with such Native trees and shrubs as would not readily carry fire. Such planting would, of course, involve considerable expense. If the attitude of the Governments of the future is such as we have known in the past, the proposal to make revenue by utilizing the open sheep-lands of the island will, sooner or later, prove irresistible, although now these Crown lands are allowed to be used by private individuals and to the great detriment of the property of the State. If the Government runs sheep on Kapiti, it is of vital importance that no sheep should be placed on land that is not properly fenced.

We wish to express our appreciation of the courtesy and help extended to us, as representatives of the Institute, by Mr. T. W. Broderick, Under-Secretary to the Crown Lands Department, by Mr. Phillips Turner, of that Department, and by Mr. J. L. Bennett, the caretaker of the island.

16th January, 1919.

On the motion of Mr. Eliott, seconded by Mr. Hill, it was resolved, That the Minister of Lands be urged to acquire the remaining portion of the Island of Kapiti from the private owners, in order to prevent the damage and destruction to the flora and fauna which is now taking place.

On the motion of Professor Kirk, seconded by Mr. Eliott, it was resolved, That the Government be asked to formally recognize the New

Zealand Institute as an advising body in connection with the administration of Kapiti Island and other plant and animal sanctuaries; that the Standing Committee constitute a deputation to wait upon the Hon. the Minister of Lands to give reasons for recognizing the Institute as an advising body in connection with the administration of Kapiti Island and other plant and animal sanctuaries.

Amendment of Regulation 3.—A letter from the Wellington Philosophical Society forwarding a resolution recommending the amendment of Regulation 3 was ruled out of order in not complying with the regulations.

Protection of Birds and Seals.—A letter from the Otago Institute (17/12/18), which was supported by one from the Canterbury Philosophical Institute (3/1/19), was read. On the motion of Professor Chilton, seconded by Professor Thomas, it was resolved, That the Institute again urge upon the Government the necessity of strictly enforcing the regulations for the protection of the seals and native birds of New Zealand.

On the motion of the Hon. G. M. Thomson, seconded by Mr. L. Birks, it was resolved, That the New Zealand Institute urge upon the Government of Tasmania that seals and birds upon Macquarie Island should be protected, and that a copy of this resolution be forwarded to the Royal Society of Tasmania.

Proposed New Regulations.—A letter from Dr. Hilgendorf (27/11/18), suggesting new regulations dealing with the transmission of papers from the authors to the Editor of the *Transactions* was considered.

Proposed Regulation 1: That in the Regulations under the New Zealand Institute Act, clause 5, (*a*), (2) (see *Transactions*, vol. 49, p. 573), be amended by the insertion, after the word "societies" in line 2, of the words "or any general meeting of the New Zealand Institute." Adopted.

2. That the same subclause be further amended by the insertion, after the second occurrence of the word "time" in line 4, of the words "by special resolution in each case." This was amended by the insertion of the words "for special reasons" in place of the words "by special resolution." and was carried.

3. That the same subclause be amended by the insertion, after subclause (*b*), of a new subclause as follows: "(*c*) No paper written by a person that is not a member of the New Zealand Institute shall be considered for publication unless the Council of the incorporated society before which the paper was read shall certify that it is in possession of satisfactory reasons why the author is not a member of the New Zealand Institute." On being put to the meeting this was lost.

4. That after the above there be inserted another new subclause as follows: "(*d*.) In the case of a paper read before a general meeting of the New Zealand Institute by a person that is not a member of the New Zealand Institute the paper may be accepted for publication on the statement of the Standing Committee that it considers that there are satisfactory reasons why the author is not a member of the New Zealand Institute." Withdrawn.

5. That in the same subclauses (*c*), (*d*), (*e*), (*f*) be lettered (*e*), (*f*), (*g*), (*h*), respectively. Withdrawn.

6. That the whole clause as amended be printed in the next volume of the *Transactions and Proceedings*. This was adopted with the deletion of the word "whole."

Clause 5 (*a*) of the Regulations as amended is as follows:

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;

(2.) And of transactions comprising papers read before the incorporated societies or any general meeting of the New Zealand Institute (subject, however, to selection as hereinafter mentioned), and of such other matter as the Board of Governors shall from time to time for special reasons in each case determine to publish, to be intituled *Transactions of the New Zealand Institute.*

7. That it be a recommendation to the Publication Committee to alter the "Memorandum for Authors of Papers" (see p. iii, vol. 49 or 50) by the deletion of the words "Secretary of the society before which it was read," and the insertion therefor of the words "Editor of the *Transactions.*" Adopted.

Metric System.—On the motion of Professor Kirk, seconded by the Hon. G. M. Thomson, it was resolved, That it be a recommendation to authors of papers to adhere as nearly as possible to the metric system in the statements of any weights or measures.

Election of Honorary Members.—A letter to the President from Professor Benham (28/1/19), endorsed by Professors Malcolm and Jack, was received. The Hon. Secretary pointed out that the regulations had been complied with. On the motion of Professor Easterfield, seconded by Mr. Hill, it was resolved, That the President be requested to reply to the letter from Dr. Benham, pointing out that the Hon. Secretary has acted strictly in accordance with the rules laid down by the Board of Governors.

A motion by Professor Chilton, seconded by Mr. Hill, That when vacancies are known to exist in the list of honorary members of the Institute notification of the number of vacancies be sent to the Secretaries of the local societies before the 30th September, was lost.

A motion by Dr. J. A. Thomson, seconded by the Hon. G. M. Thomson, That the Standing Committee prepare a list of vacancies of honorary members and call for nominations from the incorporated societies before the 1st June in each year, and communicate the complete list of nominations to each incorporated society before the 1st September, was lost.

On the motion of Mr. L. Birks, seconded by Professor Thomas, it was resolved, That vacancies in the list of honorary members be announced at each annual meeting of the Board of Governors, and such announcement be communicated as early as possible to each incorporated society, and that each such society nominate on or before the 1st December one person for each vacancy as honorary member, and that the election take place at the next annual meeting of the Board of Governors, notification of the vacancies now on the roll of honorary members to be sent to the incorporated societies at once.

On the motion of Professor Easterfield, seconded by the Hon. G. M. Thomson, Dr. J. W. Mellor was unanimously elected an honorary member of the New Zealand Institute. It was also resolved that Professor Easterfield and the Hon. G. M. Thomson prepare for the Press an account of the life and work of Dr. Mellor.

Election of Officers.—The officers for the year 1919 were unanimously elected as follows: President, Dr. L. Cockayne, F.R.S.; Hon. Editor, Dr. C. A. Cotton; Hon. Treasurer, Mr. C. A. Ewen; Hon. Librarian, Dr. J. A. Thomson; Hon. Secretary, Mr. B. C. Aston.

Election of Committees.—Publication Committee: Professor Kirk, Professor Easterfield, Dr. Cotton, Dr. J. A. Thomson, and Mr. Aston.

Library Committee: Professor Sommerville, Dr. J. A. Thomson, and Dr. Cotton.

Research Grants Committee: Professor Easterfield, Mr. Furkert, and Mr. Aston.

Hector Award Committee: Mr. Elsdon Best (convener), Sir E. Baldwin Spencer, Mr. T. F. Cheeseman, and Dr. J. A. Thomson.

Date and Place of the Next Annual Meeting.—On the motion of the Hon. G. M. Thomson, seconded by Professor Kirk, it was resolved, That the next annual meeting be held in Wellington, it being left with the Standing Committee to fix the exact date.

Expenses of Governors and Hon. Secretary.—It was resolved to pay the expenses of Governors attending the present meeting, as usual, and the Standing Committee were instructed to provide such clerical assistance for the Hon. Secretary as may be necessary.

Hearty Votes of Thanks were accorded to the officers of the Philosophical Institute of Canterbury for their efforts in direction of the Congress, and for the arrangements for holding the annual meeting; to the Chairman of the Canterbury College Board of Governors for the use of the Board room; and to the honorary officers of the Institute for their services during the past year.

PROCEEDINGS OF THE NEW ZEALAND INSTITUTE SCIENCE CONGRESS, 1919,

A SERIES OF MEETINGS OF THE MEMBERS OF THE NEW ZEALAND INSTITUTE, HELD IN THE CANTERBURY COLLEGE BUILDINGS, CHRISTCHURCH, 4TH TO 8TH FEBRUARY, 1919.

INTRODUCTORY NOTE.

By section 9 of the New Zealand Institute Act, 1908, the Board of Governors of the Institute is empowered to make arrangements from time to time for the holding of general meetings of the Institute 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. This section had been inserted in the Act on the suggestion of the late Captain F. W. Hutton.

On more than one occasion the Board of Governors endeavoured to arrange for general meetings of the members of the Institute, but for geographical and other reasons these efforts were not successful.

At the meeting of the Board of Governors at Wellington in January, 1918, the representatives of the Philosophical Institute of Canterbury, acting on behalf of that Institute, invited the New Zealand Institute to hold a series of meetings in Christchurch early in the year 1919. This offer was accepted, and later in the year preliminary arrangements were made and it was decided that, while the Philosophical Institute of Canterbury would be responsible for the local arrangements, the selection of the papers, lectures, and other matters connected with the meeting should be attended to by the New Zealand Institute through its Standing Committee, and a sub-committee of the Standing Committee was appointed for this purpose. Some progress with the arrangements was made, but in November, 1918, owing to the illness of some members of this sub-committee and other causes the Standing Committee requested the Philosophical Institute to take over the whole of the preparations necessary for the meetings, and this the Council agreed to undertake.

At the request of the Council, the Mayor of Christchurch, H. Holland, Esq., had previously convened a public meeting of the citizens of Christchurch to consider what steps should be taken to provide for hospitality to the visiting members and for other local arrangements. At a subsequent meeting a Hospitality Committee, an Excursions Committee, and a Finance Committee were set up, and many offers of assistance were received.

The influenza epidemic during the latter part of the year, and the consequent alteration of the dates of the meeting of the Senate of the New Zealand University and of the Matriculation Examination gave rise to unexpected difficulties, but the meeting was successfully held at the time previously agreed upon, 4th to 8th February, 1919, in the Canterbury College buildings, the use of which had been kindly granted by the Board of Governors and the Professorial Board of the College.

A small handbook containing the provisional programme, the list of officers, and notes for visitors was prepared, and early in January, 1919, was widely distributed among the members of the New Zealand Institute.

Officers of the Congress.

PRESIDENT.

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

HON. SECRETARY.

Mr. William Martin, B.Sc.

EXECUTIVE COMMITTEE.

The Officers and Council of the Philosophical Institute of Canterbury, and the Chairman of the Hospitality, Excursions, and Finance Committees—viz.: Officers and Council of Philosophical Institute of Canterbury (President, Professor C. C. Farr, D.Sc., F.P.S.L.; Vice-Presidents, Messrs. W. H. Skinner and L. P. Symes; Hon. Secretary, Mr. William Martin, B.Sc.; Hon. Treasurer, Dr. Charles Chilton, F.L.S., C.M.Z.S.; Hon. Librarian, Mr. W. G. Aldridge, M.A.; Hon. Auditor, Mr. G. E. Way; Council, Dr. F. W. Hilgendorf, M.A., Messrs. L. Birks, B.Sc., L. J. Wild, M.A., F.G.S., A. V. Mountford, M. H. Godby, M.A., B.Sc., James Drummond, F.L.S., F.Z.S.); Chairman Hospitality Committee, Sir John Denniston; Chairman Excursions Committee, Mr. E. F. Stead; Chairman Finance Committee, Mr. A. Kaye.

HOSPITALITY COMMITTEE.

Sir John Denniston (Chairman), His Worship the Mayor (Mr. H. Holland), Mrs. Carey Hill, Miss R. Tabart, Miss M. Ferrar, Dr. H. T. J. Thacker, M.P., Messrs. R. C. Bishop, H. D. Acland, R. Scott, G. T. Booth, A. W. Beaven.

EXCURSIONS COMMITTEE.

Messrs. E. F. Stead (Chairman), R. E. Alexander, L. Birks, C. M. Ollivier, N. L. Macbeth, H. G. Ell, M.P., R. Speight, R. M. Laing, C. J. Williams, H. F. Skey, H. J. Marriner.

FINANCE COMMITTEE.

Mr. A. Kaye (Chairman), Professor R. J. Scott, Councillors Howard and Flesher, Messrs. B. Seth-Smith, G. Humphreys, A. W. Jamieson, J. Keir, T. J. McBride, William Reece, and Dr. W. P. Evans.

General Meeting, Tuesday, 4th February, 1919, 11 a.m.

Present: Dr. L. Cockayne, President, in the chair, and a large number of members of the New Zealand Institute.

The President announced the general arrangements of the Science Congress.

On the motion of the President, it was decided that the sections, with their officers, be as follows:—

Section 1.—BIOLOGY AND AGRICULTURE.

President, Dr. C. J. Reakes, M.R.C.V.S.; Vice-President, Hon. G. M. Thomson, F.L.S; Hon. Secretaries, Dr. C. Chilton, F.L.S., C.M.Z.S., and Dr. F. W. Hilgendorf, F.G.S.

Section 2.—GEOLOGY.

President, Mr. P. G. Morgan, F.G.S.; Vice-President, Dr. C. A. Cotton, F.G.S.; Hon. Secretary, Mr. L. J. Wild, F.G.S.

Section 3.—CHEMISTRY, PHYSICS, AND ENGINEERING.

President, Professor T. H. Easterfield, F.I.C., F.C.S.; Vice-President, Professor D. M. Y. Sommerville, F.R.S.E.; Hon. Secretaries, Messrs. S. Page, B.Sc., and D. B. McLeod, M.A., B.Sc.

Section 4.—GENERAL.

President, Ven. Archdeacon H. W. Williams, M.A.; Vice-President, Dr. J. Allan Thomson, F.G.S.; Hon. Secretary, Mr. W. Martin, B.Sc.

In view of the recent death of Mr. Hill it was decided not to take advantage of the offer of the Canterbury Aviation School to arrange an exhibition of flying, but to send a letter of appreciation to the directors for their offer and of sympathy with them in the loss of their director.

Dr. Chilton and Dr. Hilgendorf made announcements with regard to the excursions to Arthur's Pass, Riccarton Bush, and Lincoln College respectively.

Several invitations to visit works of scientific or industrial interest round Christchurch were accepted with thanks, also an invitation from the United Club to place the facilities of their grounds at the disposal of the members.

On the motion of Dr. J. A. Thomson, it was decided to hold another general meeting on Friday, 7th February, at 12 noon.

Civic Reception, Tuesday, 4th February, 1919, 11.30 a.m.

His Worship the Mayor of Christchurch, H. Holland, Esq., gave a civic reception to the officers of the New Zealand Institute and to the visiting members in the City Council Chamber. The meeting was largely attended by members of the City Council and by many prominent citizens.

Addresses of welcome were delivered by the Mayor and Dr. C. Coleridge Farr, President of the Philosophical Institute of Canterbury, and were responded to by Dr. L. Cockayne, President of the New Zealand Institute.

Opening Ceremony, Tuesday, 4th February, 1919, 8 p.m.

The chair was taken by the President, Dr. L. Cockayne, F.R.S., and there were present His Excellency the Governor-General, Lady Liverpool, and suite; the Hon. G. W. Russell, Minister of Internal Affairs; His Worship the Mayor of Christchurch (H. Holland, Esq.); the Chairman of the Board of Governors of Canterbury College (H. D. Acland, Esq.); and a large number of members of the Institute and their friends.

The Congress was opened by His Excellency the Governor-General, who in his address called attention to the necessity for scientific research in connection with public health and industries, particularly forestry and fisheries.

The Hon. G. W. Russell, Minister of Internal Affairs, thanked His Excellency for opening the Congress, and said he hoped that the Science Congress would be held annually. He stressed the necessity for the development of the industries, mineral resources, and fisheries of New Zealand, and said that what was required was the creation of a scientific atmosphere throughout the Dominion.

The President then delivered his annual address to the New Zealand Institute (see pp. 485–95).

General Meeting, Friday, 7th February, 1919, Noon.

Present: Dr. L. Cockayne, President, in the chair, and a number of members from the sections.

Resolutions from various sections were received and adopted, as follows:—

Pure Seeds.

1. That this Congress urges upon the Government that no time should be lost in placing on the statute-book a Pure Seeds Act on the lines urged by Government officers, farmers, and dealers for over twenty years past.

Dominion Herbarium.

2. That the Science Congress of the New Zealand Institute considers that a comprehensive herbarium should be established in the Dominion Museum, and that a fully qualified keeper of the herbarium be appointed.

Pronunciation of Scientific Terms.

3. That it is advisable that a Committee of the New Zealand Institute be set up to go into the details and draw up a logical, uniform, scientific system of pronunciation of scientific terms: that the scheme when complete should be adopted by the Institute, and that every possible effort should be made to introduce and explain it in all the University colleges and all institutions where science (even elementary science) is taught, with a view to establishing such uniformity as may be possible.

Uniformity in Biological Language.

4. That a committee be appointed to consider uniformity in biological language, the committee to consist of Professors Johnson, Kirk, Benham, and Chilton (convener).

Soil Survey.

5. That a soil survey be undertaken as soon as possible.

Spray Compounds.

6. That the Government be asked to introduce legislation to provide for the purity and standardization of spray compounds.

Palaeontology.

7. That a Palaeontologist be appointed immediately as a permanent member of the Geological Survey.

Seismology.

8. That seismological instruments of the most modern character be installed in Wellington to replace the present ones.

Astronomy.

9. That the Congress urge on the Government the importance of having systematic tests made of the suitability of sites for astronomical and geophysical observatories, beginning with an investigation of Central Otago.

Meteorology.

10. That the Congress place on record its appreciation of the work of the very numerous voluntary observers in New Zealand who helped meteorological science by daily observations in connection with the Dominion Meteorological Department.

11. That the Congress point out to the Government the desirability of investigation into the climatic winds of the Dominion, and that the assistance of the Meteorological Department be invoked in the matter.

Magnetic Survey.

12. That the desirability of establishing an electrograph at the Christchurch Magnetic Observatory be urged on the Government.

Longitude.

13. That the Congress urge on the Government the importance of New Zealand acting jointly with the Australian observatories in the determination of longitude by radio-telegraphic methods, during the month of May, 1919.

Bench-marks.

14. That the Congress urge on the Government the importance of establishing permanent bench-marks and tide-gauges, and to connect the bench-marks by lines of precise levelling.

Preservation of Fauna.

15. That the New Zealand Institute combine with acclimatization societies in urging the Government to pass fresh legislation to preserve the native fauna, and that the subject be introduced into the State schools.

Standard Time.

16. That the Government be asked to alter the standard time from eleven and a half to twelve hours in advance of Greenwich time.

The Philosophical Institute of Canterbury was asked to draw up a record of the proceedings of the Congress.

MEETINGS OF SECTIONS.

SECTION I.—BIOLOGY AND AGRICULTURE.

TUESDAY, 4TH FEBRUARY, 1919.

Members of this section met in the Biology lecture-room at noon. Present: Hon. G. M. Thomson, Vice-President, in the chair, and several members. Papers for the following day's session were arranged for. The two excursions, one to Lincoln Agricultural College, for agriculturists chiefly, and the other to Riccarton Bush, were decided upon for Tuesday afternoon.

WEDNESDAY, 5TH FEBRUARY, 1919, 10 A.M.

Present: Hon. G. M. Thomson, Vice-President, in the chair, and over thirty members.

An excursion was arranged to the Dyer's Pass Rest-house for the afternoon.

Papers.—"Yellow Flax Disease of *Phormium tenax*," by Dr. L. Cockayne and Mr. A. H. Cockayne

"Seed-testing," by Mr. E. B. Levy.

"The Vegetation of Banks Peninsula, with a List of Species (Flowering-plants and Ferns)," by Mr. R. M. Laing. (Printed in the *Transactions*, pp. 355–408.)

THURSDAY, 6TH FEBRUARY, 1919, 10 A.M.

Present: Hon. G. M. Thomson, Vice-President, in the chair, and a number of members.

Papers.—"Control of Animal-disease in New Zealand," by Dr. C. J. Reakes.

"The Need of a Comprehensive Dominion Herbarium," by Mr. D. Petrie. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 260–62, 1919.)

"Polymorphism in the Common New Zealand Limpet, *Cellana radians* (Gmelin)," by Dr. J. A. Thomson. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 264–67, 1919.)

"A New Discoglossoid Frog from New Zealand (*Liopelma hamiltoni*)," by A. R. McCulloch. (Printed in the *Transactions*, pp. 447–49.)

"The Pronunciation of Scientific Terms in New Zealand, with Special Reference to the Terms of Botany," by Professor A. Wall. (Printed in the *Transactions*, pp. 409–14.)

"A Plea for Greater Simplicity in Biological Language," by Dr. C. Chilton.

FRIDAY, 7TH FEBRUARY, 1919.

Present: Hon. G. M. Thomson, Vice-President, in the chair, and a number of members.

At this session, in order to cope with the number of papers still to be read, it was found necessary to hold separate meetings for the Biology and Agriculture subsections.

Subsection 1a, Biology.

Papers.—"The Status of Entomology in the Economy of the Dominion," by Mr. D. Miller. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 269–73, 1919.)

"Descriptions of New Zealand Lepidoptera," by Mr. E. Meyrick. (Printed in the *Transactions*, pp. 349–54.)

"Notes on the Autecology of certain Plants of the Peridotite Belt, Nelson," by Miss M. W. Betts. (Printed in the *Transactions*, pp. 136–56.)

"A History of Hagley Park, Christchurch, with Special Reference to its Botany," by Miss E. M. Herriott. (Printed in the *Transactions*, pp. 427–47.)

"The Seedling Form of *Helichrysum coralloides*," by Dr. L. Cockayne. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 274–78, 1919.)

"Some Geological Inferences from the Distribution of *Ranunculus paucifolius*," by Professor A. Wall.

"Convergent Evolution in the Crustacea," by Dr. C. Chilton.

"New Zealand Fisheries and their Future Development," by the Hon. G. M. Thomson.

Subsection 1b, Agriculture.

Papers.—Plant-breeding Methods and some Results," by Dr. F. W. Hilgendorf.

"The Control of Succession in Surface-sown Grassland," by Mr. A. H. Cockayne.

"Compatibility of Spraying-mixtures," by Mr. W. C. Morris.

"Nitrification in Relation to the Calcium-carbonate Content of Canterbury Soil," by Mr. L. J. Wild.

ABSTRACT.

The work necessary to the completion of this paper was interrupted at a critical time by an attack of pneumonic influenza. The problem may be briefly stated as follows: It is generally accepted that a good supply of calcium carbonate is necessary in the soil for the efficient carrying-on of the process of nitrification, though it is difficult to say in quantitative terms exactly what amount constitutes a sufficiency. Analyses, of which the results are as yet unpublished, show that the quantity of carbonate of lime in Canterbury Plains soils is small—from 0·1 to 0·2 per cent.—and yet nitrification apparently proceeds at a satisfactory rate, since, so far as we know, ordinary crops are not markedly benefited by supplies of nitrogenous fertilizers. This research aims at determining the effect on the rate of nitrification produced by adding varying quantities of carbonate of lime to typical soils.

"Cold Storage of Fruit," by Messrs. Logan and W. C. Morris.

"Agriculture's Debt to Science," by Sir James Wilson.

SECTION 2.—GEOLOGY.

TUESDAY, 4TH FEBRUARY, 1919, NOON.

Present: Dr. C. A. Cotton, Vice-President, in the chair, and a number of members.

Apologies for absence were received from Drs. Marshall and Henderson, Professor Park, and Messrs. Uttley and Bartrum.

The programme of papers for the meeting of the following day was arranged, and the question of excursions by the section was discussed.

WEDNESDAY, 5TH FEBRUARY, 1919, 9.30 A.M.

Present: Dr. C. A. Cotton, Vice-President, in the chair, and thirteen others.

Excursion.—Mr. Speight announced that he had made arrangements for an excursion to Quail Island in the afternoon.

Papers.—"The Older Gravels of North Canterbury," by Mr. R. Speight. (Printed in the *Transactions*, pp. 269–81.)

"Geological and Palaeontological Notes on the Palliser Bay District," by Dr. J. Allan Thomson.

ABSTRACT.

The Wairarapa limestone, of Waitotaran age, which McKay describes as present on the eastern side of the Wairarapa depression from Cape Kidnappers south to Martinborough, does not continue to Palliser Bay. The probable explanation is that the Haurangi Mountains, consisting of greywackes and argillites, represent a block uplifted along a nearly north–south fault on their east side, and that the continuation of the limestone will be found in the fault-angle to the east. In the Ruakokopatuna Valley, near McLeod's station, along part of which the fault runs, the western side is formed by greywackes and argillites, but the eastern by Wairarapa limestone separated from the underlying greywacke by a thin bed of greensand. This is the first known glauconitic horizon in the Waitotaran, and, as was expected, it yielded new species of brachiopods—viz., *Neothyris* sp. and *Terebratulina* sp.

The mudstones forming the cliffs on the north-west corner of Palliser Bay rest on a thin bed of gritty sandstone containing *Terebratella neozelandica* and *Hemithyris antipodum*, and this in turn rests unconformably on greywackes. The lowest layers of the mudstone contain numerous fossil

mollusca, of Oamaruian and probably Awamoan age, including a form resembling *Struthiolaria tuberculata*, but distinguished by an enormously swollen inner lip. Mudstones considerably higher up in the succession contain a Waitotaran fauna, with such species as *Verconella orbita* (Hutt.), *Cominella purchasi* Suter, and *Pecten delicatulus* Hutt. The succeeding sandy and gravelly beds at the mouth of the Ruamahunga River yield mostly Recent species, including *Pecten delicatulus*.

The nature of the beds and the succession of the fossil faunas in the Palliser Bay district show a close parallelism with those of the Awatere series in Marlborough, and evidently belong to the same diastrophic subdistrict, characterized by a marine transgression commencing near the close of the Oamaruian and extending throughout the Waitotaran, and affecting areas of pre-Notocene rocks not submerged during the lower Notocene transgressions.

Specimens of *Pecten delicatulus* showing clearly the ornament of both valves were obtained both from Palliser Bay and from mudstones intercalated in the Wairarapa limestone at Twaite's cutting, near Martinborough. These show that the assumption of Hutton, which was accepted by Suter, that *Pecten difluxus* is a synonym of *Pecten delicatulus* cannot be upheld, and the former must therefore be regarded a valid species. There is a Recent specimen in the Dominion Museum, labelled "New Zealand," which appears to be *Pecten delicatulus*.

Thursday, 6th February, 1919.

Present: Mr. P. G. Morgan, President, in the chair, and twelve others.

Votes of thanks were passed to Mr. Speight for arranging and conducting the excursion to Quail Island, Lyttelton, and to Dr. C. Coleridge Farr for assistance with the lantern.

Papers.—"The Significant Features of Reef-bordered Coasts," by Professor W. M. Davis: communicated by Dr. Benson. (Printed in the *Transactions*, pp. 6–30.)

"Rough Ridge, Otago, and its Splintered Fault-scarp," by Dr. C. A. Cotton. (Printed in the *Transactions*, pp. 282–85.)

"Geography: Some Educational Aspects of the Subject," by Mr. E. K. Lomas. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 282–85, 1919.)

"Report of a Committee on the Natural Features of the Arthur's Pass Tunnel," by Dr. F. W. Hilgendorf. (Printed in the *Transactions*, pp. 422–26.)

"Range of Tertiary Mollusca in the Oamaruian of North Otago and South Canterbury," by Dr. J. A. Thomson.

ABSTRACT.

The Oamaruian is divided into five stages, four of which are marine at Oamaru and contain fossil molluscs. A very large number of fossils have been collected from the Oamaru, Waitaki, Waihao, Pareora, and Kakahu districts by officers of the Geological Survey and others, and have been determined by the late Mr. H. Suter. The plotted lists exhibited show the range of each species for each of these several localities. The majority of species found in the lowest, or Waiarekan, stage are also present in the highest, or Awamoan, stage, but there is a small proportion confined to single stages. This is particularly so in the case of the Awamoan stage, but

the collecting, especially by Marshall in the Oamaru district, has been much more exhaustive for this stage than for any of the others. The difference in station of the species found in the Ototaran and Hutchinsonian probably accounts for the absence in these stages of many species common to the Waiarekan and Awamoan, and also for the presence of other species absent from the two last-named stages. The general result of the analysis is to show that the molluscan fauna did not change greatly during the Oamaruian, and hence distant correlations with individual stages based solely on mollusca are difficult to establish. A closer study of the fossils on evolutionary lines might lead to the discrimination of species now lumped together which might prove to have a zonal value.

"The Geology of the Middle Clarence and Ure Valleys, East Marlborough, New Zealand," by Dr. J. A. Thomson. (Printed in the *Transactions*, pp. 289–349.)

FRIDAY, 7TH FEBRUARY, 1919.

Present: Mr. P. G. Morgan, President, in the chair, and a number of others.

Papers. "A Quantitative Study of the Silica-saturation of Igneous Rocks," by Dr. J. A. Thomson.

ABSTRACT.

Variation curves for chemical constituents (mainly oxides) plotted against silica have been given by Harker for Pacific and Atlantic rocks, but trial plottings of a large number of analyses show that the points representing given rocks group themselves together into curved belts (a sort of Milky Way) and do not tend to lie on lines, as Harker's diagrams might suggest. If these belts could be sufficiently defined by the plotting of all reliable analyses, each rock could be then classified as abnormally high, normal, or abnormally low for each chemical constituent compared to silica, and a valuable means of comparing rock-analyses would result. The combination of all such classifications for each important constituent, however, would yield more classes of analyses than there are superior analyses and would be cumbersome. The attempt has therefore been made to obtain a small number of functions of the analyses combining relationships between various oxide molecules such as exist in minerals. A norm somewhat similar to that of the American classification has been adopted, but in order to avoid the difficulty of attempting comparisons of such related molecules as orthoclase and leucite, albite and nepheline, hypersthene and olivine, in which the second mineral in each of the groups named is undersaturated in silica, it has been assumed in calculation that unlimited silica is available. The amount of silica actually used in satisfying the various bases on the assumption of complete silica-saturation is then compared with the amount shown to be actually present by the analysis, and a percentage figure is obtained expressing when positive the amount of free quartz present in the norm, and when negative the degree of undersaturation of silica. A further difference from the American norm is also the calculation of excess Al_2O_3 and Fe_2O_3 to hydrous silicates $Al_2O_3.SiO_2.2H_2O$ and $Fe_2O_3.SiO_2.2H_2O$, since alumina and ferric iron control at least an equivalent of silica in the alferric minerals after possible feldspars and metasilicates have been calculated. By this means a quantitative estimate of silica-saturation for any rock-analysis is obtained. This in turn is plotted against total silica, and a variation belt obtained as in the case

of the oxides. Other functions used are the total feldspars (calculated on the assumption of unlimited silica), the total metasilicates, and the iron-ores and minor accessories. A trial plotting of the feldspars has not shown very definite grouping into a belt, and if a further series of analyses does not remedy this defect it will be necessary to seek for other functions of the analyses which do satisfactorily group themselves.

About a thousand analyses have been calculated and plotted, but some years ago the research was laid aside in view of the anticipated early publication of the second edition of Washington's *Superior Analyses of Igneous Rocks*, which would render unnecessary the individual collation of analyses from original papers. This publication was, however, delayed by the war, and has not yet reached New Zealand. It is hoped to resume and complete the research by the aid of a Government research grant. Meanwhile it is of interest, in view of recent discussion of silica-saturation from the qualitative point of view, to point out that a quantitative study could easily be made.

"The Tectonic Conditions accompanying the Intrusion of Basic and Ultra-basic Igneous Rocks," by Professor W. N. Benson.

"Notes on the Mechanical Composition of the so-called Loess at Timaru," by Mr. L. J. Wild. (Printed in the *Transactions*, pp. 286–88.)

"The Organization and Functions of a State Geological Survey," by Mr. P. G. Morgan. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 289–99, 1919.)

Resolutions.—The following resolutions were adopted:—

1. "That the Government be urged to appoint a Palaeontologist as a permanent member of the Geological Survey at the earliest possible opportunity, such an officer being essential for the proper carrying-on of any geological survey." (Proposer, Mr. R. Speight; seconder, Dr. C. A. Cotton.)

2. "That this meeting urges upon the Government the importance of instituting a seismographic installation of the most modern type, as the instruments used in New Zealand at present, though giving very useful information, are not capable of work of the highest character." (Proposer, Professor W. N. Benson; seconder, Dr. C. A. Cotton.)

SECTION 3. CHEMISTRY, PHYSICS, AND ENGINEERING.

Wednesday, 5th February, 1919, 10 a.m.

Present: Professor T. H. Easterfield, President, in the chair, and a number of others.

Papers.—"An Improved Planisphere," by Professor D. M. Y. Sommerville. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 193–95, 1919.)

"Tables of Mathematical Functions," by Dr. C. E. Adams.

"The Leather Industry," by Mr. A. V. Mountford.

Thursday, 6th February, 1919, 10 a.m.

Present: Professor T. H. Easterfield, President, in the chair, and many others.

Papers.—"The New Zealand Climate," by Mr. F. L. Wooles.

"The North-west Winds of Canterbury," by Mr. H. F. Skey. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 300–1, 1919.)

"The Harmonic Analysis of Tidal Observations and the Prediction of Tides," by Dr. C. E. Adams.

ABSTRACT.

Practically all existing methods used for the harmonic analysis of tidal observations have many numerical approximations employed in their practical applications. It therefore becomes difficult to determine whether the method of harmonic analysis gives the best representation of the tide curve.

In the method here described no arithmetical approximations are used, so that a criterion is obtained to test the application of Fourier's series to tidal observations.

A description is given of the method of prediction of tides used in New Zealand. An illustrated description of this process appeared in the Survey Reports of the Lands and Survey Department for the years 1910–14, and to these reports reference should be made for the details. The process is a graphic one, controlled by calculation. The results of the predictions for Wellington and Auckland are published in the *New Zealand Nautical Almanac* by the Marine Department.

"A Slide-rule for solving the Quadratic Equation," by Professor D. M. Y. Sommerville.

"Porosity of Porcelain Insulators," by Dr. C. C. Farr. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 302–7, 1919.)

"Interference of Power Circuits with Telephone Circuits," by Mr. E. Parry. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 308–14, 1919.)

"The Effect of Low Power-factor from the Standpoint of Electric-power-station Operators," by Mr. E. E. Stark. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 314–17, 1919.)

FRIDAY, 7TH FEBRUARY, 1919, 10 A.M.

Present: Professor T. H. Easterfield, President, in the chair, and a number of others.

Papers.—"National Hydro-electric Schemes for New Zealand," by Mr. H. Hill.

"Exhibit of Photographs on Glass of Solar Corona, taken by Lick Observatory, 8th June, 1918, at Goldendale, Washington, U.S.A.," by Dr. C. E. Adams. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 317–19, 1919.)

"Determination of the Position of the Moon by Photography, and Exhibit of Photographs of the Moon and Surrounding Stars," by Dr. C. E Adams.

ABSTRACT.

An exhibit was made of photographs, taken at the Lick Observatory, of the moon and surrounding stars, to determine with great accuracy the position of the moon. This work was undertaken to enable Professor E. W. Brown, the eminent mathematical astronomer at Yale, to check his new tables of the moon. On the original plates stars as faint as the tenth

magnitude were successfully photographed at full moon. The exposures were usually 4 minutes on the stars, then ⅓ second on the moon, and then another 4 minutes on the stars. The excellent star-images secured speak well of the Crossley reflector telescope, which was driven without any guiding, and the photographs prove that the position of the moon and terrestrial longitude can be determined with high precision.

"The Almucantar Method of Observation for the Determination of Time and Latitude," by Dr. C. E. Adams.

"A Nomogram for Transit Instrument Star Factors," by Dr. C. E. Adams.

SECTION 4.—GENERAL.

Wednesday, 5th February, 1919, 10 a.m.

Present: Archdeacon H. W. Williams, President, in the chair, and many others.

Papers.—"Moriori Art," by Mr. H. D. Skinner.

"Some Notes on the Language of the Chatham Islands," by Archdeacon H. W. Williams. (Printed in the *Transactions*, pp. 415–22.)

"The Natural Laws of Poetry," by Mr. J. C. Andersen. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 320–39, 1919.)

Friday, 7th February, 1919, 9.30 a.m.

Present: Archdeacon H. W. Williams, President, in the chair, and many others.

Papers.—"Afforestation in New Zealand," by Mr. W. H. Skinner.

"Some Proposals with regard to Natural Afforestation in a New Zealand Mountain Area," by Mr. W. G. Morrison. (Printed in the *N.Z. Journal of Science and Technology*, vol. 2, pp. 339–49, 1919.)

"Preservation of New Zealand Fauna," by Mr. E. G. Stead.

Discussion.—"Daylight-saving," by Dr. C. E. Adams.

PUBLIC EVENING LECTURES.

Wednesday, 5th February.

"Vestiges of the Primeval Plant World," by the Rev. Dr. J. E. Holloway.

Thursday, 6th February.

"Mountain Sculpture," by Dr. C. A. Cotton.

"Mountain Structure," by Professor W. N. Benson.

Friday, 7th February.

"The Influenza Epidemic," by Dr. A. B. Pearson.

GARDEN PARTY.

On Thursday afternoon, 6th February, 1919, Mr. and Mrs. E. F. Stead gave a garden party to the members of the Institute at their residence at Ilam, Riccarton. There were present His Excellency the Governor-General, Lady Liverpool, and suite, the President of the Congress (Dr. L. Cockayne, F.R.S.), His Honour Sir John Denniston, the Mayor of Christchurch (H. Holland, Esq.), Mrs. Luke (Mayoress of Wellington) and other visiting Red Cross Council delegates many officers and members of the Institute, and a large number of citizens of Christchurch. The beautiful lawns and garden, with its fine representation of native plants and its winding paths exhibiting glorious hydrangeas growing on the river-banks, were much enjoyed by the visitors, and combined with the brilliant sunshine, music, and the social intercourse to make the occasion memorable.

EXCURSIONS.

During the Congress excursions were made to the hydro-electric power-station at Lake Coleridge, to the Agricultural College, Lincoln, to Riccarton Bush, and to Dyer's Pass on the Port Hills.

Geological excursions were made to Quail Island, Lyttelton Harbour, and to Grey River.

Other excursions were made by different members to various places of scientific and industrial interest in the vicinity of Christchurch.

PRESIDENTIAL ADDRESS.

By L. Cockayne, Ph.D., F.R.S.

Your Excellencies, Ladies and Gentlemen.—At those great Science Congresses held by the British Association for the Advancement of Science —the mother of such associations throughout the world the President has dealt not infrequently with the more recent history of scientific advance in that special branch of knowledge which is his life-work. At future public meetings of the New Zealand Institute addresses of like character would be most desirable. The history of New Zealand science itself in its various branches would be of especial moment and form a basis for further advance. But on this occasion—the first time, indeed, that the New Zealand Institute since its initiation has come before the public—it seems fitting rather to deal, but of necessity briefly, with the history of the Institute itself, touching on its modest beginnings, its past achievements if I dare so call them—and its activities at the present time. Then I shall say something about what I take to be the aspirations of the Institute, and its aims.

To the great majority of the people of this Dominion the New Zealand Institute is at best but a name. The world over, the incalculable benefits of science are accepted without a thought as to how or from whom such benefits are derived.

This present time is assuredly a critical period in the history of mankind ; it is even a critical period in the history of this wonderful New Zealand, endowed though she be with an infinity of riches and potentialities for greatness. At no time in the history of the British Empire has the untiring prosecution of science been more urgently demanded.

As for New Zealand, it is not sufficient to rely upon investigations carried on beyond her borders. She has her special problems, which can be solved only upon her own soil, and which ought surely to be investigated by her own sons and daughters. It is essential, then, that the sole scientific body of the Dominion—the New Zealand Institute—should get into much closer touch with the people, and that the relation of the Institute to the progress of the Dominion, both materially and intellectually, should become more fully understood.

The New Zealand Institute had its beginnings in certain small societies which were formed at Nelson and Wellington respectively in the early days of those provinces. The colonists had brought with them the freedom and the manners and customs of the Motherland, and, so equipped, their intention was to form a Britain in this far south. Evidently some of these colonists were not forgetful of those splendid British learned societies which had their origin in that small coterie—soon to become the Royal Society—which met in London in 1651, even while the Civil War was raging. Therefore quite early certain scientific bodies were established. The Nelson Society yet remains as the Nelson Institute. The New Zealand Society founded in Wellington in 1851 by Sir George Grey soon became defunct owing to the departure of its gifted founder from New Zealand. In 1859 a new society, but bearing the same name, was formed in Wellington. Some years later, at the instance of Bishop Abraham, the name was changed to the "Wellington Philosophical Society." In 1862 the Philosophical Institute of Canterbury was founded, and, later on, the Auckland Institute. All the above bodies had as their main, though not their sole, object the prosecution of scientific research. Amongst the earliest workers the names of Buchanan, Buller, Colenso, Haast, Hector, Monro, Sinclair, and Travers stand out prominently. These small societies were greatly hampered not only through lack of funds, but for want of a local journal in which the results of the investigations of their members could be published. This crying need was met by the establishment in 1867 of the New Zealand Institute by means of an Act of the General Assembly. The Institute as thus constituted consisted of a Board of Governors, three of whom were members *ex officio*, six were nominated by the Government, and three were elected by the Board of Governors from nominees of the incorporated societies. Dr. (afterwards Sir James) Hector, F.R.S., was appointed Manager—a position unknown in learned societies in general. This important post he filled most ably until his retirement from the Public Service in the year 1903.

The societies originally incorporated with the New Zealand Institute were the Wellington Philosophical Society, the Auckland Institute, the Philosophical Institute of Canterbury, and the Westland Naturalists' and Acclimatization Society. A year later (1869) the Otago Institute was incorporated, and in 1874 and 1875 the Hawke's Bay Philosophical Institute. Each incorporated society had by statute to consist of "not less than twenty-five members, subscribing in the aggregate a sum of not less than fifty pounds sterling annually for the promotion of art, science, or such other branch of knowledge for which it is associated." Moreover, each incorporated society had to spend not less than one-third of its annual revenue towards a local public museum or library, or towards the extension or maintenance of the museum and library of the New Zealand Institute.

This provision has led to the building-up of scientific libraries in Auckland, Wellington, Christchurch, and Dunedin, which, though inadequate for many classes of research, have been and still are of no small benefit to New Zealand science.

The most important feature of the New Zealand Institute was, however, that it provided, and at first adequately enough, for the publication of scientific papers of all kinds. This was made possible by a statutory grant of £500 per annum—quite a bold step for a young colony, and one which showed great foresight in the Government of the day. The publications were to consist of *Transactions of the New Zealand Institute* and *Proceedings of the New Zealand Institute;* the latter was to give a current abstract of the proceedings of the incorporated bodies and the former to consist of selected papers read before them. These two publications are issued in one volume under the title *Transactions and Proceedings of the New Zealand Institute*, which, in citation, is usually limited to *Transactions of the New Zealand Institute*, as the *Proceedings* are at best of mere local or ephemeral interest. So far fifty volumes have been published—*i.e.*, a volume every year since 1869.

In addition to publishing scientific papers and forming a library, the Institute at first had control of the Colonial Museum, the Colonial Laboratory, and the meterological records. All the above were under the direction of Dr. Hector, who was also Director of the Geological Survey.

The inaugural meeting of the New Zealand Institute was held on the evening of the 4th August, 1868, "when" (so read the minutes of the meeting) "many members of various local societies for the promotion of art and science assembled to listen to the inaugural address of the Governor," who at that time was *ex officio* President of the Institute. In his prefatory remarks His Excellency, referring to the presence of so many members of the Legislature while an important debate was in progress in the House of Representatives, said their presence was "a proof that the attractions of intellect and science could even triumph over the excitement of politics." After His Excellency had delivered his address, which may be seen in volume 1 of the *Transactions of the New Zealand Institute*, Mr. Fox delivered a truly eloquent speech. I should like to quote it in full, but must be content with a few extracts. Everywhere, he said, describing what he had seen during his recent visit to Europe and Asia, the mighty developments of Western civilization were marvellous. It was something to see in Egypt—the cradle of learning, and the tomb of a past civilization—Western Europe taking back to her the results of a little seed which ages ago had been sown on the banks of the mighty Nile. In Greece the same metamorphosis was in progress. Rome, too, was being elevated from its ruins. We in New Zealand were not behindhand, the speaker declared, but were engaged in the heroic work described by Lord Bacon—we were here to lay the basis of a true civilization: not only to subdue nature and till the soil, but, impelled by Anglo-Saxon ardour and energy, to develop all that was worthy of development.

The first volume of the *Transactions of the New Zealand Institute* appeared in May, 1869. In the preface is a list of thirty-one subjects which the Editor suggested should be dealt with by the various incorporated societies. Most of these subjects are strictly utilitarian—*e.g.*, fisheries, best localities and seasons for fishing; habits of animals, especially of those destructive to trees and cultivated plants; plants suitable for live fences in this country; experiments in the improved breeding of stock; plans and descriptions of mines; harbour improvements; proposed lines of railway; machines and processes for washing sheep; adulteration of food. It rather looks as if the Manager were attempting to camouflage the public: even meteorological phenomena has the word "extraordinary" before it, while plants or animals to be of interest must be "rare." There is hardly a mention of those subjects which have filled most of the fifty volumes!

In the year 1903 Sir James Hector resigned the Directorship of the Museum and the Geological Survey, and with these the position of Manager of the Institute. For a number of years the members of the incorporated societies had been dissatisfied with their scanty representation on the Board of Governors and their right of nomination only. Consequently the retirement of Hector gave a chance for the Institute to be reconstructed. The matter was taken up, in the first place, by the Philosophical Institute of Canterbury, which, supported by the other societies, succeeded in getting a new Act passed in 1903 by which the major societies each elected two Governors and the minor societies each one Governor. Thus at the present time the nine affiliated societies are represented by thirteen members, there are two *ex officio* members (His Excellency the Governor-General and the Hon. the Minister of Internal Affairs), and there are four members nominated by the Government. Instead of there being a permanent Manager, the Governors must elect a President, who need not of necessity be one of themselves. The above and other regulations which need not be detailed put the New Zealand Institute on an entirely new footing. No longer was the policy to be directed entirely from Wellington; no longer was the supreme power to be in the hands of one alone—no matter how capable—but the whole Dominion could take a hand; in short, from autocratic the Institute became democratic.

The first President of the reconstructed Institute was the late Captain F. W. Hutton, F.R.S. What he has done for New Zealand science need not be told to a Christchurch audience. He was succeeded by the late Sir James Hector, F.R.S., a fitting compliment to one who had virtually founded the Institute, raised it to a proud position amongst the learned societies of the world, and gained an honoured name amongst the scientific men of the last century. Next came the Hon. G. M. Thomson, F.L.S., whose connection with the Institute dates from 1872. He has published many excellent papers, both zoological and botanical, one of the latter, dealing with the pollination of New Zealand plants, being a classic. Further, above all, in season and out of season has Mr. Thomson striven to advance the cause of science. Then the late Mr. Augustus Hamilton occupied the chair, a man of wide knowledge with many scientific interests: the author, too, of that splendid pioneer work *Maori Art*. Then came New Zealand's premier botanist, Mr. T. F. Cheeseman, F.L.S., who has been a member of the Institute since its foundation, and whose first paper in the *Transactions* appeared in 1871, in the fourth volume. But not in pure science alone is Cheeseman truly great; under considerable difficulties he has built up the admirable Auckland Museum. After Cheeseman came Professor Charles Chilton, D.Sc., C.M.Z.S. Since he first joined the Institute in 1881 he has year by year added to the world's knowledge of the Crustacea, so that now he is the foremost authority of the day on that group so far as the great Southern Hemisphere is concerned. Mr. Donald Petrie, M.A., was the next President. He has done much for the Institute. Paper after paper shedding a flood of light on the New Zealand flora he has produced since the year 1879. He and the Hon. G. M. Thomson were the first to explore Stewart Island scientifically. Furthermore, Mr. Petrie is the leading authority on the classification of New Zealand grasses. Then (1916–17) Professor W. B. Benham, F.R.S., occupied the chair. He was the first representative of our men of science who had come much later into the Institute than the foregoing. His scientific work in New Zealand broke new ground when he carefully studied the earthworms and through this study threw great light on the relation of the New Zealand biological world to that of South America.

Perhaps the most noticeable change brought about since the reorganization of the New Zealand Institute has been a considerable improvement both in the matter and in the mode of presentation of the papers published. The greater number of the papers which have appeared of recent years would have been accepted by the scientific journals of Great Britain or America, if the numerous papers strictly of local interest be excluded from this estimate.

This too brief history of the New Zealand Institute has cleared the path for an account of what the Institute has done towards advancing science. This can be seen, in part, by giving a few statistics regarding the papers which have appeared in the fifty volumes of the *Transactions*.

To begin with, the total number of papers in the fifty volumes is 3,117, making about sixty contributions each year. The above estimate does not include abstracts of communications published in the *Proceedings*; if such are considered, the contributions of all kinds exceed four thousand. The whole of these papers, many the results of months of toil, have been produced without pay of any kind, while many have represented no small monetary outlay. Only a few of the authors were professional scientific men; most were daily engaged in other pursuits—they had only their few hours of leisure for study and research. All classes of the community have borne their share in the labour of love: there are contributions by more than one Governor of the colony; there are others by working-men. Class distinctions cease to be in the pages of these historic volumes. Taking the papers themselves, there are certainly various degrees of merit. Some have gained a place in the select scientific literature of the world—no mean achievement—while a few should never have been published. Generally speaking, there are not many papers which do not fill a want, and as a whole they shed a strong light upon the natural history of New Zealand, and tell not a little regarding the general progress of the Dominion. Surely no five hundred pounds yearly of the people's money has been spent more profitably or more for the benefit of the people themselves than that which has produced these fifty volumes.

If an analysis be made of the contents of the fifty volumes, using the same classification of subjects as in the index to the first forty volumes, except that the two headings "Trade" and "Economics" are united under the latter name, the following is the result, the number after each subject denoting the number of published contributions: Zoology, 1,143; botany, 654; geology, 503; anthropology, 204; physics, including astronomy and meteorology, 152; chemistry, 135; engineering, 76; mathematics, 40; economics, 37; history, 34; presidential addresses, 29; metaphysics, 22; medicine, 20; literature, 15; education, statistics, and obituary notices, 12 each.

Certain of the above numbers do not reflect accurately the scientific output of members of the Institute. At times specially important papers have been published in scientific journals of Great Britain. Geology since the very early days of the colony has had State assistance, and much research has found its way into Government publications. So, too, the Departments of Agriculture and Lands have published a good deal which otherwise would have found its way into our *Transactions*. In the case of anthropology, the excellent *Polynesian Journal* has published much which otherwise would have come before our Institute.

A consideration of the statistics given above shows clearly that natural history, using that term in a broad sense, fills the greater part of the volumes. This was to be expected in a new land with both the fauna and the flora so little investigated and containing so much that is endemic. Also, if the papers on zoology and botany be referred to, it will be seen that by far the greater part are devoted to classification. This must have been so; it is the natural evolutionary process in the history of biological research the world over. But even in New Zealand this stage is passing away, and in botany the ecological study of the vegetation as opposed to the floristic study of the species is making headway, and is even being applied to economic ends—another step in the evolution of a science. So, too, in zoology, animal ecology, a more difficult study, is also coming to the fore. Botany with its 654 papers apparently makes a poor showing alongside zoology with its 1,143 contributions. It must be remembered, however, that there are many groups of animals, and frequently a worker confines himself to one group. Also, a considerable number of papers deal with birds, a subject in which so many people take an interest who really care little for science as a whole. As for chemistry and physics, which make but a poor showing in the work of the New Zealand Institute, it must be pointed out that little progress can be made in these sciences without well-equipped chemical and physical laboratories and men specially trained in such. Laboratories of this class are now attached to the various University colleges, and chemical and physical contributions—the work of trained students—are slowly but surely finding a place in the *Transactions*.

The *Transactions* have not been the sole publication of the Institute, by any means. Thus there are the magnificent volumes of Hamilton's *Maori Art;* Major Broun's *Manual of the Coleoptera* and his three bulletins on the same group; H. N. Dixon's *Studies in the Bryology of New Zealand* —an important revision of our moss-flora: and Tregear's *Mangarera Dictionary*. Then, the Canterbury branch of the Institute has published the *Index Faunae Novae-Zealandiae*, and the admirable *Subantarctic Islands of New Zealand*, a work in two quarto volumes with many beautiful illustrations

The New Zealand Institute has control of the Hutton and the Hector Memorial Funds. With regard to the former a bronze medal is awarded every three years for original research in New Zealand zoology, botany, or geology. There is also a small income from the fund, from which grants are made for purposes of research. The Hector Fund also supplies a medal, but with this goes the yearly interest of the fund—some £45—as a prize. Medal and prize are alloted yearly, but each year to a different science, six sciences being included. Thus the medal for any particular science is awarded only every six years. Three Hutton and seven Hector medals have been awarded up to the present time. These medals have already done a good deal to stimulate research; as year succeeds year the value of these awards will greatly increase.

The influence of the New Zealand Institute has been very considerable on New Zealand science other than that under its actual control. There is no Government Department connected in any way with science which is not constantly indebted either to the publications or libraries of the Institute. The following important works would never have appeared had there been no New Zealand Institute: Kirk's *Forest Flora*, Kirk's *Students' Flora*, Cheeseman's *Manual of the New Zealand Flora*, and Suter's *Manual of the New Zealand Mollusca*. So, too, with many important papers and reports issued by various Government Departments.

Certainly, training is given by the various University colleges in some of the sciences, but the very nature of their relation to that purely examining body—the New Zealand University—reduces to a minimum the value of these colleges as a training-ground for the all-important scientific research. This crying want is supplied to some extent by the New Zealand Institute, whose *Transactions* are open for papers from young aspirants for scientific research if they appear to show aptitude at all. Had it not been for this, scientific career after career would have been stifled at its birth.

The meetings, too, of the incorporated societies are not mere gatherings for specialists. They are open to the public, and popular lectures are frequently delivered by the leading scientific men of the Dominion. Nor are the ordinary evenings devoted to original papers barren for the student or even for the non-scientific listener. To hear a master of his subject detailing the methods, objects, and results of his research is most inspiring. Mere technical papers are taken as read; any one is free to ask questions after the reading of a paper, and illuminating discussions may ensue. Finally, the student comes into personal touch with those working at that branch of science he would pursue if he knew how; he is inspired by the enthusiasm of the older worker; friendships beneficial to science may arise which endure for life.

The various activities of the New Zealand Institute have been supported by the statutory grant of £500 per annum, an amount deemed necessary by the Government in 1868. However, the population of the Dominion has greatly increased during the subsequent fifty-one years, and so, too, in proportion the monetary requirements of the Institute. So acute has the position become that for some time past it has been necessary to make a levy of about £200 on the affiliated societies, who, with their responsibilities for their local museums or libraries, to say nothing of their other activities, could ill bear the imposition of such a burden. Many papers of great value await publication; much work of national interest awaits its initiation; but there are hardly funds sufficient to publish the *Transactions*. Happily, more than a gleam of hope appears. The Hon. Mr Russell is not unmindful of the call of science; full well does he know its inestimable value to the nation. Already has he greatly assisted the Institute by special grants for economic science, and now he has promised to do his utmost to place the New Zealand Institute on a firm financial footing. Thus it seems not unlikely that this Congress heralds a new era of usefulness for the Institute.

The New Zealand Institute possesses a library of scientific works, at present housed in that worn-out wooden building—a true fossil—called "the Dominion Museum." The *Transactions of the New Zealand Institute* since their commencement have been sent to a great number of the leading scientific bodies throughout the world. These in like manner send the Institute their publications. It stands out clearly, then, that an important collection of scientific literature is in the possession of the Institute, and that it is being added to year by year. For years there have been no funds for binding, the resources of the Institute having been strained to breaking-point to pay the rapidly-increasing cost of its *Transactions*. The Museum authorities certainly do their best to make the library available for scientific workers, but any one who has occasion to use it knows that it is of little benefit. This the Board of Governors fully realized some time ago, and an offer was made by them to the Government, which was accepted, to hand over the library as a nucleus of a real scientific library as soon as a proper building was erected and a qualified librarian appointed. Nothing has been done as yet—with a war raging it was not to be expected—but we live in hope. With the power of exchange possessed by the New Zealand Institute through its *Transactions* virtually all the publications of every scientific society throughout the world could be acquired. But this would not be enough, for equally important are the many scientific journals which can only be acquired by purchase. Then there is the host of books, constantly appearing, essential for scientific progress. Obviously, the maintenance of such a library is far beyond the income of the Institute, were that quadrupled. But the Institute could supply the lion's share of the acquisitions. Much also could be done by the various scientific Departments of the Government, whose libraries should also be added to this central library. I do not know of anything that is so greatly needed for scientific research as such a library, and if it were only of one-half the value to the nation which I am claiming for it this evening no money should be less grudged by the people, and no money would be better invested. As it is, every serious worker must at his own expense greatly supplement the scanty literature available; this has been done for years willingly, and it will continue to be done, but it does not seem to me an altogether creditable state of affairs.

This fundamental question of an adequate scientific library leads me at once to other aspirations of the New Zealand Institute—that body of scientific folk, and believers in science, who are banded together to add something to human knowledge and to advance thereby the interests of this glorious country of which they are citizens. Next to provision for the library, the Institute desires recognition by the people of New Zealand as a body devoted entirely to their interests, both material and intellectual—a body ready at any time to advise the Government on scientific matters, and to assist to the utmost in any national service for which science is required.

In the early days of the Institute most of the scientific workers were amateurs. These, it is true, were endowed with the holy fire of enthusiasm, but had their limitations nevertheless. At the present time highly trained men—not holders of degrees merely, but men trained by years of experience in research—most of them New Zealand born—are fully competent to undertake almost any scientific investigation. To one like myself, growing old, it is a joy to see how many capable young men belonging to our Institute have come to the front of recent years.

Before dealing specifically with certain branches of research which I think might well be undertaken by members of the Institute, or others in this country who ought to be members, I must say something regarding the separation of science into the two classes, "pure" and "applied," as they are called, the former at best merely tolerated by the public, who value a scientific discovery only if it has an evident practical bearing. This state of mind would certainly kill all advance. If carried out for a sufficient time throughout the world civilization would not merely remain at a standstill, but deterioration would rapidly set in. The purely scientific must come first, and the practical, without any special coddling by the State, will assuredly follow. The cure of an infectious disease is only the last link—for the time being—in a long chain of researches nine-tenths of which were purely academic, but each leading slowly but surely to the final result. And this great wealth of research—apparently medical—was the work of the biologist, the chemist, and the physicist. The electric tram, the frozen lamb, the marconigram, the spraying of an apple-tree, the moving picture, the field of turnips—all these and far more of our every-day life are but the final—again I say, "for the time being"—practical application of exact knowledge painfully acquired by enthusiasts such as Michael Faraday—the mighty, the maker of history—with his £100 a year, a room or two to live in, and coals and candles! "Faraday's early investigations on the chemical aspects of electrolysis," wrote in March, 1918, Professor Pope, President of the Chemical Society, "and his studies on magnetic induction, led immediately to the invention of the dynamo, and, through Clerk Maxwell, to the introduction of wireless telegraphy. This one branch of Faraday's investigations, in point of fact, constitutes the groundwork of the whole stupendous vista of results of the general introduction of the electric current into modern life which is so familiar to us all. Cavendish's early production of nitric acid by the passage of an electric spark through the air, reproduced on an enormously large scale, is now furnishing Central Europe with the nitric acid without which no explosives could be manufactured." The Faradays of the present day, instead of being able to devote all their time to research, in order to get their daily bread are forced to waste their time as teachers. For this fair wages are available; for the prosecution of pure science there is usually nothing, unless temporarily, and that for inexperienced young men.

On this matter of pure and applied science let me quote a resolution of the Inter-Allied Conference on International Scientific Organizations held by the Royal Society during October, 1918. Thus the resolution runs: "The Conference, being of opinion that all industrial, agricultural, and medical progress depends on pure science, draws attention of the various Governments to the importance of theoretical and disinterested researches, which after the restoration of peace should be supported by large endowments. The Conference urges similarly the creation of large laboratories for experimental science, both private and national."

New Zealand is above all else a farming community. Many of Nature's secrets of a hundred years ago are now the priceless possessions of man. These when more generally applied than at present will make our fields yield a much greater return. This would be a great advance, but without the discovery of further fundamental principles, now unknown, agriculture can only reach a stage far from perfection. Our scientific duty as a nation is not only to apply to the best of our ability our present knowledge, but by means of purely academic investigations to discover further fundamental principles on which the greatly improved farming of the future will depend. Suppose, for example, such characters as we wished could be bestowed at will upon certain fodder plants or food plants—*i.e.*, that the plant-breeder could by methods now unknown create exactly the plant suitable for a special environment, just as one can forge a special tool. Experiments of seemingly the most worthless kinds in genetics might lay the foundation for such knowledge, the value of which is beyond our wildest dreams. Even open-air studies on the plants of bog, or lake, or forest, or mountain-top well might lend valuable assistance.

Finally, with regard to the New Zealand Institute—and, indeed, with regard to this Dominion's science in general—what should be some of our immediate aims, having regard to those special New Zealand problems which early in this address I declared could only be carried out on New Zealand soil? In this farming community nothing more demands years of close study than this soil itself. The world over, soil science, notwithstanding many books on the subject, is in its infancy. Chemical analysis of a soil, even were the methods for so doing far more satisfactory than at present, is only one portion of the question. The extremely difficult matter of soil-physics at once confronts the investigator. Then there is the rich soil-flora and the rich soil-fauna. When more of a fundamental character is known as to the relation of soil-physics, soil-chemistry, and soil-biology to one another, then undoubtedly new methods of soil-utilization will be in sight.

Turning to a very different matter, there is the science of economics—really hardly a science as yet. A small community such as we are offers material not too bulky to estimate rightly. The effect of our legislation called "experimental," and of that which is non-experimental also, ought to be gauged with fair ease. Problem after problem is offered, but all such problems must be approached in the spirit of true science; all political bias must go to the winds; doubt may unhesitatingly be felt for many accepted dogmas; the accurate methods of science must alone be used.

In the domain of anthropology there is no need always to confine one's investigations to primitive races. Amongst the settlers of a new land evolution in certain directions goes on apace. The question of dialect among the people of New Zealand would form a valuable study. The mere record of how various words of the English language are generally or occasionally pronounced in various parts of the Dominion would make a beginning in the study of that gradual change of dialect which is taking place, but which is far more noticeable by the old than by the young. The *Oxford Dictionary* lays down the so-called correct pronounciation of each word. But no one follows its dictum. On the other hand, according to its tenets the most cultured are constant sinners.

Education—still far away from being a science—should be approached by true scientific methods. At present the best that can be got are opinions more or less biased. The teacher of classics of the present day will explain that Latin affords the perfect mental training: the schoolmaster in Queen Elizabeth's time would explain that it was necessary to read and write the Latin tongue fluently, since it was the written language of the learned. Many subjects are taught not because any one really knows that they are essential, but because it is the fashion to teach them; and so too with the methods of teaching. Certainly the sooner education becomes an exact science the better for the nation, so that less time be wasted in teaching useless subjects or using bad methods. The use of standards in the elementary school may be necessary, but it is biologically unsound, as it assumes that all the scholars are equal in intellect. At one time—and the custom is not extinct by any means here in New Zealand—every girl in an English middle-class school was taught music, no matter the degree of tone-deafness with which she was afflicted. How many, too, I wonder, are there in our schools who are forced to study subjects for which they have no aptitude?

There is room for much research in New Zealand history, young though our country may be. The splendid gift of his library to the people of the Dominion by the late Mr. A. H. Turnbull should certainly stimulate historical research. With this end in view we may cordially welcome the establishment of an historical section by the Wellington branch of our Institute.

One more example out of the many subjects crying aloud for research in this country and I have done. Our cultivated plants of all kinds are subject to attacks of parasitic fungi, the majority of which are considered identical with those affecting similar plants in other countries. For the suppression of such fungi many fungicides have been devised, especially in France and America. Now, that these methods have been successful on trees in the country of their origin does not say that similar methods will serve equally well here. A certain apple-tree growing in California will probably differ from the same variety grown on the clay soil of Nelson. The effect of the fungus on such a New Zealand tree and the life-history of that fungus must be studied in New Zealand; so, too, must be investigated the use of the fungicide. This method of attacking the pests of fruit-trees by means of fungicides and insecticides costs the State of California alone about £400,000 per annum. At best it is a rather clumsy way of dealing with the pests. It is exactly a case in point with regard to pure and applied science. Pure science paved the way by first classifying and then finding out the life-histories of the fungi; pure science had also to devise by aid of much experiment the beautiful technique with regard to pure cultures, and so on, which can now be learnt in the laboratory. Then pure science devised fungicides, and finally applied science is brought into the orchard in the form of the spray pump and its contents. But is science content to rest at this stage? Is she not eagerly seeking to find out more about the relation of fungus and host, more about the cause of parasitism? Here comes in the plant-physiologist, who seeks to find out more about the actual life processes of the plant, whose ultimate aim is perhaps to discover what is life itself. This latter problem seems well-nigh hopeless, but long before the problematical success is achieved science will know so much about the plant that new methods of combating disease will be in the hands of every orchardist. The Cawthron Institute of Scientific Research could easily spend all its income on investigations with regard to plant-diseases, but it would not be performing its full scientific duty if it were not carrying out plant-physiological researches with regard to the living tree as it grows in the orchard, and thus working not for the present day alone but for posterity. This, I take it, is also the attitude of the New Zealand Institute and should be the attitude of this Dominion. Not for the present alone but for the future must this New Zealand of ours—our beloved country—strive with might and main if she is to become truly great.

WELLINGTON PHILOSOPHICAL SOCIETY.

Eight general meetings of the society were held during the year 1918, at which the following papers and addresses were read:—(24th April) "Control of Milk-supply," by Mr. R. L. Andrew; (22nd May) "Discovery and Rediscovery of Wellington," by Mr. Elsdon Best; (26th June) "Notes on the Rate of Growth of New Zealand Native Trees," by Mr. E. Phillips Turner; (24th July) Presidential address, "The Need for Research," by Mr. G. Hogben; "New Species of Mollusca from various Dredgings taken off the Coast of New Zealand, the Snares Islands, and the Bounty Islands," by Miss M. K. Mestayer; "Stephen Island, a Natural Sanctuary for Land-animals," by Dr. J. Allan Thomson; (28th August) "Mountains," by Dr. C. A. Cotton; (25th September) "The Nature of X-ray Spectra," by Professor H. Clark; (18th December) "The Distillation of Waikaia Shales" by Mr. W. Donovan; "New Zealand Clays," by Mr. P. G. Morgan; "Graphs showing the Rate of Growth of New Zealand Trees," by Mr. E. Phillips Turner; "The Edible Fish, &c., of Taupo-nui-a-Tia," by the Rev. H. J. Fletcher.

At the annual meeting, which was held on the 18th December (having been postponed owing to the epidemic), the annual report and balance-sheet were adopted.

Abstract of Annual Report.

Membership.—The roll of members as on the 20th September, 1918, stood as follows: Life members, 10; ordinary members, 164, of whom 23 are on active service. Thirteen new members were elected during the year, six members resigned, and four members died, of whom two were on active service.

Roll of Honour.—The following names were added to the roll of honour during the year: Sergeant-major L. J. Comrie and Dr. W. M. Thomson.

Grant to the Astronomical Section.—During the year a sum of £8 16s. 6d. was paid on behalf of the Astronomical Section for mounting the King telescope, and the section was further authorized to incur a liability to an amount not exceeding £20 for the current year.

Ramsay Memorial Fund.—The Council gave a sum of five guineas to the Ramsay Memorial Fund.

Hamilton Memorial Prize.—Pursuant to a recommendation of the Committee of the Hamilton Memorial Fund that the balance of the fund should be invested by the New Zealand Institute, and that each year one half of the interest should be added to the principal, the other half of the interest to be devoted to a prize to be known as the Hamilton prize, the Council at its meeting on the 23rd January adopted the recommendation, and formulated a number of conditions relating to the award of the prize. The resolution was communicated to the New Zealand Institute, the Board of Governors of which has authorized its Standing Committee to co-operate with the Wellington Philosophical Society in arranging the terms upon which the balance of the Hamilton Memorial Fund should be handed over in trust to the New Zealand Institute.

Fellowship of the New Zealand Institute.—Resolutions of the Committee of the Board of Governors on the subject of the fellowship on the New Zealand Institute were considered, and were afterwards approved in an amended form.

Research Grant.—An announcement was received from the Secretary of the New Zealand Institute that the sum of £500 had been voted to the Institute as a grant for research work. The announcement was circulated among the members of the society. Advice was received from the New Zealand Institute that the application from Professor Easterfield for £50 for carrying out investigations on the wax content of brown coals, and from Messrs. La Trobe and Adams for a further £75 in aid of the cost of construction of a tide-predicting machine, were recommended for approval. The Council was later informed by the New Zealand Institute that the Minister of Internal Affairs had declined to approve of the Institute's recommendation in regard to the grant to Messrs. La Trobe and Adams.

Formation of an Historical Section.—On the 28th August it was resolved that an Historical Section should be formed. Since that date one meeting of the new section has been held, and a number of new members have joined the society as a result of the formation of the section.

Library Account.—The library was credited during the year with £39 15s. 7d., which, together with a balance of £68 1s. 7d. from last year's account, makes a total credit of £107 17s. 2d. The expenses amounted to £18 14s. 1d., leaving a credit balance of £89 3s. 1d.

The following officers and Council were elected for the year 1919: *President*—R. W. Holmes, I.S.O., M.Inst.C.E. *Vice-Presidents*—C. E. Adams, D.Sc., F.R.A.S.; J. Allan Thomson, M.A., D.Sc., F.G.S. *Council*—B. C. Aston, F.I.C., F.C.S.; E. Best; C. A. Cotton, D.Sc., F.G.S.; W. Donovan, M.Sc.; T. H. Easterfield, M.A. Ph.D.; F. W. Furkert, Assoc.M.Inst.C.E.; A. C. Gifford, M.A., F.R.A.S.; S. H. Jenkinson; H. B. Kirk, M.A.; E. K. Lomas, M.A., M.Sc.; P. G. Morgan, M.A., F.G.S. *Secretary and Treasurer*—C. G. G. Berry. *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.

ASTRONOMICAL SECTION.

The Observatory was open to the public early in the year, but has been closed since the 4th April owing to the erection of the King telescope and the alterations entailed to the Observatory. The 5 in. Cooke has been removed to the Hector Observatory and stored, while the King telescope has been erected in the section's observatory, the erection and adjustment being carried out by the Director of Instruments (Dr. Adams) and members of the committee. It has been found necessary to renew the sliding shutter, and an estimate is being prepared for the work. Urgent repairs to the roof and dome were carried out during November, 1917.

The following papers were read before the section during the year 1918:—(5th June) "Is Earth-rotation the Cause of the Ocean Currents?" by A. W. Burrell; (3rd July) "New Stars," by A. C. Gifford; (7th August) "Occultation by Venus of 7 Aquarii" by C. E. Adams; (4th September) "A Graphical Method of Predicting Eclipses and Occultations," by D. M. Y. Sommerville; (2nd October) "A Novel Star Atlas," by C. W. Adams; "Maori Star Lore," by Elsdon Best.

Committee and Officers for 1919.—*Chairman*—A. C. Gifford, M.A., F.R.A.S. *Vice-Chairmen*—D. M. Y. Sommerville, M.A., D.Sc.; W. S. La Trobe, M.A. *Committee*—E. Parry, B.Sc., M.I.E.E.; C. P. Powles; H. Clark, M.S., Ph.D.; C. Monro Hector, M.D., B.Sc., F.R.A.S.; G. S. Hooper; R. D. Thompson, M.A. *Director and Curator of Instruments*—C. E. Adams, D.Sc., F.R.A.S. *Hon. Treasurer*—C. E. Adams, D.Sc., F.R.A.S. *Hon. Secretary*—C. G. G. Berry.

TECHNOLOGICAL SECTION.

The following papers were read during the year:—(8th May) Inaugural address, "Some Consideration on National Efficiency," by S. H. Jenkinson; (12th June) "The Electrification of Railways," by Evan Parry; (10th July) "The Functions of the State in Relation to Technical Education," by W. S. La Trobe; (14th August) "The Distillation of Coal and the Resulting By-products," by Professor T. H. Easterfield; (9th October) "Electric-arc Welding," by M. Cable; (11th September) "Littoral Drift on New Zealand Coasts," by R. W. Holmes; (11th December) "The Surge-chamber Problem" and "Control of Floods," by E. Parry; "Compression Tests on Papa Concrete," by F. Kissel.

The officers for the year 1919 were elected as follows: *Chairman*—S. H. Jenkinson. *Vice-Chairmen*—W. S. La Trobe, M.A.; A. J. Paterson. *Committee*—R. W. Holmes, M.Inst.C.E.; H. Sladden, member of Surveyor's Board; H. Clark, M.S., Ph.D.; J. S. Maclaurin, D.Sc., F.C.S.; F. W. Furkert, Assoc.M.Inst.C.E. *Hon. Secretary*—A. C. Owen.

GEOLOGICAL SECTION.

The following papers were read during the year 1917–18:—(19th September, 1917) "The Geology of the Papakaio District," by G. H. Uttley; "A Comparison of the New Zealand and Western North American Cretaceous and Tertiary Formations," by P. G. Morgan: (17th October, 1917) "Natural Regions in New Zealand," by E. K. Lomas: (15th May, 1918) "The Geomorphology of the Coastal District of South-western Wellington," by C. A. Cotton: (19th June, 1918) "Notes on the Post-Tertiary History of New Zealand," by J. Henderson: (17th July, 1918) "The Origin of the Amuri Limestone and Flint-beds," and "Notes on the Geology of Stephen Island," by J. A. Thomson; "Permo-Carboniferous or Maitai Rocks of the East Coast of the South Island," by P. G. Morgan: (21st August, 1918) "The Post-Tertiary History of the Ohau River and of the Adjacent Coastal Plain, Horowhenua County, North Island," by G. L. Adkin: (18th September, 1918) "The Geology of the Southern Wairarapa District," by J. A. Thomson; "Further Notes on the Horowhenua Coastal Plain and the Associated Physiographic Features," by G. L. Adkin: (16th October, 1918) "The Significant Features of Reef-bordered Coasts," by W. M. Davis; "Tertiary Geology of the Waitaki Valley between Duntroon and Kurow," by G. H. Uttley.

The officers for the year 1919 were elected as follows: *Chairman*—E. K. Lomas, M.A., M.Sc., F.R.G.S. *Vice-Chairman*—G. H. Uttley, M.A., M.Sc., F.G.S. *Committee*—W. Donovan, M.Sc.; J. Henderson, M.A., D.Sc.; R. W. Holmes, I.S.O., M.Inst.C.E.; P. G. Morgan, M.A., D.Sc., F.G.S.; J. A. Thomson, M.A., D.Sc., F.G.S. *Hon. Secretary*—C. A. Cotton.

HISTORICAL SECTION.

An Historical Section of the Philosophical Society of Wellington was formed, and officers appointed, on the 10th September, 1918, its objects being—the advancement of the knowledge of the history, economics, and ethnology of New Zealand and the adjacent regions; the study of history and economics in general; the promotion of the claims of history, economics, and ethnology in education; the affording of assistance to the Board of Science and Art in the collection of historical material.

The following papers were read during the year 1918: (15th October) "Native Tradition of the Death of Marion du Fresne at Bay of Islands in 1772," "First Visit of Captain Cook, and of Du Surville, in 1769, &c.," by Elsdon Best; "Place-names in New Zealand, with Special Reference to Banks Peninsula," by J. C. Andersen.

The officers for the year 1919 were elected as follows: *Chairman*—Elsdon Best. *Vice-Chairman*—T. W. Porter, C.B. *Committee*—C. Prendergast Knight, LL.D.; Rev. Father Gilbert; F. P. Wilson, M.A., F.R.E.S.; Charles Wilson; F. E. Edwards. *Hon. Secretary*—Johannes C. Andersen.

AUCKLAND INSTITUTE.

At the annual meeting, 24th February, 1919, the annual report of the Council was read and adopted.

Abstract.

In presenting the fifty-first annual report of the Auckland Institute and Museum the Council can once more direct attention to the steady progress of the society, and the increasing interest taken in its operations by the community.

It is also satisfactory to state that this year has witnessed the successful completion of the attempt to obtain a new site for the Museum, in a situation where it is possible to erect a building free from the many drawbacks and deficiencies of the existing site, and where there is not only room for present needs, but ample space for future extension.

Members.—Mainly through the activity of the Hon. E. Mitchelson and Mr. H. E. Vaile, forty-eight new members have been elected during the year. On the other hand, thirty-six names have been withdrawn from the roll—eighteen from death, eleven by resignation, and seven by non-payment of subscription for more than two consecutive years. The net gain has thus been twelve, the number on the roll at the present time being 462. It may be incidentally mentioned that not one of the other societies incorporated with the New Zealand Institute has a members roll of over 200.

The number of members removed by death is far above the average, and includes several who have long been in association with the Institute. Mr. C. Cooper served upon the Council from 1886 to 1894, and contributed several papers on conchological subjects; Mr. T. Buddle, Mr. M. Casey, Mr. J. W. Ellis, Mr. H. Larkin, and Mr. H. H. Metcalfe have all been of considerable service to the society in one direction or another. It should be mentioned that the Institute still retains on its roll, as dormant honorary members, all those of its subscribers who are at present serving their King and country in the New Zealand Expeditionary Force, the number of such being twenty-one.

Finance.—The total revenue of the Working Account, excluding the balance in hand at the beginning of the year, has been £1,678 13s. 9d. This is a little under last year's amount, the difference being altogether due to a temporary delay in the payment of certain items of interest on investments. Examining the various headings, it will be seen that the members' subscriptions have yielded £437 17s., against £420 contributed last year, and being the largest sum yet received from that source of income. The receipts from the Museum Endowment, consisting of rents and interest, have amounted to £656 15s. 6d., the previous year's contribution being £713 12s. 11d. The invested funds of the Costley Bequest have provided £432 17s. 6d., the amount for the previous year being £453 18s. 1d. The total expenditure has been £1,717 6s. 9d., being somewhat smaller than last year's amount, which totalled £1,763 11s. 4d. It is satisfactory to state that a sum of £200 has been paid in final liquidation of the cost of fitting up the foreign ethnographic hall. The cash balance in hand at the present time amounts to £127 7s. 6d.

There is little to report respecting the invested funds of the Institute, which have been increased during the year by the sum of £76 0s. 2d., mostly obtained from the sale of some small endowments. The total amount now stands at £22,945 13s. 9d., almost the whole of which is satisfactorily placed in specially selected mortgages or municipal debentures.

Members are aware that during the last session of Parliament the Institute submitted a petition praying for the refund of a sum of £912, paid under protest as mortgage-tax, on the ground that the income of the Institute, as a scientific body not carried on for private pecuniary profit, was not liable for taxation. The Petitions Committee upheld the contention of the Institute, and recommended the petition to the "favourable consideration of the Government." Notwithstanding this, the Cabinet has decided that "after careful consideration, it was regretted that no action could be taken in the matter."

Meetings.—At the beginning of the session a Meetings Committee was appointed to ascertain how far the Institute could take a more active interest in the dissemination of scientific knowledge by means of lectures. After consideration it was decided to increase the number of lectures, and also to provide, in a tentative manner, for the introduction of courses of lectures in cases where it was obvious that the subject was

too extensive for proper treatment within the scope of a single lecture. These changes proved decidedly popular, and led to a considerable increase in the attendance. The following is a list of the lectures and papers contributed: "The Story of the Constellations," by G. Aldridge; "Alcohol in its Industrial and Scientific Aspects," by A. Wyllie, Electrical Engineer to the City of Auckland; "Recent Scientific Thought concerning Light and the Ether, Part I," by E. V. Miller; "Recent Scientific Thought concerning Light and the Ether, Part II," by E. V. Miller; "The Theatre and Stage Effects in Shakespear's Time," by Professor C. W. Egerton, M.A.; "Combustion, Part I," by Professor F. P. Worley, M.Sc.; "Combustion, Part II," by Professor F. P. Worley, M.Sc.; "House-flies and Public Health," by Professor J. C. Johnson, M.Sc.; "The Fossiliferous Beds at Kawa, Port Waikato," by J. A. Bartrum; "New Fossil Mollusca," by J. A. Bartrum; "Some Recent Additions to the New Zealand Flora," by T. F. Cheeseman; "Contributions to a Knowledge of the New Zealand Flora, Part VI," by T. F. Cheeseman; "Descriptions of New Native Flowering-plants," by D. Petrie; "A New Variety of *Pteris macilenta*," by H. Carse.

Library.—Last October, when it became evident that the end of the war was drawing near, an unusually large order was sent to the society's London agents. The books may be expected about the middle of March or early in April, and will be welcomed by frequenters of the library. It is hoped to forward another order shortly after the arrival of the first. The magazines and serial publications subscribed to have been regularly received, and made available for the use of members. A considerable expenditure has been incurred in binding the back numbers of these publications, over sixty volumes having been placed in the library from that source alone. The usual presentations and exchanges have been received from foreign societies, and several donations from private individuals have been added to the library.

No department of the Institute suffers more from the want of room than the library, and now that the purchase of books has been resumed the need of accommodation will soon become a burning question.

Museum.—The recent epidemic of influenza has greatly affected the attendance at the Museum. In the first place, it necessitated the closing of the institution from the 3rd November to the 1st December, or nearly a full month; and after the reopening it was at least another month before the attendance became normal. Taking the Sunday visitors first, the register kept by the attendant shows that 20,842 people entered the building on that day, being an average of 453 for each Sunday. The greatest attendance was 934 on the 7th July, and the smallest 75 on the 28th April, an exceedingly wet day. On the eight chief holidays of the year the total number of visitors was 6,801, being a daily average of 850. The largest attendance on any single holiday was 1,246 on Labour Day, closely followed by 1,232 on King's Birthday, and 1,145 on Easter Monday. On ordinary week-days the visitors can only be occasionally counted; but the daily average is believed to be not less than 200, which would make a total of 55,000, after deducting the days on which the Museum was closed on account of the epidemic. Adding to this number that already given for Sundays and holidays, the total number of visitors for the whole year can be stated at 82,643. Last year the estimate was 87,350.

In the present congested state of a large portion of the Museum it is difficult to make any satisfactory progress, or to exhibit more than a small proportion of the additions that are regularly being received. A considerable amount of work has been done in the Maori Hall in the direction of rearranging the larger carvings on the eastern wall. By erecting a new framework over the show-cases space has been obtained for the exhibition of several fresh carvings of interest, while the general appearance has been much improved. During the coming season it is intended to carry out a similar improvement on the western side of the hall. It should be stated that the labelling of the Maori Hall has been practically completed, only a few recent additions being now without printed descriptive labels.

Numerous additions and donations have been received; but only the more important can be mentioned here. Prominent is a magnificent *pare*, or carved architrave for the doorway of a Maori house, evidently of great age, and in perfect condition. It was dug up in a peat swamp in the Hauraki Plains, and has been deposited for a long period by the finder, Mr. L. Carter, together with several other interesting articles.

An ancient house-carving, found in the mud of a branch of the Kaipara River, and presenting several unusual features, has been kindly donated by Mr. A. S. Bankart. It is presumed to be the work of the now extinct Waiohua Tribe, which once occupied the whole of the district between the Auckland Isthmus and the Kaipara River.

Other noteworthy additions to the ethnographical collections comprise several valuable carvings deposited by Mr. A. Eady, who has already placed many specimens in the Museum; a fine carved burial-chest, purchased from Mr. E. Spencer; a considerable number of Maori and Polynesian articles presented by Mr. G. Graham, who for many years has been a constant contributor to the Museum; a collection of 109 Melanesian and Polynesian specimens purchased from Archdeacon Comins; and, finally, an elaborate gold-lacquered Japanese cabinet presented by Mr. H. Shaw.

Among the war relics presented during the year the first place must be given to an interesting collection formed by Mr. C. J. Parr, C.M.G., during his recent visit to the western front, and which includes several noteworthy articles. Several contributions of value have also been received from Colonel Boscawen, Mr. H. Norton, Mr. F. G. Calver, and others.

Among the zoological specimens the following may be mentioned: An excellent skin of a lion, from a specimen that died at the Onehunga Zoo, presented by the proprietor, Mr. J. J. Boyd; a specimen of the sooty tern (*Sterna fuliginosa*), driven in by the cyclonic storm on the 20th March, and presented by Mr. H. F. Smith. This bird has not been previously noticed on the mainland of New Zealand. The severe weather experienced during the whole of the month of July drove in many thousands of oceanic dove-petrels, birds very seldom seen on the mainland. Through the kindness of several correspondents in the country the Museum has received an excellent series of these pretty little birds.

In the natural-history department Mr. Griffin has completed the elaborate group illustrating the breeding habits of the black-fronted tern (*Sterna frontalis*), referred to in last year's report as being under preparation, and it is now on exhibition. He has also mounted in excellent style the head of the well-known racehorse Carbine, which has been presented to the Museum by the Auckland Racing Club. At present he is engaged in setting up a remarkably fine specimen of the sea-leopard, stranded some little time ago in the Manukau Harbour. Various other natural-history specimens have been prepared and mounted during the year, in addition to work in other departments of the Museum.

Drawbacks and Deficiencies of the Present Museum.—In many successive annual reports it has been the duty of the Council to speak more or less openly in regard to the limitations and deficiencies of the present buildings, and to show how much these have interfered with the work of the Museum, and have stood in the way of its proper expansion. Now that there are prospects of better accommodation in the future it seems advisable to describe shortly the obstacles that should be removed, and the most desirable improvements to be effected.

In the first place, there is no department of the Museum that has sufficient room for exhibition purposes. With regard to the ethnographical collections, the Curator has frequently pointed out how greatly the teaching value of the Maori portion would be improved, and its appearance enhanced, if it were possible to remove the carved houses, canoes, and other large objects from their present quarters and place them in a separate hall, where they could be treated as occupying the central courtyard of a Maori village, similar to one of those that in past days stood on the shore of the Waitemata Harbour. Similarly, the Polynesian collection is obviously overcrowded, although the visitor may not know that all recent collections are packed away in store-boxes.

Turning to the natural-history department, a glance at the show-case containing the New Zealand birds will prove that no space remains for further additions. The preparation of special groups illustrating the life-history of New Zealand birds, which have proved to be such popular exhibits, has had to be suspended, there being no available space in which to place the show-cases. A small amount of room has been reserved for the collection of fishes, now being formed, but with that exception there is no unfilled space. Yet in some sections, such as insects and other invertebrates, hardly anything has been done. No attempt has yet been made to form a botanical museum. The geological and mineralogical collections require many additions, and the substitution of better specimens for most of those exhibited.

One of the most disturbing facts connected with the present overcrowded condition of the Museum is that several large collections of natural-history specimens at present in the hands of private owners would be gladly presented if there was a reasonable probability that such could be suitably exhibited, and made available for scientific study and research. These collections have been patiently formed by the labour of many years, and it would be little less than a calamity if the chance of obtaining them for Auckland should be lost.

The present want of accommodation and equipment for collecting, research, and the convenience of visitors is a most serious drawback. The Museum has no proper storerooms; no accommodation for students who may wish to make use of the collections; no rooms in which specimens can be sorted, examined, and determined, or packed away as duplicates. There is no inquiry-room where strangers in search of information can be received and their questions answered; nor are there any retiring-rooms where visitors can leave their belongings, or have an opportunity of consuming a hasty lunch. All progressive Museums provide the above adjuncts, and their want has long been felt in Auckland. To sum up, no satisfactory progress in the Museum can be hoped for until these drawbacks and deficiencies are removed. This can only be done in a much larger, better planned, and more completely equipped building.

The Need for a New Building.—In last year's report the Council showed that the existing site of the Museum was not large enough for present requirements, to say nothing of future needs. It was also proved that the cost of enlarging the site by the purchase of adjoining land was altogether beyond the means of the Institute, even if there was any prospect of financing a scheme involving the purchase of expensive city property as well as the erection of new buildings. The inevitable conclusion was the removal of the Museum from its present position. After much consideration it was decided to apply to the City Council for a site on Observatory Hill, in the Auckland Domain, a situation which possesses the fundamental advantages of room for future expansion, decreased risk of fire, and freedom from dust and smoke. The City Council, desirous to assist the Institute in its search for a new home, unanimously agreed to give the necessary permission, subject to the Council of the Institute promoting any legislation that might be required. The result of this action was reported to the last annual meeting, and was confirmed by a very large majority.

As the solicitors to both the City Council and the Institute were of opinion that a validating Act was necessary, arrangements were at once made for the drafting of such, the terms being agreed upon at a conference of the two bodies. Under this Act power is given to sell the present site and apply the proceeds towards the erection of a new Museum in the Domain: while the City Council receives authority to lease to the Institute, at a nominal rent, an area of nearly 3 acres on Observatory Hill. It is also provided that the Mayor, *ex officio*, and two members of the City Council annually appointed shall in future represent the city on the Council of the Institute.

The Act, which bears the title of "The Auckland Institute and Museum Site Empowering Act," was placed in the charge of Mr. C. J. Parr, C.M.G., and, being practically unopposed, had a rapid passage through Parliament. It has since received the Governor's assent, and is now law. The Council have great pleasure in stating that from the first inception of the scheme for transferring the Museum to the Domain up to the present time no opposition of any moment has been raised, while many expressions of support have been volunteered. It is doubtful whether any proposal advocating a site for an important public building in Auckland has been so favourably and so generally accepted. In this connection, the Council wish to state their high appreciation of the action of the City Council in so generously acceding to the wishes of the Institute.

As for the character of the site, all that need be said here is that it is in every way suited for the purpose. It has all the advantages of a commanding position, greatly reduced risk of fire, freedom from dust and smoke, and, above all, room for future expansion. Few of the larger Museums of the world are so happily placed. In granting a portion of Observatory Hill as the site of the future Museum for Auckland the city has cheerfully and willingly given of its best. Let the Institute look to itself that full use is made of such great opportunities.

A War Memorial Museum.—Closely allied to the attempt to erect a Museum worthy of the city of Auckland on the slopes of the Domain is the formation of a collection illustrating the share that this country has taken in the Great War. It has long been the aim and hope of the Institute that an important part of the new building to be erected shall consist of a War Memorial Museum, capable of adequately commemorating the trials and hardships, the labour and sacrifice, of the many thousands of soldiers of all classes who have left New Zealand to assist in crushing the German peril. Many of these have given up their life in the struggle, others will return maimed and suffering—perhaps never to recover health. Is there to be no "Hall of Memory" in Auckland to keep alive for all time a knowledge of the many brave deeds of these men—to commemorate their dauntless courage and steadfast devotion to duty? The very idea is almost unthinkable—but time is fleeting, and opportunities are being lost.

Election of Officers for 1919.—*President*—Mr. J. H. Gunson, Mayor of Auckland. *Vice-Presidents*—Hon. E. Mitchelson; Mr. C. J. Parr, C.M.G., M.P. *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*—Mr. T. Peacock, Mr. J. Reid, Professor A. P. W. Thomas, Mr. J. H. Upton, Mr. H. E. Vaile. *Secretary and Curator*—Mr. T. F. Cheeseman. *Auditor*—Mr. S. Gray.

PHILOSOPHICAL INSTITUTE OF CANTERBURY.

During the year 1918 nine meetings were held (including the annual meeting, 18th December), and the following addresses and papers were read:— (1st May) "The Decorated Cave Shelters of Canterbury," presidential address by Mr. W. H. Skinner: (5th June) "Testing High-tension Insulators," by Mr. L. Birks: (7th August) "Some Remarks on Soil Organisms," by Mr. L. J. Wild; Discussion of Daylight-saving Proposals: (21st August) "Yeast, and its Influence in the Manufacture of Bread," by Mr. S. R. Cowley: (4th September) "A Preliminary Investigation of the Age and Manner of Growth of Brown Trout in Canterbury, as shown by Examination of their Scales," by Mr. M. H. Godby: (18th September) "Description of a New Species of the Family Cerithiidae," by the late Mr. H. Suter, communicated by Mr. R. Speight; "Further Notes on the Castle Hill or Trelissick Basin," by Mr. R. Speight; "The Teachin of the Classical Languages," by Mr. H. D. Broadhead: (2nd October) "The Tuatara and its Kindred," by Professor W. B. Benham: (6th November) "The New Zealand Amphipoda belonging to the Genera *Hyale* and *Allorchestis*," by Dr. Charles Chilton; "The Sand-hoppers of New Zealand belonging to the Genus *Orchestia*," by Dr. Charles Chilton; "The Passing of the Forest, with some Notes on Afforestation," by Mr. W. H. Skinner: (18th December) "The Late Tertiary Gravels of Canterbury," by Mr. R. Speight; "Notes from the Canterbury College Mountain Biological Station —No. 7, Catalogue of the Pteridophytes and Spermaphytes of the Upper Waimakariri River Basin," by Dr. L. Cockayne and Miss E. M. Herriott; "Studies in the New Zealand Species of the Genus *Lycopodium*—Part 3, the Plasticity of the Species," by the Rev. Dr. Holloway; "*Ceina*, an Aberrant Genus of the Amphipod Family Talitridae," by Dr. Charles Chilton.

At the annual meeting the election of officers and Council for 1919 resulted as follows: *President*—Dr. C. Coleridge Farr. *Vice-Presidents*—Mr. W. H. Skinner and Mr. L. P. Symes. *Secretary*—Mr. W. Martin. *Treasurer.*—Dr. C. Chilton. *Librarian*—Mr. W. G. Aldridge. *Council*—Dr. F. W. Hilgendorf, Mr. L. Birks, Mr. L. J. Wild, Mr. A. V. Mountford, Mr. M. H. Godby, Mr. J. Drummond. *Auditor*—Mr. G. E. Way

Abstract of Annual Report.

Membership.—The number of members on the roll is now 177. During the year nine new members were elected and thirteen memberships lapsed.

Members on Active Service.—The Council wishes to place on record the names of the following members on war service: Drs. H. Acland, F. J. Borrie, and J. Guthrie; Messrs. G. E. Archey, J. W. Bird, F. M. Corkill, E. Kidson, C. E. Foweraker, A. Fairbairn, H. T Ferrar, A. Taylor, G. T. Weston, F. S. Wilding, A. M. Wright, and H. Rands.

Obituary.—With great regret the Council has to record the death of Dr. Walter Thomas, a life member since 1892, who held the office of President in 1897; of Mr. H. Suter, a member since 1897, who by his numerous and valuable papers on New Zealand Mollusca established his position as the leading authority on this group of animals; also of the following members: Messrs. M. Dixon, T. S. Foster, G. C. Robinson, and M. G. Wallich.

Government Research Grants.—Early in the year the Government voted the sum of £500 to the New Zealand Institute for research work. Five applications for allotments were made through this Institute, and the Council is pleased to report that the following grants were made to members: £200 to Dr. W. P. Evans, for investigation of New Zealand brown coals; £50 to Dr. Charles Chilton, for investigation of New Zealand flax (phormium); and £30 to Mr. L. J. Wild, for a soil survey of the Canterbury Plains district.

Co-ordination of Science and Industry.—The action of the Institute in this direction during the past year led to the establishment by the Board of Governors of Canterbury College of a Technological Section in the Public Library. The need of modern technical literature has been very much felt during the past four years by those engaged in the many attempts to establish industries of a chemical or more or less scientific nature.

Riccarton Bush.—The Institute's representative on the Board of Trustees of the Riccarton Bush reports that the bush has been open to the public during the year at the usual times, and has been visited by large numbers. Owing to grants received from several local bodies, the funds of the Board have been sufficient to allow of an increase in the salary of the ranger and to cover other necessary expenditure, but are still too limited to allow of such further improvements being made as the Trustees would desire. The bush continues to be of great use to the botanical students in the neighbourhood of Christchurch and to members of the Institute.

Library.—The war period, including the current year, has interfered somewhat seriously with the library routine. Many parts of journals have failed to arrive—forty-two parts of seventeen volumes are missing—interfering seriously with the possibility of keeping the binding of journals up to date. The inability to proceed with the binding, and the delay in securing publisher's accounts, are responsible for the small sum shown as expended on the library.

Finance.—The balance-sheet shows that the total receipts, including the balances on the Ordinary Account, the Tunnel Investigation Account, the Australasian Antarctic Expedition Account, and the research grants were £473 4s. 8d. This sum includes a deposit received during the year of £100 for the Australasian Antarctic Expedition Account. Owing to war conditions a considerable number of subscriptions for the year are still outstanding. The expenditure includes the payment of two levies to the New Zealand Institute—namely, £21 17s. 6d. in connection with volume 49 of the *Transactions*, and £23 2s. 6d. for volume 50, both the volumes having been published during the financial year. The expenditure on the library was £24 10s. 10d., including a special contribution of £10 10s. to the Technological Library. Owing to shortage of hands in the office of the London agent, Messrs. William Wesley and Son, no account for scientific journals or periodicals supplied was received during the year. The balance for the Tunnel Investigation Account still stands at £147 7s. 3d., and that of the unexpended research grants at £60. The balance of the Australasian Antarctic Expedition's Account is £9 14s. 7d., and the balance of the Ordinary Account £18 17s. 10d. The Life Members' Subscription Account shows a balance of £152 17s. 3d., deposited with the Permanent Investment and Loan Association of Canterbury.

OTAGO INSTITUTE.

Eight ordinary meetings had been arranged for, but one of these lapsed owing to the date being the 12th November, the day on which news of the Armistice reached New Zealand.

At these meetings the following papers, embodying the results of research work, were read or received: "On Two Anomalies of the Vascular System of *Hyla aurea*," by Professor W. B. Benham, F.R.S.; "Notes on the Birds of South-west Otago," by A. Philpott; "Descriptions of New Species of Lepidoptera," by A. Philpott; "Some Remarks on Maori Fish-hooks," by H. D. Skinner, B.A.; "Earthworms from Stephen Island," by Professor W. B. Benham, F.R.S.; "Notes on the Autecology of certain Plants of the Peridotite Belt, Nelson, Part I—Structure of some of the Plants (No. 2)," by Miss M. W. Betts, M.Sc.; "On the Occurrence of Three Bands of Marble in South Peak, near Hampden, Otago," by J. Park, F.G.S.

The following addresses were also delivered during the session: "Flying" (presidential address), by Professor R. Jack; "Underground Warfare," by Professor D. B. Waters; "Radio-activity," by Professor Jack, Professor Inglis, and Dr. Cameron; "New Caledonia and the Isle of Pines," by Professor J. Park; "Corals and Coral Reefs," by Professor W. N. Benson; besides various short addresses and exhibits by Professor Benham, Mr. W. G. Howes, Dr. Fulton, and Mr. H. D. Skinner.

At the annual meeting (10th December) the annual report, including the balance-sheet, was adopted, and the following were elected office-bearers for 1919: *President*—Hon. G. M. Thomson, M.L.C. *Vice-Presidents*—Professor R. Jack and Dr. R. V. Fulton. *Hon. Secretary*—Professor J. Malcolm. *Hon. Treasurer*—Mr. H. Brasch. *Hon. Auditor*—Mr. J. W. Milnes. *Hon. Librarian*—Professor Benham. *Council*—Professor Benham, Professor Park, Professor Benson, Messrs. W. G. Howes, H. Mandeno, J. A. Gray, and F. J. Jones.

Abstract of Annual Report.

Besides the routine work of arranging for the meetings, passing accounts for payment, and sanctioning expenditure on the library and meeting-room, only two matters of general interest occupied the attention of the Council during 1918.

A further stage in the proposals for reform of the New Zealand Institute was reached when the draft regulations for the holding and appointment of Fellows of the New Zealand Institute were considered and sent to the Institute with suggestions regarding certain of the clauses.

A circular letter was sent to the affiliated societies asking their co-operation in securing, through the New Zealand Institute and the Government, more efficient protection for native wild birds and seals in New Zealand.

The Council also decided to offer to the University Council to pay half the cost of installation of electric light in the biology class-room, with a view to installation of a projection lantern.

During the year seven new members have been elected; five have resigned, so that the roll now stands at 166. Sixteen of these are, or have been, members of the New Zealand Expeditionary Force.

The Institute regrets having lost the services of Mr. E. J. Parr, M.A., B.Sc., as Hon. Secretary, a position he filled with great success for over seven years.

TECHNOLOGICAL BRANCH.

Early in the year it was decided by the Committee that owing to war conditions no full course of meetings should be attempted.

The annual and only meeting was held on the 15th October, when addresses were delivered as follows: "A New Device for Damming Swift Rivers," by Professor Park; "Military Mine Engineering," by Professor Waters.

At the same meeting the following office-bearers were elected for 1919: *Chairman*—Professor Waters. *Vice-Chairmen*—Professor Park, Messrs. B. B. Hooper and F. W. Payne. *Committee*—Messrs. M. C. Henderson, F. J. Jones, H. Mandeno, George Simpson, and R. N. Vanes; *Hon. Secretary*—Mr. H. Brasch.

ASTRONOMICAL BRANCH.

The annual meeting (the only meeting of the session) was held on the 29th October, when a paper on "Stonehenge as an Astronomical Station" was contributed by Professor D. A. White. Owing to the progress made in the removal of Tanna Hill, the telescope-house has been dismantled and Mr. Skey's telescope returned to him. The thanks of the meeting were directed to be conveyed to Mr. Skey for his kindness in placing his telescope at the service of members for so many years. Master A. G. Crust was complimented on his early discovery of Nova Aquila.

Officers elected for year 1919: *Chairman*—Mr. R. Gilkison. *Vice-Chairmen*—R. Jack, J. Park, and D. R. White. *Committee*—Rev. D. Dutton, F.R.A.S.; Dr. Cameron; Messrs. H. Brasch, C. Frye, W. S. Wilson, and J. W. Milnes (Hon. Secretary).

HAWKE'S BAY PHILOSOPHICAL INSTITUTE.

The following papers and addresses were read during the year 1918: (17th May) President's inaugural address, "Scientific Development, Past, Present, and Future"; (19th June) "A Visit to a Montessori Infant School," by the Hon. Sir R. Stout, K.C.M.G.; (16th July) "The Marvels of the Spectroscope," by J. W. Poynton; (15th August) "Some Remarks and Experiments on Combustion," by J. H. Edmundson; (13th September) Lantern address on "Rhodesia, Mashonaland, &c.," by Thomas Probert.

At the annual meeting the following officers for the year 1919 were elected: *President*—W. A. Armour, M.A., M.Sc. *Vice-President*—E. G. Loten. *Council*—W. Dinwiddie; A. Anderson; H. Hill; D. A. Strachan, M.A.; G. Stubbs; T. C. Moore, M.D. *Hon. Secretary and Treasurer*—C. F. H. Pollock. *Hon. Auditor*—J. S. Large. *Hon. Lanternist*—H. Cottrell. *Representative to New Zealand Institute*—H. Hill, B.A., F.G.S.

Abstract of Annual Report.

Meetings.—Five general meetings were held, at which three papers were read. Two further meetings were arranged for in November and December, at which addresses were to be given by Mr. D. A. Strachan, M.A., on "Some Recent Developments in Economics," and Mr. J. W. Poynton, S.M., on "Radium and its Wonders." In view of the disastrous influenza epidemic, however, these had to be abandoned.

Membership.—Ten new members have been elected during the year, and eight have resigned. The total membership is now eighty.

Members on Active Service.—The Council desires to place on record the names of the following members on war service: Surgeon-Colonel H. F. Bernau, Surgeon-Colonel J. P. D. Leahy, and Messrs. E. F. Northcroft, E. G. Wheeler, and P. Loftus Poole.

Obituary.—With great regret the Council records the death of the following members during the year: Mr. H. W. Antill, a past Vice-President; Dr. E. H. W. Henley, a former President; Mr. T. Tanner, a past President, and one of the original founders; and Mr. Peter Dinwiddie, a member for thirty-four years.

Hawke's Bay Educational Conference.—The President and Hon. Secretary were appointed delegates to represent the Institute at this conference, held at the Athenaeum on the 7th and 8th October.

Finance.—The balance-sheet shows the satisfactory credit balance of £50 16s. 3d.

MANAWATU PHILOSOPHICAL SOCIETY.

Seven general meetings were held during the year, at which the following papers were read: "The Ethics of the British Constitution," by Lance-Corporal C. E. Ferris, N.Z.M.C.; "The Origin of Ocean Currents," by A. W. Burrell; "Mangahao *versus* Waikaremoana as Sources of Electric Power," by C. N. Clausen; "The Panama Canal," by Captain Spence, N.Z.M.C.; "The Hot Springs of Querta del Inca," by W. R. Mummery, F.I.C.; "Mountains," by Dr. C. A. Cotton, D.Sc.

Abstract of Annual Report.

As the result of an application by the society for an annual subsidy the Borough Council has granted a subsidy of £10.

At the annual meeting of the 13th December, 1917, it was resolved that the number of members of Council be increased from six to twelve. This resolution was confirmed at a general meeting held on the 8th March.

During the year five new members were elected, and two, Drs. Stowe and Barnett, who had been on active service, returned.

With very deep regret the Council has to record the loss which the society, in common with the town and district, has suffered by the death of Mr. J. E. Vernon, M.A., B.Sc., Rector of the High School, who was a member of the society from its foundation, constantly occupied a seat on the Council, and served the office of President. Another member has been removed by death in the person of Mr. David Buick, M.P., who was at all times ready to use the influence of his position to further the interests of the society.

The Council is also about to lose, though happily in this case only by his official removal from Palmerston, another most valued member in Mr. J. W. Poynton, S.M., who, ever since his coming to Palmerston, has been a most active member of Council, has for three successive years been President, and has contributed many valuable papers.

The attendance at the Museum has kept up to the average of from twenty-five to thirty each afternoon, but the majority of these are quite young, and it is still a matter of regret that their visits are not made more systematically and under due supervision. A good many additions have been made to the Museum, including a collection of about fifty moths and butterflies from Dr. Thomson, curios from the Solomon Islands presented by Archdeacon Comins, and a number of pamphlets and leaflets relating to the war from the British Museum.

There is little doubt that the absorbing interest of the war has had a bad effect both on the number of our subscribers and the attendance at our meetings, and now that there is a prospect of a speedy return to normal conditions we may hope for an improvement in both.

The officers for the year 1919 were elected as follows: *President*—Mr. M. A. Eliott. *Vice-Presidents*—Messrs. J. A. Colquhoun, M.Sc.; C. N. Clausen. *Officer in Charge of the Observatory*—Mr. R. A. H. Grace. *Council*—Miss Ironside, M.A.; Messrs. J. L. Barnicoat; R. Edwards; J. B. Gerrand; E. Larcomb; W. R. Mummery, F.I.C.; W. Park; C. T. Salmon, Associate in Eng.; H. Seifert; D. Sinclair, C.E.; A. Whitaker. *Secretary and Treasurer*—K. Wilson, M.A. *Auditor*—W. E. Bendall, F.I.A.N.Z.

WANGANUI PHILOSOPHICAL SOCIETY.

During the session of 1918 three meetings were held, at which the following papers were read: "The New Star," by W. J. T. Ward; "New Stars," by Mr. A. C. Gifford; "New Stars reviewed," by Mr. Thomas Allison; "The Geology of Wanganui," by Dr. P. Marshall, F.G.S.; "To what Extent is Earth-rotation the Cause of the Ocean Currents?" by Mr. A. W. Burrell, of Stratford (communicated by Mr. J. T. Ward). The following papers were taken as read: "Occurrence of Moa-bones in the Lower Part of the Wanganui Beds," by Dr. P. Marshall; "Fossils and Age of the Hampden Beds," by Dr. P. Marshall; and "Some New Species of Fossil Mollusca," by Dr. P. Marshall and Mr. R. Murdoch.

The annual meeting was held on the 10th December, 1918, when the report and balance-sheet were adopted. The roll shows a falling-off in the membership, and now stands at thirty-three ordinary and two life members.

The following officers were elected for the year 1919: *President*—Dr. P. Marshall. *Vice-Presidents*—Messrs. J. T. Ward and J. A. Neame, B.A. *Council*—Messrs. T. Allison; C. Palmer Brown, M.A., LL.B.; R. Murdoch; T. W. Downes; H. E. Sturge, M.A.; Dr. H. R. Hatherly; and (*ex officio*) H. Drew, Hon. Curator, Museum. *Hon. Secretary*—Mr. C. Reginald Ford, F.R.G.S.

NELSON INSTITUTE.

During the two years following the meeting on the 22nd December, 1916, no meetings whatever of the scientific and literary branch have been held, a circumstance due to a number of causes, the chief being the pressure of business created by the European war. The signing of the Armistice last November, however, and the prospect of a speedy peace, give rise to the hope that during the ensuing session the activity of the branch may be revived and a suitable programme be carried out.

As is only natural during such a period as we have just passed through, the membership has dwindled, but it is hoped that in this respect also the conclusion of peace will have a beneficial effect.

The Atkinson Observatory has been opened to the public at intervals, and has been in the charge of Mr. J. R. Strachan on those occasions.

During the period also several interesting relics of Admiral Lord Nelson have been presented to the Museum by Mr. W. F. Gordon, of New Plymouth, and these, together with the letters already in the Museum, have enabled a case to be set aside as a "Nelson case." An extremely fine model of the St. George has also been presented to the Museum by the trustees of the Suter Art Gallery. In addition, we are indebted to Dr. F. A. Bett for two specimens, one of the saddleback and one of the jackbird, and these have been placed on exhibition in the Museum.

APPENDIX.

NEW ZEALAND INSTITUTE ACT, 1908.

For the New Zealand Institute Act, 1908, and Regulations thereunder see vol. 49, 1917, pp. 570–74.

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, where 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.

Grant from the Hutton Memorial Research Fund

1919. Miss M. K. Mestayer—£10, for work on the New Zealand Mollusca.

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.
1918. T. F. Cheeseman, F.L.S., F.Z.S.—For researches in New Zealand systematic botany.
1919. P. W. Robertson—For researches in chemistry.

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 aid 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 acknowledgment 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.

Research Grants from Vote (£2,000) to 31st March, 1919.

Through the Philosophical Institute of Canterbury:—

Mr. L. J. Wild, £30 for investigations for a soil survey; granted 31st December, 1918.

Through the Otago Institute:—

Professor Jack, £25 for investigating the electric charge on rain; granted in 1917; paid 29th January, 1919.

Through the Wellington Philosophical Society:—

Dr. C. E. Adams, £55 for optical apparatus; granted March, 1919.

Through the New Zealand Institute:—

New Zealand Institute Library, £250 for binding volumes of technological library; granted March, 1919.

THE CARTER BEQUEST.

For extracts from the will of Charles Rooking Carter see vol. 48, 1916 pp. 565–66.

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-General.
The Hon. the Minister of Internal Affairs.

NOMINATED BY THE GOVERNMENT.

Mr. Charles A. Ewen (reappointed December, 1918); Dr. J. Allan Thomson, F.G.S. (reappointed December, 1917); Mr. B. C. Aston, F.I.C., F.C.S. (reappointed December, 1917); Dr. Charles Chilton, F.L.S., C.M.Z.S. (reappointed December, 1918).

ELECTED BY AFFILIATED SOCIETIES (DECEMBER, 1918).

Wellington Philosophical Society ...	Professor H. B. Kirk, M.A. Professor T. H. Easterfield.
Auckland Institute	Professor H. W. Segar, M.A. Professor A. P. W. Thomas, M.A.
Philosophical Institute of Canterbury ...	Dr. F. W. Hilgendorf, M.A. Mr. L. Birks, B.Sc.
Otago Institute	Hon. G. M. Thomson, F.C.S., F.L.S., M.L.C. Mr. E. J. Parr, M.A., B.Sc.
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. M. A. Eliott.
Wanganui Philosophical Society ..	Dr. P. Marshall, F.G.S.

OFFICERS FOR THE YEAR 1919.

PRESIDENT: Dr. L. Cockayne, F.R.S.
HON. TREASURER: Mr C. A. Ewen.
HON. EDITOR: 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. G. G. Berry, Railway Buildings, Wellington	10th June, 1868.
Auckland Institute ..	T. F. Cheeseman, Museum, Auckland	10th June, 1868.
Philosophical Institute of Canterbury	William Martin, 51 Matai Street, Riccarton, Christchurch	22nd October, 1868.
Otago Institute	Professor John Malcolm, University, Dunedin	18th October, 1869.
Hawke's Bay Philosophical Institute	C. F. H. Pollock, P.O. Box 166, Napier	31st March, 1875.
Nelson Institute	E. L. Morley, Waimea Street, Nelson	20th December, 1883.
Manawatu Philosophical Society	K. Wilson, 92 Rangitikei Street, Palmerston North	6th January, 1905.
Wanganui Philosophical Society	C. R. Ford, College Street, Wanganui	2nd December, 1911.
Poverty Bay Institute.. ..	John Mouat, Adams Chambers, Gladstone Road, Gisborne	1st February, 1919.

FORMER HONORARY MEMBERS.

1870.

Agassiz, Professor Louis.
Drury, Captain Byron, R.N.
Finsch, Professor Otto, Ph.D.
Flower, Professor W. H., F.R.S.
Hochstetter, 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 Richard, 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.
Pickard-Cambridge, Rev. O., M.A., F.R.S., C.M.Z.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.

Berggren, Dr. S.
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.

Lydekker, Richard, F.R.S.

1900.

Agardh, Dr. J. G.

Avebury, Lord, P.C., F.R.S.

Massee, George, F.L.S., F.R.M.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.

1914.

Arber, E. A. Newell, M.A., Sc.D., F.G.S., F.L.S.

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.

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.

1915.

Petrie, D., M.A., Ph.D.

1916–17.

Benham, W. B., M.A., D.Sc., F.Z.S., F.R.S.

HONORARY MEMBERS.

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, Cambridge, Mass., 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.

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, Cambridge, England.

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, Cambridge, Mass., U.S.A.

Hemsley, Dr. W. Botting, F.R.S., Kew Lodge, St. Peter's Road, Broadstairs, Kent, England.

1914.

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.]

Ackland, E. W., P.O. Box 928, Wellington.
Adams, C. E., D.Sc., A.I.A. (London), F.R.A.S., Hector Observatory, Wellington.
Adkin, G. L., Queen Street, Levin.
Andersen, Johannes C., Turnbull Library, Wellington.
Anderson, W. J., M.A., LL.D., Education Department, Wellington.
Andrew, R. L., Dominion Laboratory, Wellington.
Anson, Miss J. C., Lower Hutt.
Aston, B. C., F.I.C., F.C.S., P.O. Box 40, Wellington.
Atkinson, E. H., Agricultural Department, Wellington.†
Bagley, G., care of Young's Chemical Company, 14 Egmont Street, Wellington.
Baillie, H., Public Library, Wellington.
Bakewell, F. H., M.A., Education Board, Mercer Street, Wellington.
Baldwin, E. S., 215 Lambton Quay, 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.
Best, Elsdon, Dominion Museum, 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.
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.*
Cameron, Dr. R. A., 148 Willis Street, Wellington.
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.
Chapman, Martin, K.C., Brandon Street, Wellington.
Chudleigh, E. R., Orongomairoa, Waihou.
Clark, Professor H., Victoria University College, Wellington.
Clarke, J. T., care of Messrs. Searle, Joy, and Co., 61 Victoria Street, Wellington.
Cockayne, L., Ph.D., F.L.S., F.R.S., Ngaio, Wellington.
Comrie, L. J., M.A., Wapiti Avenue, Epsom, Auckland.
Cotton, C. A., D.Sc., F.G.S., Victoria University College, Wellington.
Cowan, J., Department of Internal Affairs, 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.
Doré, A. B., Bacteriological 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.
Edwards, F. E., 307 Willis Street, Wellington.
Ewen, Charles A., Heretaunga, Upper Hutt.
Farquhar, A. S., Scots College, Wellington.
Ferguson, William, M.A., M.Inst.C.E., M.I.Mech.E., 131 Coromandel Street, Wellington.
Field, W. H., M.P., 160 Featherston 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.
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New Zealand Official Year-book.
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Statistics of New Zealand.

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Australasian Institute of Mining Engineers: *Proceedings.*
Australian Antarctic Expedition, 1911–14: *Reports.*
Commonwealth of Australia. Fisheries: *Parliamentary Report.*

New South Wales.

Agricultural Department, N.S.W.: *Agricultural Gazette.*
Australian Museum, Sydney: *Records; Annual Report.*
Botanic Gardens and Government Domains, N.S.W.: *Report.*
Critical Revision of the Genus Eucalyptus.
Linnean Society of N.S.W.: *Proceedings.*
Northern Engineering Institute of N.S.W.: *Papers.*
Public Health Department, N.S.W.: *Annual Report.*

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Geological Survey of Queensland: *Publications.*
Royal Society of Queensland: *Proceedings.*

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Adelaide Chamber of Commerce: *Annual Report.*
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Mines Department and Geological Survey of South Australia: *Mining Operations; G.S. Bulletins and Reports: Metallurgical Reports; Synopsis of Mining Laws.*
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Royal Society of South Australia: *Transactions and Proceedings.*

Tasmania.

Royal Society of Tasmania: *Papers and Proceedings.*

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Mines Department and Geological Survey of Victoria: *Annual Report; Bulletins; Records.*
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Geological Survey of Western Australia: *Bulletins.*

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British Association for the Advancement of Science: *Report.*
British Museum: *Catalogues; Guides; Scientific Reports of British Antarctic Expedition, 1910.*
Cambridge Philosophical Society: *Proceedings.*
Geological Society, London: *Quarterly Journal.*
Geological Survey of Great Britain: *Summary of Progress.*
Linnean Society: *Journal* (Botany); *Proceedings; List of Members.*
Liverpool Biological Society: *Proceedings.*
Marine Biological Association: *Journal.*
Mineralogical Society: *Mineralogical Magazine.*
North of England Institute of Mining and Mechanical Engineers: *Transactions; Annual Report.*
Oxford University: *Calendar.*
Royal Anthropological Institute of Great Britain: *Journal.*
Royal Botanic Gardens, Edinburgh: *Notes.*
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Royal Geographical Society: *Geographical Journal.*
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Royal Society of Literature: *Transactions.*
Royal Statistical Society, London: *Journal.*
Victoria Institute, London: *Journal of Transactions.*

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Revista Geographica Italiana.
Società Africana d'Italia : *Bollettino.*
Società Toscana di Scienze Naturali, Pisa : *Processi verbali.*

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Agricultural Department, Calcutta : *Report on Progress of Agriculture.*
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Malay States Government Gazette.

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American Geographical Society, New York: *Geographical Review.*
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MEXICO.

Instituto Geologico de Mexico: *Anales.*

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HAWAII.

Bishop Museum: *Memoirs.*

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INDEX.

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