ART. LVI.—*On the Marine Tertiaries of Otago and Canterbury, with Special Reference to the Relations existing between the Pareora and Oamaru Series.*

By Professor JAMES PARK, M.A.Inst.M.E., M.Inst.M.M., F.G.S., Director Otago University School of Mines.

[*Read before the Otago Institute, 13th September, 1904.*]

Plate XLVIII.

TABLE OF CONTENTS.

	Page
Introduction	489
Historical	490
General Conclusions	491
Distinctive Fauna of Oamaru Series	494
Physical Characteristics	496
Conditions of Deposition of Oamaru Series	498
Distribution of Oamaru Series	498
Physical Geology	498
Basement Rocks	501
Influence of Basement Rocks	501
Effects of Differential Elevation	501
Contemporary Volcanic Eruptions	502
Life of Oamaru Series	502
Age of Oamaru Series	503
Relations of Oamaru Series to Lower Tertiaries of North Island	504
Age of Waipara Series	505
Hampden Beach Beds	506
Kakanui Valley, near Maheno	507
Sea-coast near Kakanui Mouth	508
Awamoa Creek	511
Cape Oamaru	513
Teschemaker's	517
Devil's Bridge	518
Pukeuri	518
Hutchinson Quarry Beds	519
Black Point, Waitaki Valley	520
Marawhenua	522
Wharekuri Basin	522
Waihao Forks	527
Pareora River	530
Tengawai River	531
Kakahu Bush	532
Trelissic Basin	534
Waipara and Weka Pass	535
Lower Awatere	547
Port Hills, Nelson	548
Résumé	550
Classification of New Zealand Formations	551

INTRODUCTION.

Ever since 1870 there has been a difference of opinion among New Zealand geologists as to the sequence and relations of the members of the marine Tertiaries of Otago and Canterbury, and it is not a little surprising that no general agreement has yet been arrived at upon a subject which is of supreme scientific and economic importance to the colony.

The chief points of disagreement have mainly centred around the stratigraphical position of the beds which contain the Pareora fauna. The views of different writers have involved so many points of radical disagreement that it has been impossible for students of New Zealand geology to reconcile the differences.

In the hope of throwing some light upon this difficult problem I spent two months of the present year in an extended examination of the typical sections throughout North Otago and Canterbury, beginning at Hampden and ending at Waipara.

As the subject was largely palæontological I made considerable collections of fossils, which, with the exception of the brachiopods, I afterwards named by comparing them with the Tertiary types in the Canterbury Museum, all of which had recently been renamed by Captain Hutton, F.R.S., in accordance with latest nomenclature adopted in Europe.

The brachiopods in my collections were named by Captain Hutton, who kindly supplied the revised names as they appear in his paper on "The Revision of the Tertiary *Brachiopoda* of New Zealand." (See p. 474 of this volume.)

Altogether over twelve hundred fossils were examined and named. Without the aid of Captain Hutton this would have been a stupendous task; but the work was rendered comparatively easy through the unrivalled knowledge which he possesses of our Tertiary *Mollusca*.

Historical.

The name Pareora was first used in 1864 by Sir Julius von Haast* to designate certain fossiliferous marine beds in the valleys of the Pareora, Opihi, and Otaio Rivers in South Canterbury, as well as the Motanau and Greta beds in North Canterbury. Captain Hutton† subsequently, in his report on the geology of Marlborough and north-east district of Canterbury, in 1873, introduced the Pareora formation into his table of formations, assigning it at this time to the Upper Miocene. Like Haast, he referred the Motanau and Greta beds to this formation; but afterwards, in 1888, as the result of a more complete knowledge of the fossil contents of the different beds, he divided the Pareora formation into an upper and lower group, the former including the Greta beds, which contained about 66 per cent. of living forms.‡

The Pareora series of Captain Hutton now comprises

* Haast, "Geology of Canterbury and Westland," 1879, p. 323.
† Reports of Geol. Explorations, 1872–73, p. 47.
‡ Trans. N.Z. Inst., vol. xx., 1888, p. 262.

the Kakahu, Pareora River, Waihao Forks, Awamoa, and Hampden beds, all of which, he contends, contain a closely related fauna, of which some 37·5 per cent. are living species.* The Pareora series of the Geological Survey embraces the Greta, Pareora River, Mount Harris, and Awamoa beds; but excludes the Kakahu, Waihao Forks, and Hampden beds, which are placed below the Oamaru stone.

The present position is therefore as follows: According to Captain Hutton all the beds which contain the characteristic Pareora fauna are of Lower Miocene age, and are believed by him to overlie the Oamaru stone, often unconformably.† According to the Geological Survey the Pareora and Awamoa beds are believed to be of Lower Miocene age, and to overlie the Oamaru stone unconformably; while the Kakahu, Waihao Forks, Black Point, and Hampden beds, also containing a Pareora fauna, are admitted to underlie the Oamaru stone conformably.

GENERAL CONCLUSIONS.

(1.) That there are two limestones in the Oamaru series where the sequence is complete, separated by the Hutchinson Quarry beds and its associates. The upper limestone is a yellowish-brown calcareous sandstone characterized by such fossils as *Meoma crawfordi*, *Cirsotrema browni*, and *Pseudamussium huttoni*. It is the closing member of the series in Otago, Canterbury, and throughout the North Island. The lower limestone is the well-known Oamaru building-stone, typically developed in the Oamaru district. It is absent in South Otago, Waitaki Valley, Waihao, and Kakahu, but is represented by limestones in the Trelissic basin and Waipara district. A consideration of its distribution in the Oamaru district shows that it gradually decreases in thickness towards the west, dwindling to nothing long before the old shore-line is reached. In other words, it is a deposit formed in comparatively deep, clear water. For the upper limestone I propose to use the name Waitaki Stone, and for the lower Oamaru Stone. The Geological Survey and Captain Hutton, recognising only one limestone in the Oamaru district, have applied the name Oamaru or Ototara Stone indifferently to both the upper and lower limestones, which has naturally led to a good deal of confusion with respect to the relations of the Hutchinson Quarry and associated beds to the Waitaki Stone. Of the geologists who have examined North Otago, Mr. McKay was the only one to recognise two limestones. His view is that the Oamaru building-stone is the closing member of the Oamaru series, and that the Waitaki Stone and under-

* Hutton, "Geology of Otago," 1875, p. 58

† Hutton, Trans. N Z. Inst., vol. xxxii., 1899, p. 171.

lying Hutchinson Quarry beds are members of a younger series.

(2.) That the Awamoa and Hutchinson Quarry beds are the upper and lower members of the same series, and lie below the Waitaki Stone and above the Oamaru building-stone.

(3.) That the Hampden, Awamoa, Waihao Forks, Pareora, and Kakahu beds belong to the Oamaru series.

(4.) That Captain Hutton was right in separating the Motanau beds from the Pareoras.

(5.) That the Motanau beds overlie the Oamaru series unconformably.

(6.) That the Geological Survey is right in placing the Kakahu, Waihao Forks, Black Point, and Hampden beds below the Waitaki Stone, but wrong in ascribing the Pareora, Mount Harris, and Awamoa beds to a position above the Waitaki Stone, and wrong in correlating the Motanau and Pareora beds..

(7.) That the Pareora fauna is only found in beds underlying the Waitaki Stone.

(8.) That nowhere in Otago or Canterbury are beds containing the Pareora fauna to be seen overlying the Oamaru series.

(9.) That there are two horizons of littoral shells in the Oamaru series—namely, the Awamoas, lying above the Hutchinson Quarry beds, and the Waihao Forks beds, overlying the coal.

(10.) That the Oamaru series at Weka Pass rests unconformably upon the Weka Pass Stone.

(11.) That the Weka Pass Stone is conformable to the Amuri limestone, and is the closing member of the Waipara series in Canterbury.

(12.) That the Motanau and Awatere beds belong to the Te Aute series of Older Pliocene age.

Grouping the beds in the order of their superposition and according to their relationships, we get the following table of formations:—

Older Pliocene ..	Te Aute series	—Motanau beds.
Miocene ..	Oamaru series	*a.* Waitaki Stone. *b.* Awamoa beds. *c.* Mount Brown beds. *d.* Oamaru Stone. *e.* Waihao sandstone. *f.* Awamoko shales, grits, and conglomerates, with brown coal.
Upper Cretaceous ..	Waipara series	*a.* Weka Pass Stone. *b.* Amuri limestone. *c.* Waipara greensands. *d.* Saurian beds. *e.* Puke-iwi-tahi fireclays, grits, and conglomerates, with coal.

The Motanau beds, containing some 70 per cent. of living forms, rest unconformably upon the Mount Brown beds, as will be shown later on. They contain none of the large extinct molluscs which characterize the Pareora and Awamoa beds.

The Pareora beds are nowhere seen to overlie the Waitaki Stone, not even in the typical sections at Pareora and Awamoa. At these places, unfortunately, the sections are so obscure that the relationships cannot be determined.

In the Waihao district the Mount Harris beds, assigned by Captain Hutton and the Geological Survey to the Pareora series, rest not upon the Waitaki Stone, which is present everywhere, but upon the Lower Mesozoic basement rocks. The meaning of this is somewhat significant.

The sections at Hampden, Kakanui, Enfield, Wharekuri, Waihao Forks, and Kakanui afford conclusive evidence of the inferior position of beds which are admitted by Captain Hutton to contain the Pareora fauna, and supply a satisfactory solution of the problem at Mount Harris.

The typical Hutchinson Quarry beds are exposed at the old quarry of that name near the Town of Oamaru. Here they form a small isolated patch obscured by a thick deposit of the Oamaru silts. They are intercalated with tuffs, and themselves consist of yellowish-coloured calcareous sands and thin bands of limestone. The Oamaru building-stone is absent in this neighbourhood, and consequently the relationship existing between the Hutchinson Quarry beds and that horizon cannot be determined in the typical locality. Captain Hutton includes the Hutchinson Quarry beds in his Oamaru series, but the Geological Survey assumes that they overlie the Waitaki Stone and belong to a younger series. The underlying beds are not exposed, and the Waitaki Stone is absent, consequently there is nothing to indicate to what horizon the quarry-beds should be referred. Whatever evidence there is tends to show that they belong to the period of volcanic activity which preceded the deposition of the Oamaru Stone, for volcanic activity which commenced in the Oamaru district towards the close of the Waihao greensand period culminated during the deposition of the Hutchinson Quarry beds and ceased before the deposition of the Waitaki Stone. The Hutchinson Quarry beds possess no value for correlative purposes, since their stratigraphical position can only be ascertained by reference to sections elsewhere. The sections north of the mouth of the Kakanui River, Cape Oamaru, and Teschemaker's clearly correlate the Hutchinson Quarry beds with the horizon which underlies the Waitaki Stone. The beds of this horizon have been generally known as the Hutchinson Quarry or Mount Brown beds. In the present classification

I have used the latter name as the more appropriate of the two. The Mount Brown, Mount Donald, Hutchinson Quarry, and Kakanui River beds all belong to the same horizon.

In the Waipara district the Cretaceous, Lower and Younger Tertiaries are very fully developed, richly fossiliferous, and exposed in many magnificent sections which are easily accessible. The district possesses a combination of favourable conditions not found elsewhere, and for this reason it must be regarded as a classic locality of rare geologic importance.

Distinctive Fauna of Oamaru Series.

The fossils which distinguish the three principal horizons of the Oamaru series, as now defined by me, are as follows:—

Waitaki Stone.

Meoma crawfordi, Hutton.
Cirsotrema browni, Zittel.
Pseudamussium huttoni,* Park.
Magellania novara, Jhering.

Mount Brown Beds.

Kekenodon onomata, Hector.
Cassidaria senex, Hutton.
Cirsotrema lyrata, Zittel.
Cirsotrema browni, Zittel.
Pecten hutchinsoni, Hector.
Pecten beethami, Hutton.
Pecten hochstetteri, Zittel.
Pecten fischeri, Zittel.
Pecten polymorphoides, Zittel.
Pecten williamsoni, Zittel.
Amussium zitteli, Hutton.
Pseudamussium huttoni, Park.
Plagiostoma lævigata, Hutton.
Lima palaeta, Hutton.
Magellania parki, Hutton.
Magellania novara, Jhering.
Terebratella gaulteri, Morris.
Terebratella oamarutica, Boehm.
Terebratula tayloriana, Colenso.

---

* For more than thirty years this beautiful pecten, which is found in the Oamaru series all over New Zealand, has been erroneously known to New Zealand geologists as *Pecten hochstetteri*, Zittel. It is smooth on both valves, and easily distinguished from *P. hochstetteri*, which is smooth on one valve and marked with fine radiating ribs on the other. Mature examples of the latter are about half the size of mature shells of *Pseudamussium huttoni*.

Bouchardia elongata, Hutton.
Bouchardia tapirina, Hutton.
Trochocyathus mantelli, Tenison-Woods.
Sphenotrochus huttonianus, Tenison-Woods.
Cup-shaped *Cellepora*.

Waihao-Kakahu Beds.

Aturia australis, McCoy.
Pleurotoma awamoaensis, Hutton.
Pleurotoma alta, Hutton.
Ancilla hebera, Hutton.
Terebra tristis, Hutton.
Scaphella corrugata, Hutton.
Turritella kanieriensis, Harris.
Turritella cavershamensis, Harris.
Natica darwini, Hutton.
Crepidula incurva, Zittel.
Cirsotrema browni, Zittel.
Dentalium mantelli, Zittel.
Dentalium giganteum, G. B. Sowerby.
Ostrea wullerstorfi, Zittel.
Pseudamussium huttoni, Park.
Amussium zitteli, Hutton.
Limopsis insolita, G. B. Sowerby.
Glycymeris globosa, Hutton.
Cucullæa alta, G. B Sowerby.
Mactropsis traili, Hutton.

Of these fossils, *Cirsotrema browni* and *Pseudamussium huttoni* range from the Oamaru Stone to the base of the Waihao greensands. *Meoma crawfordi*, which first appears in the Mount Brown horizon, becomes a common form in the Oamaru Stone. *Kekenodon onomata* is characteristic of the Mount Brown beds, but at Ngapara and Marawhenua rises into the Oamaru Stone. *Pecten hutchinsoni*, *P. hochstetteri*, *P. fischeri*, and *Plagiostoma lævigata* appear to be confined to the middle or Kakanui horizon. *Amussium zitteli* is found in the Lower Waihao beds, but is never abundant. *Aturia australis*, which is fairly common in the lower division, appears occasionally in the Mount Brown horizon, but so far as known does not reach into the Waitaki Stone. Of the two fine examples of this nautiloid in the Otago Museum, one is from the Lower Kakanui limestone, and the other from the Wharekuri greensands. *Turritella kanieriensis* is abundant in the beds overlying the coal, while *T. cavershamensis* occasionally reaches into the middle of the Mount Brown beds. *Dentalium mantelli*, *D. giganteum*, *Limopsis insolita*, and *Cucullæa alta* are distinctive of both the Waihao and Mount Brown beds.

Physical Characteristics.

Oamaru Stone.

The typical Oamaru building-stone now being quarried at Deborah, Totara, and Teschemaker's, on the main south railway-line to Dunedin, is a soft pale-grey calcareous rock principally composed of comminuted corals and foraminifera. The quarries all lie east of the railway, along the eastern boundary of the outcrop of the stone—that is, on the side furthest from the old Tertiary shore-line. Passing southwards towards the Kakanui, and westward in the direction of Weston, Enfield, Ngapara, Waitaki Valley, and other places lying along or near the old Miocene shore-line, the Oamaru Stone gradually merges into a yellowish-brown calcareous sandstone containing the scattered remains of large echinoderms, a few brachiopods, *Pseudamussium huttoni*, and *Cirsotrema browni*. Close to the old shore these forms are mingled with examples of the littoral shells which abound in the overlying Mount Brown beds.

Mount Brown Beds.

These beds generally consist of glauconitic sands, often passing into a soft sandstone, or yellowish-brown coralline sands and sandstones, which in places pass into rubbly or impure limestones. In only a few places is there such an excess of carbonate of lime as to warrant the quarrying of the stone for burning into lime.

These beds are easily distinguished from the Waitaki Stone by the presence of a rich and varied fauna In addition to numerous corals, bryzoans, and broken echinoderm spines, they contain a great assemblage of pectens and brachiopods, many of which appear to be characteristic of this horizon.

At Kakanui the Waitaki Stone is separated from the Mount Brown beds by a considerable thickness of tuffs and basalt. Passing westward the volcanic matter gradually diminishes in thickness, so that at Teschemaker's they are separated by only a few feet. Westward of Weston they are directly in contact with each other, the Mount Brown horizon here consisting of glauconitic sands mixed with tufaceous matter.

It is a noticeable feature, perhaps seen to better advantage in the cliff-escarpments in the Waitaki Valley and Waihao district than elsewhere, that the Mount Brown beds gradually merge into the Waitaki Stone as they approach the old shore-line, forming a single continuous calcareous horizon. Each horizon, however, still preserves its distinctive features, the Waitaki Stone being represented by the band of yellowish-brown calcareous sandstone with *Meoma crawfordi*, &c., and the Mount Brown beds by glauconitic sands, or a band of glauconitic sandstone a few feet thick adhering to the base of the Waitaki Stone, and crowded in places with brachiopods and numerous fine examples of *Pseudamussium huttoni, Cirsotrema browni,* and more rarely *Plagiostoma lævigata.*

The calcareous sandstones at Shag Valley, Waikouaiti, and Brighton contain a varied fauna which correlates them with the Mount Brown rather than the Waitaki Stone horizon. At Waikouaiti North Head* they attain a thickness of over 350 ft., this great expansion of the lower horizon having apparently taken place at the expense of the Oamaru Stone.

At Millburn limestone quarry, south of Lake Waihola, the Mount Brown beds are represented by beds of glauconitic sandstone, which pass upward into a compact limestone† about 80 ft. thick. It is probable that the upper part of this limestone and the calcareous sandstones which overlie it are the local representatives of the Waitaki Stone.

The compact limestone at Millburn is extremely variable in quality along its horizontal extension both going north and south. Passing northward it becomes intercalated with narrow bands of glauconitic sandstone, and attempts to burn the rock for lime at different points have been unsuccessful through the excess of sandy impurity.

Waihao-Kakahu Beds.

These generally consist of blue sandy clays and soft bluish-green sandstones which often contain thin layers, or detached lens-shaped masses, of hard calcareous sandstone. Near the old shore-line these rocks sometimes consist of loose pebbly shell beds, or of loose sandy beds and blue clays alternating.

The molluscous fauna of this horizon is mainly of a littoral character, and it is not a little singular that it contains a number of recent shells that are not often seen in the overlying Mount Brown beds, and never in the Waitaki Stone. This apparent anomaly is doubtless explained by the circumstance that the whole series was deposited on a sinking shore-line, and consequently, while the gradually deepening sea-floor favoured the existence of coralline and brachiopod life, it caused the local extinction or migration of the littoral life.

Where the old coast-line was flat and shelving, the littoral shells would follow the retreating shores westward; but where the coast-line was bounded by high steep land, as we know was the case for long stretches, the littoral forms would be submerged in uncongenial depths, and compelled to migrate

* Park, "On the Geology of North Head, Waikouaiti" (Trans. N.Z. Inst., vol. xxxvi., 1903, p. 421).

† Park, "On the Geology of the Rock Phosphate Deposits of Clarendon, Otago" (Trans. N.Z. Inst., vol. xxxv., 1902, p. 391).

to places where the conditions were more favourable for their existence.

Among the living shells found in this horizon, *Lucina divaricata* has not been identified in either the Kakanui beds or Waitaki Stone. *Rhynchonella nigricans* ranges through the three horizons, while *Ancilla australis, Scapella gracilis, Siphonalia nodosa,* and *Struthiolaria populosa* are common to both the Waihao and Kakanui horizons, but absent from the Oamaru Stone, as would naturally be expected.

Conditions of Deposition.

The succession of grits and conglomerates, with coal, clays, and sandstones with a littoral marine fauna, followed by coralline sandstones and limestones, clearly prove that the Oamaru series was formed during a period of slow submergence of the old Tertiary shore-line. The grits, and conglomerates, and fire-clays accumulated on the sea-shore and in estuaries, forming the narrow low-lying beach on which the fringe of coal-vegetation afterwards established itself and flourished. The slow progressive sinking of the land in time submerged the forests and destroyed the vegetation, which became covered with littoral sands and estuarine clays, while the littoral deposits in turn became covered by the coralline accumulations of the deeper seas.

The character of the fauna and the large size of the shells indicate warm conditions of a subtropical sea.

Distribution.

After the deposition of the Waitaki Stone the sinking movement ceased, and there began a period of elevation. The newly formed beds now emerged from the sea, arranged as a narrow marginal fringe or bench which contoured around the bays and headlands of the old Tertiary shore-line. They also stretched far back among the mountains, into inland basins and winding fiords, some of which for length and diversity of form are without a parallel at the present time.

Physical Geology.

From the marginal distribution of the Miocene Tertiaries we gather some interesting information with respect to the physical geography of New Zealand in the Eocene. We learn, in the first place, that the main mountain features had already been determined; and, in the second place, that the old Tertiary fiords and inland basins, before the Miocene submergence, were merely deep valleys of erosion which the sinking of the land enabled the sea to encroach and flood like the submerged valleys forming the fiords of south-west Otago in the present day.

The Wharekuri basin had access to the open sea by a narrow channel on the south side of Kurow Hill; the Trelissic basin had its outlet by the Broken River into the estuary of the Waimakariri. In Marlborough there were the famous Clarence and Awatere fiords, long, almost straight, parallel gutters stretching far back between the overhanging Kaikouras. The old outlet of Clarence fiord was in a line with the present course of the valley. But in Pleistocene times, during the great extension of the glaciers, a subsequent stream which entered the sea ten miles south of Shades Creek cut its channel back through the northern end of the Seaward Kaikouras until it tapped the drainage-area of the Clarence River. Having a shorter course, and consequently a greater velocity and erosive power, the subsequent stream in time diverted the Clarence to its own course. The nakedness of the landscape, the sharpness of the outline of mountain and ridge, are such as to stamp the impress of newness upon the features of the country. To the geologist this newness is apparent and not real. It is a mental deception conveyed to the eye mainly through the exaggerated height of the surrounding mountains compared with the width of ridge and valley. But we know that the old floor of these fiords for a distance of over forty miles is occupied by Miocene Tertiaries, and therefore we are unable to escape from the conclusion that the valleys they occupy were carved prior to the Miocene.

Proceeding to Nelson we find that the same conditions prevailed. The Tertiaries ramify the old fiord-valleys of the Motueka and its tributaries the Tadmor, Wangapeka, and Baton; of the Takaka and Aorere.

On the west coast of Nelson the marine beds follow and contour around the Inangahua and Buller Valleys and their branches. The ramifications of the old Buller fiord were of greater extent than those of any fiord existing at the present time. A long arm extended up to the foot of Mount Owen, throwing off a lateral branch which reached eastward nearly to the Mount Hope. Another stretched south-east to the base of the main divide, opening out into a great inland basin, now known as the Maruia Plains.

The Tertiary bench formed an encircling fringe around the whole of the South Island. After its emergence from the sea it became carved and eroded before the Pliocene submergence, during which the Greta and Wanganui beds were deposited.

The next great uplifting of the land took place near the close of the Pliocene, and the upward movement continued until the elevation was such as to permit the accumulation of great masses of glacier-ice among the higher mountain-chains. This was in the Pleistocene—that is, the glacier period of New Zealand was contemporary with the glacial period of northern continental Europe.

Of the maximum elevation reached we know nothing. One thing, however, is certain—namely, that as soon as the maximum elevation was reached the sinking of the land at once set in. The glaciers now began their retreat to the main divide, and at this time the great Southland, Canterbury, and Moutere* gravel plains were formed on the gradually sinking surface of the land. Thus we find that New Zealand since the close of the Secondary period has been rising and sinking with singular regularity.

The South Island of New Zealand at the close of Eocene consisted of a long narrow mountain-chain with many descending ridges and outlying rocky islets. The watershed was so narrow that no large streams existed, while the sinking of the land lessened the height of the dry land and correspondingly decreased the velocity of the descending meteoric waters. Torrential streams were absent, and denudation of the land was comparatively slow. The Tertiary deposits were laid down on the floor of the open sea, and in all the bays, deep indentations, and long fiords existing at the time; and everywhere the same conditions of quiet deposition appear to have existed.

The uniformity of the contained fauna is not less remarkable than the uniformity of the sediments. Some localities yield forms that are specially distinctive of the place, but it is notorious that the characteristic fossils of each horizon are the same from one end of New Zealand to the other.

In the majority of places near the coast the Tertiary beds are lying flat, or are only slightly inclined, except where faulted, or disturbed by igneous intrusions. In the neighbourhood of Lake Wakatipu, and along the flanks of the Kaikouras in Marlborough, they are nipped up and entangled among the older rocks by extensive faulting. But the involvement is not great, and, in the case of the Kaikouras, of no structural or tectonic importance, as is clearly shown where the sections are drawn to natural scale.

Manifestly the main orographical features of the country were determined after the close of the Jurassic period—a view which receives support from the distribution of the Waipara series, which was apparently deposited as a marginal beach on

* The Moutere gravels, which rise from sea-level at Golden Bay to a height of over 2,000 ft. at the Hope Saddle, were formed by the Motueka at the time that river drained the north-west slopes of the St. Arnaud and Spencer Mountains. The Buller River by its rapid recession intercepted the head-waters of the Motueka, which is now greatly diminished in volume.

the old Cretaceous shore-line, like the Oamaru series at a later date. Moreover, it occurs in the Trelissic basin and in the Clarence and Awatere Valleys, which must therefore have existed as arms of the sea prior to its deposition.

BASEMENT ROCKS.

In the Waipara district, and in several parts of Marlborough, and in the country between Onekakara, near Hampden, and the Upper Kakanui, the Oamaru series rests on the Waipara formation; elsewhere it lies directly on the older Mesozoic or Palæozoic basement rocks. Thus in the Province of Otago it rests principally upon mica-schist and altered sedimentaries; in Canterbury, upon Lower Mesozoic claystones and sandstones; and in Nelson and Westland, mainly upon schists, quartzites, slates, and other altered sedimentary rocks.

INFLUENCE OF BASEMENT ROCKS.

In the places where the Oamaru series rests upon the older basement rocks its lowest member consists of grits and conglomerates, derived from the erosion of the adjacent country. Coal, too, generally occurs with these rocks—at any rate near the old shore-line; but in the localities where the series rests upon the members of the Waipara formation the grits, conglomerates, and coal are absent. The absence of the grits and conglomerates is doubtless due to the lack of the requisite hard rock in the Waipara series to supply the materials, but the absence of the coal is the result of causes which are not very obvious.

EFFECTS OF DIFFERENTIAL ELEVATION.

For the most part, the Oamaru series forms the maritime hills and downs of Otago and Canterbury, and a great part of Marlborough, Nelson, and Westland. It gradually ascends as it proceeds inland, in many places rising to an elevation of between 2,000 ft. and 3,000 ft. in the inland basins and valleys and on the flanks of the foothill ranges. And this feature is not confined to the East Coast alone—it is equally true of the western portion of the Province of Nelson, and of Westland, as the examples given hereafter will show.

In North Otago the Waitaki Stone and its associated rocks ascend the Waitaki Valley a distance of over fifty miles from the sea, ending in the Wharekuri basin, which is only a few square miles in extent, being bounded on all sides by steep mountains. Here the Tertiary beds reach a height of over 2,300 ft. above sea-level.

In the Trelissic basin the Oamaru series rises to a height of 3,200 ft. This basin is somewhat less than four miles square, and surrounded on all sides by steep mountains.

In the Waipara district the same beds form ridges reaching over 1,800 ft. high at their highest parts.

The old Tertiaries at the lower end of the Takaka Valley occur at sea-level, but they rise with the gradient of the valley, and gradually ascend till in a distance of thirty miles they reach Mount Arthur Tableland, 3,600 ft. above the sea, where they are almost horizontal. From the tableland going southward the same beds cling to the western flanks of the main range at elevations varying from 2,000 ft. to 3,000 ft., descending westward towards the sea at Mokihinui and Westport and intermediate places. This mantling fringe of Middle Tertiary marine rocks ascending from sea-level on both coasts affords a measure of the elevation of the land since the beginning of the Pliocene, and, moreover, clearly proves the differential rate of the upward movement

The greatest elevation has in all cases taken place along the main orographical axis of the Island, which is situated closer to the west coast than the east. The differential land-movement being most acute on the west coast introduced unequal stresses, which resulted in extensive faulting of the coal-measures between the sea and the axis of greatest elevation. A notable example of this faulting occurs in the Aorere Valley near Collingwood. On the south side of the river the Tertiaries lie at sea-level, but on the north side they crown the range at an elevation of 1,000 ft., and dip away to the west coast.

Contemporary Volcanic Eruptions.

While the sediments of the Tertiary fringe were accumulating on the littoral of the Miocene seas, volcanic eruptions commenced in the area lying between Moeraki and Oamaru. They were submarine, and took place at points lying some miles to the seaward of the old shore-line, most notably in the areas now known as Ngapara, Waiareka, Oamaru, and Kakanui. These eruptions were not very violent; and it was only at Kakanui, and perhaps at Oamaru, that the ejected materials were piled up so as to form volcanic islands. So far as can be ascertained from the distribution of the matter, the volcanic activity began after the close of the Waihao-Kakahu horizon, and ended before the deposition of the Waitaki Stone began. The main outbursts were apparently confined to the Mount Brown or Hutchinson Quarry period.

There is reason to believe that the volcanic eruptions in the Hauraki Gulf area which produced the tuffs interbedded with the Waitematas were contemporary with those near Oamaru.

Life of Oamaru Series.

At the time of the deposition of the sediments of this formation there lived in the New Zealand seas a zeuglodon whale (*Kekenodon onomata*, Hector), a giant penguin (*Palæudyptes antarcticus*, Huxley), a huge shark (*Carcharodon auriculatus*, Blainville), a ray (*Myliobatis plicatilis*, Davis), as well as a large nautilus (*Aturia australis*, McCoy). In the deeper waters there flourished a great variety of corals, bryzoans, and *Foraminifera*, and with these many brachiopods, pectens, and echinoderms. In the shallow water and estuaries there lived a great assemblage of molluscs, many of which were remarkable for their large size.

Among the shells, which grew to a great size in these genial Tertiary seas, were the following:—

Ostrea wullerstorfi, Zittel.
Pecten athleta, Zittel.
Pecten beethami, Hutton.
Pecten hutchinsoni, Hutton.
Pseudamussium huttoni, Park.
Plagiostoma lævigata, Hutton.
Cucullæa ponderosa, Hutton.
Cucullæa alta, Hutton.
Crassatellites ampla, Zittel.
Dosinia magna, Hutton.
Cardium patulum, Hutton.
Dentalium giganteum, Hutton.
Pleurotoma hamiltoni, Hutton.
Pleurotomaria tertiaria, McCoy.
Cirsotrema lyrata, Zittel.
Turritella cavershamensis, Harris.
Natica darwini, Hutton.

AGE OF OAMARU SERIES.

This formation is ascribed by Captain Hutton* to the Oligocene period, principally, he says, from the occurrence in it of the Cretaceous genus *Holaster*, two species of which he has described from the Cobden limestone, near Greymouth.† The genus *Holaster*, although Cretaceous, ranges into the Miocene of Europe. Of the remaining genera of *Echinodermata* recorded by Captain Hutton from the Oamaru series in his catalogue of the Tertiary *Mollusca* and *Echinodermata*, all but one or two are represented by living species. According to Zittel all of these genera are Tertiary and Recent with the exception of the genus *Cidaris*, which ranges from Permian to Recent.

* Hutton, "The Geological History of New Zealand" (Trans. N.Z. Inst., vol. xxxii., 1899, p. 170).

† Hutton, "On some Fossils lately obtained from the Cobden Limestone at Greymouth" (Trans. N.Z. Inst., vol. xx., 1887, p. 268).

The Pareora series of Captain Hutton contains from 20 to 65 per cent. of living molluscs. The Waihao and Kakahu greensands, and the Hampden clays, according to that writer, contain the same fauna as his Pareora series, which he regards as Miocene.*

Sir James Hector and Mr. McKay have always maintained, and, I think, rightly, that these beds underlie the Waitaki Stone, so that, even disregarding the position of the typical Pareora for the moment, we are compelled to admit that a Miocene fauna exists below the Waitaki Stone. For this reason I think that the Oamaru series must be referred to the Miocene period, having regard for the large proportion of living species which it contains.

In Europe, where the Tertiary record is complete, it is easy to divide the scale of time into small units each characterized by some peculiar feature of its fauna or flora; but in New Zealand, where the Eocene is absent, and where the oldest Tertiaries contain a purely local fauna of which from 20 to 30 per cent. are still living, it is not possible to refer the beds with any degree of accuracy to the finer divisions recognised in the Northern Hemisphere.

Relations of Oamaru Series to Lower Tertiary Beds in the North Island.

I will deal first with the marine Tertiaries in the Waitemata district of Auckland.

The pectens which distinguish the Mount Brown or Hutchinson Quarry horizon of the Oamaru series are also characteristic of the middle division of the Waitemata beds near Auckland, which yielded a number of the types originally described by Zittel.

Among the forms common to the middle division of the Oamaru formation and the Waitemata beds are *Pecten fischeri*, *P. vellicatus*, *P. polymorphoides*, *P. williamsoni*, *Pseudamussium huttoni*, and *Amussium zitteli*. A large number of the corals, bryzoans, and *Foraminifera* found in the Orakei Bay beds are also present in the lower limestone at Kakanui and Teschemaker's, commonly associated with the pectens enumerated above. On the other hand, the brachiopods, which are so plentiful at Kakanui, Hutchinson Quarry, Waitaki Valley, Mount Brown, and some parts of Mount Donald, are practically absent from the Waitematas. This, however, can hardly be regarded as surprising in places so widely separated. Even in the Oamaru and Waipara districts the brachiopods are by no means evenly distributed in the same bed, but mostly occur in colonies, often comprising a vast number of individuals.

* *Loc. cit.*, p. 171.

This partial distribution in horizontal extension is well seen in the long line of horizontal limestone escarpment on the south side of the Waitaki Valley between Black Point and the Marawhenua, and also along the limestone crests of Mount Donald and Mount Brown, in the Waipara district.

The palæontological evidence seems to be sufficiently strong to connect the middle horizon of the Oamaru series, comprising the Kakanui, Hutchinson Quarry, and Mount Donald beds, with the Orakei Bay beds of the Waitematas of Auckland.

The basement beds or lower division of the Waitematas, as exposed at Cape Rodney, Kawau Island, Motutapu Island, and Papakura, contain a molluscous fauna which includes many of the characteristic fossils of the Waihao horizon of the Oamaru series. They contain, for example, such characteristic forms as *Ostrea wullerstorfi*, *Pecten burnetti*, *P. beethami*, *Crassatellites ampla*, *Pseudamussium huttoni*, *Rhynchonella nigricans*, and should, I think, be correlated with the Waihao horizon.

The equivalent of the Waitaki Stone is absent in the Waitemata area, but a calcareous sandstone or limestone makes its appearance further south in the Lower Waikato, Aotea, Raglan, Pirongia, Waipa, Kawhia, Upper and Lower Mokau, where it contains *Meoma crawfordi*, *Cirsotrema browni*, *Pseudamussium huttoni*, and *Magellania novara*, all characteristic of the Oamaru Stone horizon.

The sandstones lying conformably below the Waipa limestone, resting on the coal-measures, contain *Cirsotrema browni*, *Calyptræa calyptræformis*, *Cassidaria senex*, *Pseudamussium huttoni*, *Pecten fischeri*, *Cucullæa alta*, *Lucina divaricata*, and *Dentalium lævis*, all of which are found in the Waihao beds above the coal.

AGE OF WAIPARA SERIES.

Sir Julius von Haast* states that he found the impressions of dicotyledonous plants, including *Fagus ninnissiana*, *Phyllites eucalyptroides*, *Loranthophyllum dubium*, *Griselina mytifolia*, in the lowest part of this series at Waipara and Malvern Hills.

If these species, and the relations of the plant beds to the saurian beds, have been accurately determined, we have a condition of things resembling that of the Laramic (lignitic) series of the Rocky Mountains in the United States, which is referred by American geologists to the Upper Cretaceous.

---

* Haast, "Geology of Canterbury and Westland," Christchurch, 1879, p. 291.

Hampden Beach Beds.

Stratigraphy.

In the sea-cliffs opposite the Township of Hampden the beds consist of sandy clays, in the upper part of which there occur a few layers of hard calcareous masses. The strata dip N.N.E., and proceeding along the beach towards Kakanui the higher beds exposed in the sea-cliffs are more sandy and become fossiliferous. They are seen to pass under the Waiareka tuffs, as described by Sir James Hector* and Mr. McKay.†

Fossils.

A collection of fossils from these beds included the following forms:—

1. *Aturia australis*, McCoy.
2. *Siphonalia nodosa*, Martyn.
3. *Ancilla australis*, Sowerby.
4. *Ancilla hebera*, Hutton.
5. *Scaphella pacifica*, Lamarck.
6. *Scaphella corrugata*, Hutton.
7. *Pleurotoma fusiformis*, Hutton.
8. *Natica zelandica*, Quoy and Gaimard.
9. *Natica darwini*, Hutton.
10. *Struthiolaria papulosa*, Martyn.
11. *Calyptræa calyptræformis*, Lamarck.
12. *Crepidula monoxyla*, Lesson.
13. *Turritella kanieriensis*, Harris.
14. *Lotorium spengleri*, Chemnitz.
15. *Cirsotrema browni*, Zittel.
16. *Dentalium mantelli*, Zittel.
17. *Chione stutchburyi*, Gray.
18. *Glycimeris globosa*, Hutton.
19. *Limopsis insolita*, Sowerby.
20. *Cucullæa alta*, Sowerby.
21. *Pecten hutchinsoni*, Hutton.
22. *Pseudamussium huttoni*, Park.
23. *Ostrea angasi*, Sowerby.
24. *Trochocyathus mantelli*, M. Edw. and H.
25. *Notocyathus pedicellatus*, Tenison-Woods.
26. *Flabellum radians*, Tenison-Woods.

Of the twenty-four molluscs in this collection, ten, or 41·5 per cent., are still living. Captain Hutton,‡ in his paper "On the Geology of the Country between Oamaru and Moeraki," gives a list of thirty-five molluscs reported from

* Hector, Repts. of Geol. Expls., 1883–84, p. xxiv., and 1886–87, p. xx.

† McKay, Repts. of Geol. Expls., 1883–84, p. 61., and 1886–87, p. 6.

‡ Hutton, Trans. N.Z. Inst., vol. xix., 1886, pp. 246–47.

the Hampden clays, of which seventeen, or 48·6 per cent., are living forms.

Captain Hutton's list contains the following fossils not found by me:—

1. *Scaphella australis*, Quoy and Gaimard.
2. *Siphonalia nodosa*, var. *conoidea*, Hutton.
3. *Cominella*, sp. ind.
4. *Nassa tatei*, Tenison-Woods.
5. *Pleurotoma buchanani*, Hutton.
6. *Natica suturalis*, Hutton.
7. *Cerithium cancellatum*, Hutton.
8. *Turritella rosea*, Quoy and Gaimard.
9. *Trochus* (?) sp. ind.
10. *Meretrix multistriata*, Sowerby.
11. *Trigonia pectinata* (?), Lamarck.
12. *Solenella funiculata*, Hutton.
13. *Mytilus magellanicus*, Lamarck.
14. *Entalophora zealandica*, Mantell.

Of the thirteen molluscs in this list, five, or 38·5 per cent., are still living.

KAKANUI VALLEY, NEAR MAHENO.

Behind Clark's mills, on the north side of the Kakanui Valley, nearly opposite Maheno Railway-station, which is about a mile away, there is a long line of steep escarpment crowned by the Oamaru Stone. The beds forming this cliff extend northward to Teschemaker's, and eastward—that is, down the valley—about a mile. The most complete section is exposed about 6 chains below Clark's mills, where the Waiareka tuffs, forming the base of the cliff, are followed by a horizon consisting of grey clays interbedded with coralline limestone, which is in turn overlain by calcareous sandstones intercalated with two sheets or sills of olivine-basalt.

The tuffs contain a few indistinct fossils, and bed No. 7 several minute bivalves and numerous *Foraminifera*. Beds Nos. 9 and 11, and possibly No. 6, represent the Oamaru Stone proper. The presence of the basalt sill shows that volcanic activity was nearly contemporary with the deposition of the lower part of the Oamaru Stone in the Kakanui area. Elsewhere, both to the north and south, activity appears to have ceased somewhat earlier.

At Clark's mill the Oamaru Stone is interbedded with a bed of clay with white chalky joints. This bed varies from a thickness of 12 ft. behind the mill to a few inches at Teschemaker's, less than a mile distant. West of the latter place it thins out altogether. The basalt sill as seen in the longitudinal section of the escarpment, about 2 chains nearer the mill than the cross-section shown in fig. 1, has been intruded partly along the plane of the clay-bed. The sill ends

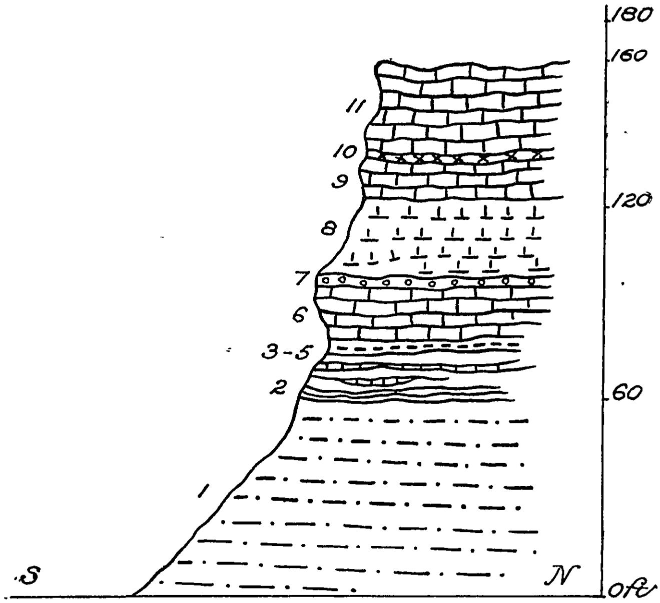


Fig 1.

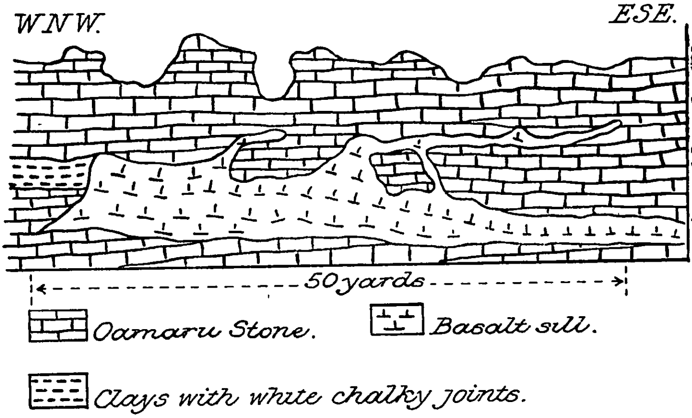
Section near Clark's Mills, Maheno.

1. Dark-green tuffs, Waiareka tuffs, 60 ft. 2. Gritty sandstone, 4 ft. 3 in. 3–5. Grey clays intercalated with layers of coralline limestone, 5 ft. 6 in. to 7 ft. 6. Yellowish-grey calcareous sandstone, 21 ft. 7. Yellowish flaky clays, foraminiferous, 4 in. to 1 ft. 6 in. 8. Sill of olivine basalt, 22 ft. 9. Yellowish-grey calcareous sandstone, 7 ft. to 8 ft. 10. Sill of olivine-basalt, 3 in. 11. Yellowish-grey calcareous sandstone, 25 ft.

abruptly at the westward end. The detached mass of limestone entangled in the basalt tends to show that the calcareous sediments had become partially consolidated before the intrusion of the lava.

Sea-coast near Kakanui Township.

From Kakanui Township northward for some distance the beach is bounded by steep cliffs, and in many places is only accessible at low tide. The Tertiaries which form the cliffs bounding the small bay or indentation between the quarry and Trig. T, a quarter of a mile to the north, are lying comparatively undisturbed, and contain several horizons crowded with the fossils characteristic of the Oamaru series.



LONGITUDINAL SECTION OF UPPER PART OF CLIFF (4 chains below Clark's Mill, Maheno).

Stratigraphy.

In the sea-cliffs a few chains north of the quarry and lime-kilns there are exposed the Oamaru Stone, and Kakanui or Hutchinson Quarry beds, together with intercalated tuffs and lavas.

The section exposed along the cliff at sea-level, 3 chains north of Kakanui quarry, is shown in fig. 3.

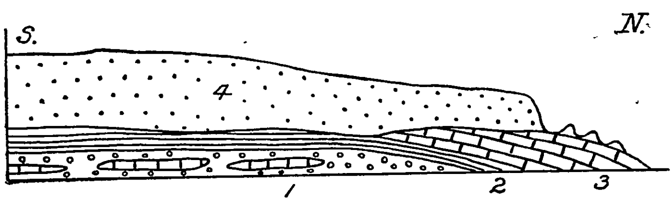


Fig 3.

SECTION ALONG SEA-CLIFF (3 chains north of Kakanui Quarry).

1. Yellow calcareous tuff, fossiliferous. 2. Banded clays and gritty sandstones 3. Calcareous sandstone passing into limestone (Kakanui limestone). 4. Yellow silts.

A few chains further north, the cross-section running from the beach westward to trig. station T is as follows :—

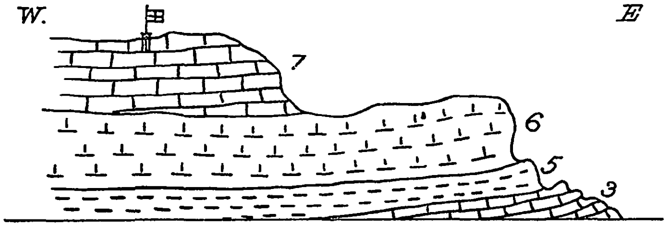


Fig 4.

CROSS-SECTION FROM SEA TO TRIG. T.

3. Calcareous sandstone (Oamaru limestone). 5. Tufaceous greensands, fossiliferous. 6. Basalt flow and tuffs. 7. Calcareous sandstone (Waitaki Stone).

Fossils.

Bed No. 1 consists of hard yellowish-coloured calcareous tuffs, in places passing into an impure limestone. In a large collection of fossils made from it at this place the following species were identified :—

1. *Aturia australis*, McCoy.
2. *Scaphella corrugata*, Hutton.
3. *Siphonalia regularis*, Hutton.
4. *Pleurotoma fusiformis*, Hutton.
5. *Nassa socialis*, Hutton.
6. *Trochus nodosus*, Hutton.
7. *Calliostoma spectabile*, A. Adams.
8. *Dentalium giganteum*, Hutton.
9. *Dentalium mantelli*, Zittel.
10. *Pecten williamsoni*, Zittel.
11. *Pecten hutchinsoni*, Hutton.
12. *Pseudamussium huttoni*, Park.
13. *Venericardia awamoaensis*, Harris.
14. *Lima paleata*, Hutton.
15. *Terebratella gaulteri*, Morris.
16. *Terebratula tayloriana*, Colenso.
17. *Bouchardia tapirina*, Hutton.
18. *Trochocyathus mantelli*, M. Edw. and H.
19. *Balanophyllia hectori*, Tenison-Woods.
20. *Sphenotrochus huttonianus*, Tenison-Woods.
21. *Meoma crawfordi*, (?) Hutton.

Small branching and net corals are very abundant. Crab-remains were also found. A large example of *Aturia australis*, 12 in. in diameter, was discovered on the upper surface of the flat ledge formed by this bed, just within the influence of high tides. On account of the hardness of the rock no attempt was made to extract it.

From bed No. 5, which overlies bed No. 3 of Figs. 3 and 4, and forms the higher part of the Kakanui limestone, I collected the following forms, at a point about 15 chains north of the quarry :—

1. *Kekenodon onomata*, Hector.
2. *Scaphella corrugata*, Hutton.
3. *Siphonalia nodosa*, Martyn.
4. *Cirsotrema browni*, Zittel.
5. *Teredo heaphyi*, Zittel.
6. *Ostrea angasi*, Sowerby.
7. *Anomia alectus*, Grey.
8. *Pecten hutchinsoni*, Hutton.
9. *Pecten burnetti*, Zittel.
10. *Cucullæa alta*, Sowerby.
11. *Lima paleata*, Hutton
12. *Venericardia awamoaensis*, Harris.
13. *Magellania novara*, Jhering.
14. *Magellania parki*, Hutton.
15. *Terebratella gaulteri*, Morris.
16. *Terebratula oamarutica*, Boehm.
17. *Terebratulina oamarutica*, Boehm.
18. *Meoma crawfordi*, Hutton.
19. *Isis dactyla*, Tenison-Woods.

Cup-shaped *Cellepora*.
Net and branching corals, very abundant.
Crab-remains.

From Kakanui the tuffs extend northward to a point about 90 chains south of Awamoa Creek. On the beach at White Rocks Road they are about 60 ft. thick, and dip east at angles varying from 30° to 35°. At this place they contain a few fossils, among which I collected *Diplodonta zelandica*, Gray, *Tellina angulata*, Hutton, some fragments of an oyster, and broken corals.

AWAMOA CREEK.

The Awamoa beds are regarded by the Geological Survey and Captain Hutton as typically representative of the Pareora beds of Canterbury. They are exposed on the beach at the mouth of Awamoa Stream, and on the banks of the stream in the immediate vicinity. The rocks forming these beds consist of bluish-green sandstones alternating with blue sandy clays. In the clays there are thin beds or bands of hard shelly sandstone, generally pebbly and gritty.

Fossils are very scarce in the bluish-green sandstone, in places quite common in the clays, and very abundant in the hard pebbly bands, which vary from a few inches to about 2 ft. thick. At the time of my visit the beach outcrops were sufficiently free from shingle to enable me to ascertain that the fossiliferous horizon was only a few yards wide, the bulk of the fossils being contained in one narrow band of shelly sandstone.

Stratigraphy.

The beds are so obscured by beach shingle and recent alluvium that nothing whatever can be made of their stratigraphical relations to the Oamaru Stone and tuffs in the neighbourhood. This information is, however, supplied by the section of Tertiaries exposed at the rifle-butts north of Cape Wanbrow.

Fossils.

A small collection of fossils from the Awamoa beds contained the following species:—

1. *Pleurotoma fusiformis*, Hutton.
2. *Pleurotoma buchanani*, Hutton.
3. *Pleurotoma traili*, Hutton.
4. *Lotorium spengleri*, Chemnitz.
5. *Siphonalia nodosa*, Martyn.
6. *Ancilla australis*, G. B. Sowerby.
7. *Ancilla hebera*, Hutton.
8. *Scaphella corrugata*, Hutton.
9. *Scaphella gracilis*, Swainson.
10. *Natica darwini*, Hutton.
11. *Cirsotrema browni*, Zittel.
12. *Struthiolaria papulosa*, Martyn.
13. *Calyptræa calyptræformis*, Lamarck.
14. *Crepidula monoxyla*, Lesson.
15. *Crepidula aculeata*, Gmelin.
16. *Turritella kanieriensis*, Harris.
17. *Dentalium mantelli*, Zittel.
18. *Dentalium lævis*, Hutton.
19. *Chione vellicata*, Hutton.
20. *Limopsis insolita*, Sowerby.
21. *Venericardia awamoaensis*, Harris.
22. *Dosinia greyi*, Zittel.
23. *Glycimeris globosa*, Hutton.
24. *Pecten williamsoni*, Zittel.
25. *Pseudamussium huttoni*, Park.
26. *Lima paleata*, Hutton.
27. *Mactropsis traili*, Hutton.
28. *Crassatellites traili*, Hutton.

Of the above twenty-eight species, eight, or 28·5 per cent., are living; and of the twenty extinct forms nine were found by me in the Hampden beds. Eight species have never, so far as I can gather, been found in beds overlying the Waitaki Stone. They are *Ancilla hebera, Cirsotrema browni, Scaphella corrugata, Dentalium mantelli, Limopsis insolita, Pseudamussium huttoni, Pecten williamsoni, Mactropsis traili.* To these should probably be added *Natica darwini* and *Pleurotoma fusiformis.*

CAPE OAMARU.

Proceeding southward from Oamaru Breakwater the sea-cliffs are found to consist of lavas and agglomerates. About 15 chains past the first point, at a shallow indentation where a blind gully descends to the sea, the agglomerates are underlain by a series of bedded ash-beds, greensands, silts, and sandstones, the two former containing bands or beds of impure limestone. The ash-beds and sandstones dip towards the north at an angle of about 25°, and rest upon a flow of basalt which occurs in pillow-form masses along the base of the cliff. The interstices between the masses are filled with calcareous sandstone or impure limestone.

The pillow-form structure of a lava is not often seen, and this is, I believe, the first record of it in New Zealand. An occurrence of this structure, almost identical with that at Cape Oamaru, is exposed on the beach near Ballantrae, in south-west Scotland. It has been described by B. N. Peach and J. Horne, and figured by them in the Memoirs of the Geological Survey of the United Kingdom for 1899.* In this case the interstices between the pillow-form masses are filled with Silurian limestone.

Stratigraphy.

Here we have unmistakable evidence of contemporary volcanic activity. The lava was poured over the floor of the sea, and in cooling assumed a remarkable pillow-form structure resembling a number of large pillows piled one upon the other. The presence of impure limestone and sandy matter filling the spaces between the pillow-form masses, and the rapidly alternating character of the tuffs and fossiliferous beds immediately overlying, present conclusive evidence of the submarine character of the eruptions. The lithological features of the rocks and the fossil contents serve to correlate these beds with the Hutchinson Quarry and Kakanui limestone horizon.

* "The Silurian Rocks of Scotland," vol. i.; London, 1903.

The arrangement and relationship of the different beds at this place are shown in fig. 5.

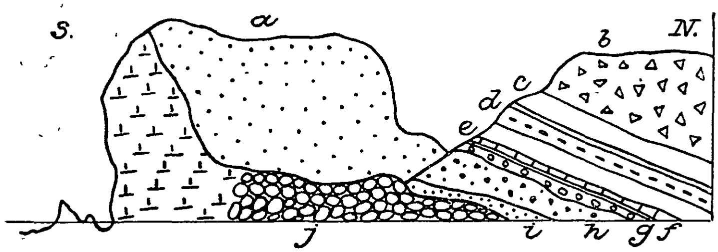


Fig 5

SECTION OF SEA-CLIFF NORTH OF CAPE WANBROW.

a. Yellow Pleistocene silts. *b.* Agglomerates and tuffs. *c.* Bedded tuffs. *d.* Greensands and tuffs, fossiliferous. *e.* Coralline limestone, 3 ft. to 3·5 ft. thick. *f.* Thin-bedded blue clays. *g.* Rubbly calcareous ash-bed, with thin layers of limestone from 2 in. to 6 in. thick near the upper part. *h.* Yellowish-green ash-bed, 18 ft. to 20 ft. thick; fossiliferous. *i.* Sands, silts, and ash, current-bedded; no fossils. *j.* Pillow-form lava and agglomerates.

Fossils.

From bed *d* I collected the following species:—

1. *Pecten hutchinsoni*, Hutton.
2. *Pseudamussium huttoni*, Park.
3. *Magellania novara*, Jhering.
4. *Terebratella gaulteri*, Morris.
5. *Terebratulina oamarutica*, Boehm.

Also numerous corals and *Cidaris* spines.

The same species were also collected from beds *e* and *f*.

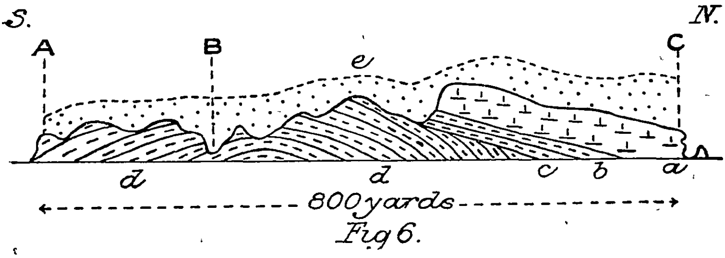
From bed *h* I obtained a greater variety of molluscs, including the following forms:—

1. *Ostrea wullerstorfi*, Zittel.
2. *Glycimeris globosa*, Hutton.
3. *Venericardia awamoaensis*, Harris.
4. *Diplodonta zelandica*, Gray.
5. *Pecten hutchinsoni*, Hutton.
6. *Pecten williamsoni*, Zittel.
7. *Pseudamussium huttoni*, Park.
8. *Limopsis insolita*, G. B. Sowerby.

Also cup-shaped bryozoans and corals.

Proceeding southward from the point formed by the pillow-form lava and agglomerates, the latter are seen to be underlaid by thin-bedded tuffs dipping northward at angles varying from 15° to 17°. At the base of these tuffs there is a band of rubbly coralline limestone from 8 in. to 12 in. thick, containing angular fragments of basalt up to 8 in. in diameter.

Still passing southward, the coralline bed is underlain by a great thickness of stratified tuffs, which are current-bedded in places, and continue to dip north until a point 2½ chains from Cape Wanbrow Creek is reached, where they turn over, and thence onward dip to the south, as shown in fig. 6.

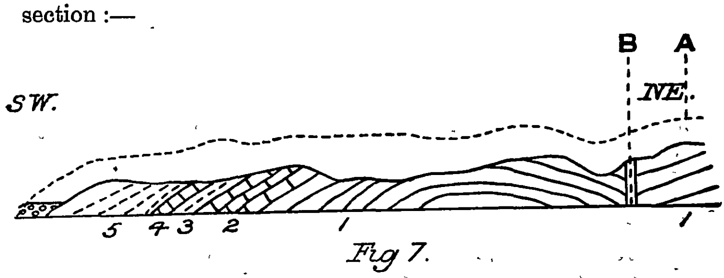


SECTION OF SEA-CLIFF FROM CAPE WANBROW NORTHWARD.

A. Cape Wanbrow. B. Wanbrow Creek. C. South end of section shown in fig. 5. *a*. Pillow-form basalt and agglomerates. *b*. Thin-bedded tuffs; angle of dip, 15° to 17°. *c*. Band of impure limestone. *d*. Stratified tuffs. *e*. Oamaru silts.

At the north end of the first small bay south of Cape Wanbrow there is a fault where the dip suddenly changes to the north-east; but some 13 chains south of the fault the tuffs resume the southerly dip, which is continued till the rifle-butts are reached, where they are followed by the Oamaru building-stone, fossiliferous tuffs, Hutchinson Quarry, and Awamoa beds.

The section from Cape Wanbrow southward to the termination of the sea-cliffs is shown in the following section:—



SECTION ALONG SEA-COAST FROM CAPE WANBROW SOUTHWARD TO RIFLE-BUTTS.

A. Cape Wanbrow. B. Fault; strike nearly N.–S. 1. Tuffs. 2. Oamaru building-stone. 3. Fossiliferous-tuff bed. 4. Hutchinson Quarry beds. 5. Awamoa beds.

The section exposed along the sea-cliff from a point about 4 chains north of the rifle-butts to the first headland is remarkably clear, and of great importance, as it shows the relations of the Oamaru Stone to the Oamaru or Waiareka tuffs and to the Hutchinson Quarry beds. It is as follows:—

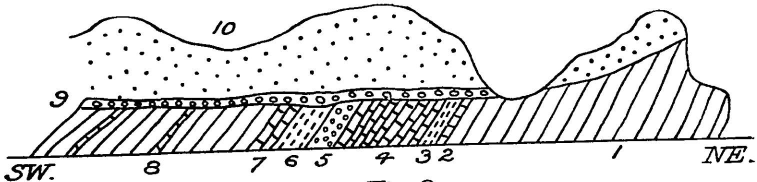


Fig 8

SECTION OF SEA-CLIFF NORTH OF RIFLE-BUTTS.

1. Tuffs. 2. Bed of coralline limestone, 6 ft. 3. Greenish-blue sandstone, 9 ft. 4. Coralline limestone (Oamaru building-stone), 80 ft. 5. Yellowish-green fossiliferous-tuff bed, 12 ft. 6. Hutchinson Quarry beds, consisting of hard rubbly limestone, 7 ft., overlain by greensands, 11 ft. thick. 7. Impure shelly limestone, 3 ft. thick, crowded with *Turritella cavershamensis*. 8. Fine bluish-green sandstones weathering brown, exposed on beach for a distance of 50 yards. 9. Raised beach, 5 ft. or 6 ft. above high water of spring tides, consisting of beach-shingle mixed with littoral shells all belonging to living species. The most common forms are *Mactra discors*, *Chione oblonga*, *Dosinia australis*, *Atactodea subtriangulata*, *Mytilus edulis*, *Trochus tiaratus*, &c.

The beds strike N.W.–S.E., and dip S.W. at angles varying from 32° to 35°. The dip of the beds as shown in fig. 8 is somewhat exaggerated, in order to crowd the strata into the width of the page.

In this section the Awamoa and Hutchinson Quarry beds are seen to be part and parcel of the same series, a contention urged on several occasions by Mr. McKay, and now admitted by Captain Hutton.

Both Captain Hutton and Mr. McKay correctly enough place the Hutchinson Quarry beds above the Oamaru building-stone, but the former, failing to recognise the existence of two limestones in North Otago, and believing the Oamaru Stone to be the closing member of the Oamaru series instead of the lower of the two limestones, ascribes the Hutchinson Quarry beds to a period subsequent to the Oamaru series.

From bed No. 8, which I believe to be the equivalent of the Awamoa beds, I collected the following forms:—

1. *Scaphella corrugata*, Hutton.
2. *Struthiolaria papulosa*, Martyn.
3. *Turritella cavershamensis*, Harris.
4. *Turritella rosea*, Quoy and Gaimard.
5. *Turritella kanieriensis*, Harris.
6. *Teredo heaphyi*, Zittel.

7. *Crassatellites ampla*, Zittel.
8. *Ostrea angasi*, Sowerby.
9. *Mytilus magellanicus*, Chemnitz.
10. *Corbula caniculata*, Hutton.
11. *Chione vellicata*, Hutton.
12. *Zenatia acinaces*, Quoy and Gaimard.
13. *Psammobia lineolata*, Gray.
14. *Cucullæa alta*, Sowerby.
15. *Solenella australis*, Zittel.

The shelly limestone, bed No. 7, underlying the Awamoa sandstones, contains large numbers of *Turritella cavershamensis*, as well as examples of *Scaphella pacifica*, *Lima paleata*, *Ostrea angasi*, and *Flabellum radians*.

From the greensands, bed No. 6, which evidently represent the Hutchinson quarry horizon, I collected from the lower part especially *Magellania novara*, *Magellania parki*, and *Bouchardia elongata*.

The yellowish-green tuff bed contains a number of small shells, including representatives of the genera *Diplodonta*, *Venericardia*, &c., mostly too minute for identification. Possibly the majority of them are new species.

The Oamaru building-stone is represented by two beds—namely, beds Nos. 2 and 4—which are separated by a thin stratum of dark bluish-green sandstone. These beds are composed principally of comminuted corals and *Foraminifera*, but the higher part of the upper band contains, besides these, a good many littoral shells, among which I collected the following:—

1. *Pecten hutchinsoni*, Hutton.
2. *Pecten williamsoni*, Zittel.
3. *Ostrea angasi*, Sowerby.
4. *Rhynchonella*, sp. nov.
5. *Graphularia*, sp. (?).
6. *Meoma crawfordi*, Hutton.

The higher part of the upper band also contains fragments of volcanic ash. The lower band is quite free from volcanic matter and from large shells, and, being of even texture and colour, furnishes the highest quality of building-stone quarried near Oamaru. The upper band is not so uniform in texture, is variable in colour, often containing streaks of a deep-yellow colour, and is in consequence regarded as of inferior quality.

TESCHEMAKER'S.

There are two bands of limestone at this place, separated by a few feet of fossiliferous tuff. They are well exposed in the old quarry near the crown of the hill overlooking the railway-line. The upper limestone is the typical clean pale yellowish-grey building-stone. The lower is glauconitic, and largely composed of comminuted corals and *Foraminifera*.

The tuffs are often pebbly, and generally crowded with corals and molluscs. Of the latter I collected the following forms :—

1. *Ostrea wullerstorfi*, Zittel.
2. *Pecten hutchinsoni*, Hutton.
3. *Pecten hochstetteri*, Zittel.
4. *Pecten burnetti*, Zittel.
5. *Pecten williamsoni*, Zittel.
6. *Pseudamussium huttoni*, Park.
7. *Amussium zitteli*, Hutton.
8. *Terebratella gaulteri*, Morris.

Devil's Bridge.

This place is situated near the source of the Oamaru Stream. Here the Waitaki Stone overlies glauconitic sandstones containing fossils in great abundance, and generally well preserved. In the collection from the sandstone the following were identified :—

1. *Calyptræa calyptræformis*, Lamarck.
2. *Teredo heaphyi*, Zittel.
3. *Dentalium mantelli*, Zittel.
4. *Dosinia greyi*, Zittel.
5. *Chione vellicata*, Hutton.
6. *Chione crassa*, Quoy and Gaimard.
7. *Meretrix acuminata*, Hutton.
8. *Venericardia awamoaensis*, Harris.
9. *Lima paleata*, Hutton.
10. *Pecten williamsoni*, Zittel.
11. *Pseudamussium huttoni*, Park.
12. *Ostrea angasi* (?), Sowerby.
13. *Limopsis aurita*, Brocchi.
14. *Cucullæa alta*, G. B. Sowerby.

Pukeuri.

This place lies north of Oamaru, from which it is distant about six miles by rail. The hills facing the railway-line, near Pukeuri, are composed of soft sandstones, which are fossiliferous, and often contain large calcareous nodules. From these beds I collected the following forms in the deep cutting on the main cart-road into the Waitaki Valley :—

1. *Scaphella corrugata*, Hutton.
2. *Scaphella pacifica*, Lamarck.
3. *Siphonalia nodosa*, Martyn.
4. *Pleurotoma fusiformis*, Hutton.
5. *Terebra tristis*, Hinds.

6. *Natica zelandica*, Quoy and Gaimard.
7. *Turritella rosea*, Quoy and Gaimard.
8. *Turritella kanieriensis*, Harris.
9. *Teredo heaphyi*, Zittel.
10. *Ancilla australis*, Sowerby.
11. *Dentalium mantelli*, Zittel.
12. *Pecten williamsoni*, Zittel.
13. *Pseudamussium huttoni*, Park.
14. *Lima paleata*, Hutton.
15. *Chione vellicata*, Hutton.
16. *Corbula caniculata*, Hutton.
17. *Mactropsis traili*, Hutton.
18. *Leda fastidiosa*, Adams.

Neither the Waitaki Stone nor the Oamaru Stone is present in the vicinity of this place, and some difficulty would be encountered in tracing the stratigraphical relations of the two horizons, on account of the great depth of superficial deposits resting on the hills. The character of the fossils, however, clearly correlates the sandstones with a horizon below the Oamaru Stone.

HUTCHINSON'S QUARRY, OAMARU.

The beds exposed near Eden Street Bridge are as follows, in ascending order:—

1. Tuffs intercalated with irregular bands of limestone, 6 ft.
2. Dark glauconitic greensands, 7 ft.
3. Yellowish-coloured glauconitic shelly sandstone, from 4 ft. to 6 ft. thick.
4. Dark glauconitic sandstone, about 14 ft. exposed.
5. Oamaru silts and clays.

From beds Nos. 2 and 3 the following species were obtained:—

1. *Ostrea wullerstorfi* (?), Zittel.
2. *Pecten hutchinsoni*, Hutton.
3. *Pecten williamsoni*, Zittel.
4. *Pseudamussium huttoni*, Park.
5. *Magellania novara*, Jhering.
6. *Magellania parki*, Hutton.
7. *Balanus* (sp. ?).
8. *Isis dactyla*, Tenison-Woods.

Corals, net and branching.
Cidaris spines.
Cup-shaped bryozoans.

The fossils and character of the material clearly relate these beds to the fossiliferous tuffs and calcareous beds at Kakanui Beach and Cape Wanbrow.

BLACK POINT, WAITAKI VALLEY.

A narrow bench of the Tertiary series runs parallel with the Waitaki Railway from near Black Point to Otekaike, a distance of some twelve miles. It rests upon the metamorphic rocks of the Kakanui series, and forms a line of bold steep escarpment which presents many fine faces for critical examination. Perhaps the most interesting and important part of this long section is that exposed at the old Black Point Coal-mine, nearly opposite Borton Railway-station, where the basement beds of the Tertiary series are very clearly exposed.

Stratigraphy.

Mr. McKay * examined, and afterwards accurately described, the stratigraphy of this place in 1876. The numbers of the Tertiary series in descending order are as follows:—

1. Waitaki Stone, with 1A adhering to base.
1A. Glauconitic sandstone, fossiliferous.
2. Sandstones, often micaceous and gritty.
3. Rusty-brown sands and sandstone, containing layers of hard calcareous nodules and lens-shaped masses.
4. Fireclays, carbonaceous shales, and brown coal.
5. Quartz and sandstone conglomerates, often limonitic.

The arrangement and relationships of these beds are shown in fig. 9.

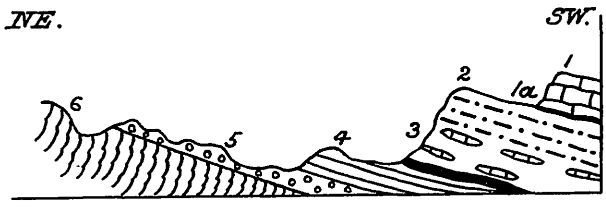


Fig 9.

SECTION AT BLACK POINT COAL-MINE.

1. Waitaki Stone. 1A. Glauconitic sandstone. 2. Sandstones, often micaceous. 3. Sandstones, with hard nodules and layers, fossiliferous. 4. Fireclays, shales, and brown coal. 5. Conglomerates, often limonitic. 6. Metamorphic rocks.

Fossils.

The sandstones overlying the coal-shales contain a large number of fossils, of which a considerable collection was made. The fossils in the hard calcareous nodules are gene-

* Reports of Geol. Expls., 1876–77, p. 52.

rally well preserved, but in the sandstone they occur mostly as casts.

Mr. McKay mentions that he made a large collection of fossils here, but does not give a list of the species. In his first report on this place he states that he discovered several genera of Secondary cephalopods, including *Ancyloceras* and *Scaphites*. In his later reports of the Waitaki Valley, in 1876, 1881, and 1882, he makes no mention of these, so it may be assumed that the reported discovery was due to a misidentification of the genera in the early seventies.

The collection made by myself at Black Point Coal-mine included the following species :—

1. *Pleurotoma awamoaensis*, Hutton.
2. *Terebra tristis*, Deshayes.
3. *Ancilla hebera*, Hutton.
4. *Scaphella corrugata*, Hutton.
5. *Siphonalia subreflexa*, Sowerby.
6. *Lotorium spengleri*, Chemnitz.
7. *Struthiolaria papulosa*, Martyn.
8. *Cassidaria senex*, Hutton.
9. *Turritella kanieriensis*, Harris.
10. *Crepidula monoxyla*, Lesson.
11. *Natica zelandica*, Quoy and Gaimard.
12. *Cirsotrema lyrata*, Zittel.
13. *Teredo heaphyi*, Zittel.
14. *Dentalium mantelli*, Zittel.
15. *Ostrea wullerstorfi*, Zittel.
16. *Anomia alectus*, Gray.
17. *Pseudamussium huttoni*, Park.
18. *Cucullæa alta*, G. B. Sowerby.
19. *Glycimeris globosa*, Hutton.
20. *Limopsis insolita*, Sowerby.
21. *Venericardia awamoaensis*, Harris.
22. *Dosinia greyi*, Zittel.
23. *Tapes curta*, Hutton.
24. *Chione vellicata*, Hutton.
25. *Psammobia lineolata*, Gray.
26. *Panopea orbita*, Hutton.
27. *Tellina angulata*, Hutton.
28. *Flabellum radians*, Tenison-Woods.
29. *Balanophyllia hectori*, Tenison-Woods.
30. *Schizaster rotundatus* (?), Zittel.

Crab-remains.
Balanus plates.

Of the twenty-seven species of molluscs enumerated above, six, or 22·2 per cent., are still living; while the majority are common to the Hampden, Kakanui, Awamoa, Waihao Forks, Wharekuri, Kakahu, and Mount Donald beds.

Marawhenua.

From the glauconitic greensands at the base of the Waitaki Stone, a mile and a half east of this place, in the cliffs facing the railway-line, I collected the following forms:—

1. *Kekenodon onomata*, Hector.
2. *Cirsotrema lyrata*, Zittel.
3. *Cassidaria senex*, Hutton.
4. *Teredo heaphyi*, Zittel.
5. *Plagiostoma lævigata*, Hutton.
6. *Lima palæta*, Hutton.
7. *Pseudamussium huttoni*, Park.
8. *Terebratella gaulteri*, Morris.
9. *Terebratella furculifera*, Tate.
10. *Terebratula oamarutica*, Boehm.
11. *Bouchardia tapirina*, Hutton.

Graphularia (15 in. long).
Balanus.
Corals.

The fine pecten *Pseudamussium huttoni* occurs in great numbers, in a fine state of preservation, and easily extracted. The brachiopods occur in thousands. The fossils and stratigraphy clearly correlate these beds with the Mount Brown and Kakanui limestones.

Wharekuri Basin.

Stratigraphy.

There are five well-marked fossiliferous horizons in this basin, which enable the Tertiaries there to be subdivided as follows:—

Waitaki Stone ..	1. Calcareous sandstone.
Mount Brown beds	2. Soft calcareous sandstone and shelly sands, often glauconitic, with *Kekenodon*.
	3. Greensand, calcareous, often dark-green, with *Aturia*, &c.
Waihao beds ..	4. Bluish-green and grey sandstones and sandy clays.
	5. Quartzose grits and brown coal.

There is no limestone in Wharekuri basin corresponding to the Oamaru building-stone proper. Beds 1 and 2 correspond closely in their fossil contents with the fossiliferous calcareous horizons below the Waitaki Stone at Kakanui. Bed 2 underlies No. 1 conformably, and contains a large number of fossils, many of which are found in bed 1.

Mr. McKay* in 1881 referred bed 1 partly to the Hut-

* Reports Geol. Expls., 1881, pp. 68 and 103.

chinson Quarry beds and partly to the Otekaike limestone, which he regarded, and I think rightly, as distinct from the Ototara (Oamaru) Stone.

Bed 1, the *Kekenodon* beds of Mr. McKay, are shown by him to underlie the Otekaike limestone conformably (section on pp. 68 and 101 of the report). Bed 3, which he calls the Wharekuri greensands, he refers to the same horizon as the Waihao greensands, as I do now; but in a section on page 64 he shows the greensands overlain unconformably by the calcareous sandstone the supposed equivalent of the Otekaike limestone.

I made a careful examination of the line of section referred to, which is obscured with gravels, but was unable to find any evidence in support of Mr. McKay's contention. He admits the obscurity of the section, and, speaking of this supposed unconformity, says, "In the section of these rocks sketched at page 64 the unconformity between *b* and *c* is made perfectly apparent, and is, I believe, exactly as the section would appear provided the obscuring gravels could be cleared away."* Exactly so. The section merely represents his view of what would be seen if the obscuring gravels were cleared away—a view in conformity with the theory of the Geological Survey, which supposes that the Mount Brown beds are of later date than the Waitaki Stone.

As a matter of fact the Tertiary beds in this basin are so much faulted, and the outcrops so obscured by heavy deposits of gravel, that it is impossible for any one to determine what are the relations between the lower greensands and the calcareous shelly sands of the Mount Brown beds. The solution of this problem can, however, be found in the Kakanui and Waipara districts, where the sections are so clear upon this point as to leave no room for theoretical deductions.

The shelly greensands with *Kekenodon* are exposed on the banks of the Waitaki River, half a mile below the junction of the Wharekuri Stream. Here they are lying almost horizontal, and can be traced in that position along the river-bank for half a mile. They also are seen near the top of the foothills running along the south side of the basin, forming conspicuous bluffs and escarpments facing the river-valley. Here the beds also lie horizontal.

We have thus two parallel lines of outcrop, separated by half a mile, one a few feet above the river-level, and the other nearly 400 ft. above the river.

The Wharekuri basin is mountain-girt, and manifestly existed before the deposition of the Tertiaries. The latter have not been folded in the course of tectonic movements, and we

* *Loc. cit.*, p. 73.

can only conclude that the present distribution of the beds at different elevations is the result of extensive faulting.

In the line of section running from the river outcrop to the south side of the basin there is no sign of faulting, nor could such be seen if it existed, on account of the gravels which cover the river-terrace and slopes of the foothills. The section as it actually appears is as shown in fig. 10.

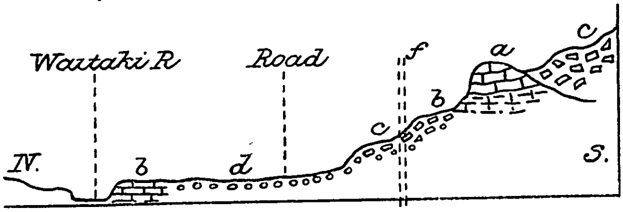


Fig 10.

Section from Waitaki southward.

a. Higher part of calcareous sandstone. *b.* Lower part of beds *a.* *c.* Remains of old river-fan. *d.* River-gravels. *f.* Approximate position of great fault.

The Wharekuri Stream cuts back into the foothills parallel with this line of section, some half a mile further north, and in its steep banks at a point about 12 chains above the bridge the beds are seen to be greatly faulted. At this place there is a great vertical fault, and four small faults or dislocations. Mr. McKay does not refer to these faults. They were examined by Mr. Hamilton and the writer in March, 1903, and are shown by Mr. Hamilton* in his paper on some fossils collected in the Wharekuri basin. The sketch made by Mr. Hamilton is shown in fig. 11.

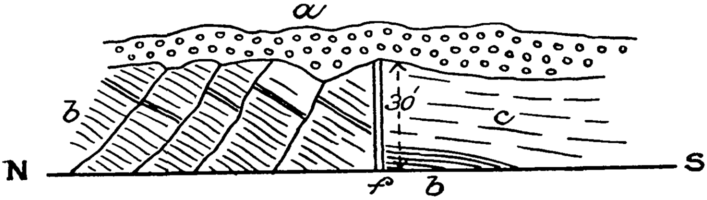


Fig 11.

Section on East Bank of Wharekuri (12 chains above Bridge).

The actual vertical displacement cannot be measured, but must be considerable, as it has brought the yellowish sand-

* Trans. N.Z. Inst., vol. xxxvi., 1903, p. 463.

stones which overlie the coal opposite the lower greensands. The position the vertical fault would occupy in section from the river-bank southward is indicated in fig. 8.

The seam of brown coal occurs in grey sandstones often yellow on surfaces, and grits, which are exposed in the narrow gorge cut in the foothills by Wharekuri, about half a mile above the bridge. The outcrops of the beds are so obscured by gravels and slope deposits that no stratigraphical relationships can be made out.

Mr. McKay refers the coal-measures to the Pareora series of supposed Miocene age, and in his sketch* of the section, shown by me in fig. 8, he shows the coal-measures and a coal-seam overlying the calcareous sandstone (Otekaike limestone) conformably. I could find no trace of the coal-measures, or of a coal-seam in this section overlying the fossiliferous Tertiaries, and I can only assume that the section figured by him is intended as a graphic representation of his views rather than a statement of the actual facts. Mr. McKay furnishes no evidence in support of a Miocene age for the coal-measures beyond assuming that the coal is associated with the gravels which cover the foothills. Of this latter theory there is no evidence whatever. These gravels are apparently the old high-level gravels formed by the Waitaki River. They can hardly be older than Pleistocene or newer Pliocene.

Sir James Hector, in his Progress Report for 1881, p. xxv., when discussing Mr. McKay's supposed Pareora gravels, says, "These beds, for no better reason than that they are usually found overlying the fossiliferous Pareora beds, have frequently been spoken of as the higher part of the Pareora formation. They have probably no connection with the series of strata with which they have in various reports been associated."

Fossils.

From the shelly sands and soft sandstones of the Mount Brown beds, exposed on the south bank of the Waitaki, half a mile below the junction of the Wharekuri Stream, I made a large collection of fossils, which included the following species :—

1. *Kekenodon onomata*, Hector.
2. *Pleurotoma fusiformis*, Hutton.
3. *Scaphella attenuata*, Hutton.
4. *Scaphella corrugata*, Hutton.
5. *Scaphella fusiformis*, Hutton.
6. *Scaphella pacifica*, Lamarck.

* Reports of Geol. Expls., 1881, pp. 68, 101.

7. *Ancilla lata*, Hutton.
8. *Ancilla hebera*, Hutton.
9. *Natica gibbosa*, Hutton.
10. *Natica darwini*, Hutton.
11. *Cirsotrema browni*, Zittel.
12. *Struthiolaria papulosa*, Martyn.
13. *Calyptræa monoxyla*, Martyn.
14. *Cassidaria sulcata*, Hutton.
15. *Cassidaria senex*, Hutton.
16. *Turritella cavershamensis*, Harris.
17. *Turritella rosea*, Quoy and Gaimard.
18. *Teredo heaphyi*, Zittel.
19. *Dentalium giganteum*, Hutton.
20. *Dentalium mantelli*, Zittel.
21. *Dentalium lævis*, Hutton.
22. *Ostrea angasi* (?), Sowerby.
23. *Anomia alectus*, Gray.
24. *Lima paleata*, Hutton.
25. *Pecten williamsoni*, Zittel.
26. *Pecten scandula*, Hutton.
27. *Pseudamussium huttoni*, Park.
28. *Cucullæa alta*, Sowerby.
29. *Glycimeris striatularis*, Lamarck.
30. *Limopsis insolita*, Sowerby.
31. *Limopsis aurita*, Brocchi.
32. *Cucularia australis*, Hutton.
33. *Panopæa orbita*, Hutton.
34. *Corbula canaliculata*, Hutton.
35. *Psammobia lineolata*, Gray.
36. *Pinna zelandica*, Gray.
37. *Mactropsis traili*, Hutton.
38. *Tellina angulata*, Hutton.
39. *Zenatia acinaces*, Quoy and Gaimard.
40. *Nucula nitidula*, Adams.
41. *Magellania novara*, Jhering.
42. *Magellania triangularis*, Hutton.
43. *Trochocyathus mantelli*, M. Edw. and H.
44. *Flabellum radians*, Tenison-Woods.

The fossils in this horizon are very numerous, generally well preserved and easily extracted. The most common species are *Limopsis insolita*, *Venericardia awamoaensis*, *Cucullæa alta*, *Mactropsis traili*, and *Dentalium giganteum*.

Of the forty-one species of *Mollusca* in the above list, ten, or nearly 24·4 per cent., are still living.

Besides prominent molluscs, these sandy beds contain a large number of small and minute forms, many of which are probably new.

From the dirty greensands underlying the *Kekenodon* beds at the Fishing Rocks, a short distance below the junction of the Wharekuri, I collected the following fossils :—

1. *Aturia australis*, McCoy.
2. *Pleurotoma fusiformis*, Hutton.
3. *Scaphella corrugata*, Hutton.
4. *Turritella cavershamensis*, Harris.
5. *Turritella mantelli*, Zittel.
6. *Cirsotrema brouni*, Zittel.
7. *Natica gibbosa*, Hutton.
8. *Teredo heaphyi*, Zittel.
9. *Pleurotomaria tertiaria*, McCoy.
10. *Ostrea angasi* (?), Sowerby.
11. *Limopsis insolita*, Sowerby.
12. *Pecten hochstetteri*, Zittel.
13. *Pseudamussium huttoni*, Park.
14. *Cucullæa alta*, Sowerby.
15. *Cardium patulum*, Hutton.
16. *Panopæa orbita*, Hutton.
17. *Psammobia lineolata*, Gray.
18. *Mactropsis traili*, Hutton.
19. *Venericardia awamoaensis*, Harris.
20. *Flabellum radians*, Tenison-Woods.

Crab-remains.
Encrinite stem.
Vertebræ of fish.

Of the above, all but *Aturia australis*, *Pleurotomaria tertiaria*, and *Cardium patulum* were found in the *Kekenodon* beds. The fossils of the *Kekenodon* and *Aturia* beds in the Wharekuri basin correlate these beds with the *Kekenodon* and *Aturia* horizons at Kakanui, where the presence of the Oamaru Stone enables us to determine the stratigraphical position of the Mount Brown beds, variously known as Hutchinson Quarry, Kakanui, or Mount Donald beds.

WAIHAO FORKS.

Stratigraphy.

The sequence of the Tertiary beds exposed on the banks of the Waihao River is as follows :—

Waitaki Stone ..	1. Calcareous sandstone.
Mount Brown beds	2. Greensands.
	3. Bluish-green sandy clays and sandstones with hard calcareous layers.
Waihao beds ..	4. Bluish-green sandstones.
	5. Grey sandstones.
	6. Quartzose grits, shales, fireclays, and brown coal.

The succession is almost identical with that seen in the Waitaki Valley. Captain Hutton* contends, that beds 3,

* Hutton, "Note on the Geology of the Valley of the Waihao in South Canterbury" (Trans. N.Z. Inst., vol. xix., 1886, p. 430).

which contain what he affirms is a Pareora fauna, overlie the Waihao or Waitaki Stone unconformably. But the stratigraphical evidence, as pointed out by Mr. McKay,* is entirely opposed to this view. The beds containing a Pareora fauna nowhere overlie the Waitaki Stone, but, on the contrary, always occur below or at a lower level than the calcareous sandstone forming that horizon. And along the course of the Waihao and in the small streams which join that river the greensands and bluish-green sandy beds follow the contours of the escarpments in such a way as to everywhere preserve the same relative position with respect to the Waitaki Stone. Captain Hutton attempts to explain this by suggesting that his Oamaru series of Oligocene age was deposited, elevated, sculptured into narrow valleys and channels, and again submerged so as to permit the accumulation of his Pareora beds† in the newly eroded channels. This view supposes that no denudation or erosion of the Waitaki Stone has taken place since the deposition of the supposed Pareoras—that is, since Lower Miocene times—a requirement which it will be difficult to maintain, for physical reasons.

The stratigraphy is not obscure nor the sections involved; and I fully concur with Mr. McKay's interpretation, which is, moreover, borne out by the sections at Black Point, Wharekuri, and Kakahu.

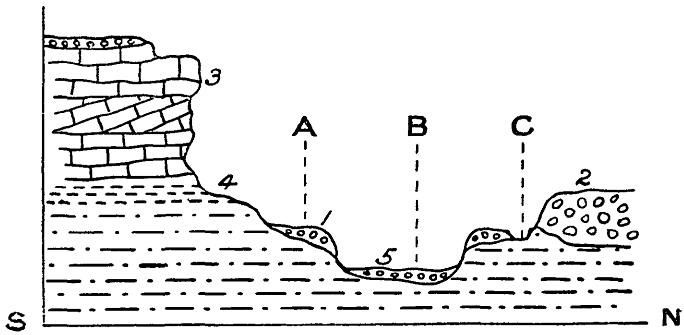


Fig 12.

SECTION AT WAIHAO FORKS ACROSS MAIN BRANCH.

A. Road. B. Waihao River. C. Railway-line. 1. River-gravels. 2. Terrace gravels. 3. Calcareous sandstones, current-bedded; Waitaki Stone. 4. Glauconitic sands and sandstone, Mount Brown beds. 5. Bluish-green sandy clays and sandstones, Waihao sandstone.

* McKay, "The Waihao Greensands, and their Relation to the Ototara Stone" (*loc. cit.*, p. 434).

† Reports of Geol. Expls., 1873–74, p. 37.

The Oamaru building-stone is not represented in the Waihao district.

The Mount Harris beds in this neighbourhood contain a fauna which is the same as that of the Waihao clayey greensands, and, although they rest upon Lower Mesozoic rocks and nowhere overlie the Waitaki Stone, they are referred by the Geological Survey to the Pareora series of Hutton.

The stratigraphy is not very clear, and leaves room for different interpretations, but the palæontological evidence clearly correlates these beds with the Waihao Forks, Black Point, and Hampden beds, which are acknowledged by the Survey to underlie the Waitaki Stone.

Fossils.

From the greensands immediately underlying the Waitaki Stone I collected the following species:—

1. *Kekenodon onomata*, Hector.
2. *Cirsotrema browni*, Zittel.
3. *Pseudamussium huttoni*, Park.
4. *Plagiostoma lævigata*, Hutton.
5. *Magellania parki*, Hutton.
6. *Magellania novara*, Jhering.
7. *Terebratella gaulteri*, Morris.

From the bluish-green sandy clays, the upper greensands of Mr. McKay, I collected the following forms:—

1. *Aturia australis*, McCoy.
2. *Pleurotoma fusiformis*, Hutton.
3. *Siphonalia nodosa*, Martyn.
4. *Scaphella corrugata*, Hutton.
5. *Ancilla australis*, Sowerby.
6. *Ancilla hebera*, Hutton.
7. *Natica darwini*, Hutton.
8. *Natica suturalis*, Hutton.
9. *Cirsotrema browni*, Zittel.
10. *Struthiolaria papulosa*, Martyn.
11. *Turritella rosea*, Quoy and Gaimard.
12. *Turritella kanieriensis*, Harris.
13. *Terebra tristis*, Deshayes.
14. *Teredo heaphyi*, Zittel.
15. *Dentalium mantelli*, Zittel.
16. *Dentalium lævis*, Hutton.
17. *Ostrea wullerstorfi*, Zittel.
18. *Amussium zitteli*, Hutton.
19. *Pseudamussium huttoni*, Park.
20. *Cucullæa alta*, Sowerby.
21. *Cucularia australis*, Hutton.

22. *Limopsis insolita*, Brocchi.
23. *Tellina angulata*, Hutton.
24. *Leda fastidiosa*, Adams.
25. *Trochocyathus mantelli*, M. Edw. and H.
26. *Flabellum radians*, Tenison-Woods.
27. *Balanophyllia hectori*, Tenison-Woods.

There are in the Christchurch Museum a number of species from the Waihao Forks not found by me. They are as follows :—

28. *Pleurotoma hamiltoni*, Hutton.
29. *Barsonia rudis*, Hutton.
30. *Mitra aculeata*, Hutton.
31. *Mitra hectori*, Hutton.
32. *Pecten medius*, Lamarck.
33. *Limopsis aurita*, Brocchi.

Of the thirty molluscs in these lists, seven, or 23·3 per cent., are still living.

Pareora River.

Stratigraphy.

The sections at the lower and upper ends of the Pareora Gorge are so obscure as to be of no value for the determination of the relations existing between the beds containing what has been known as the Pareora fauna and the Oamaru Stone.

At White Rock River, higher up the valley, the Oamaru Stone is absent, but the fossiliferous clays and sandstones exposed there rest upon the basement rock of the district.

Fossils.

From the sandstones at the lower end of the Pareora Gorge, on the south side of the river, in a steep face near the road, where the strata are interbedded with hard calcareous layers, I collected the following forms :—

1. *Ancilla hebera*, Hutton.
2. *Natica darwini*, Hutton.
3. *Turritella rosea*, Quoy and Gaimard.
4. *Turritella cavershamensis*, Harris.
5. *Crepidula monoxyla*, Lesson.
6. *Ostrea wullerstorfi*, Zittel.
7. *Anomia alectus*, Gray.
8. *Lima palæata*, Hutton.
9. *Pseudamussium huttoni*, Park.
10. *Limopsis insolita*, Sowerby.
11. *Glycimeris globosa*, Hutton.

12. *Cucularia australis*, Hutton.
13. *Panopæa orbita*, Hutton.
14. *Corbula caniculata*, Hutton.
15. *Dosinia magna*, Hutton.
16. *Psammobia lineolata*, Gray.
17. *Zenatia acinaces*, Quoy and Gaimard.
18. *Chione crassa*, Quoy and Gaimard.
19. *Chione vellicata*, Hutton.
20. *Tapes curta*, Hutton.

Of the above fossils, six, or 30 per cent., are still living.

From the bluish-green sandy clays at White Rock River I collected the following species:—

1. *Pleurotoma fusiformis*, Hutton.
2. *Siphonalia nodosa*, Martyn.
3. *Siphonalia subnodosa*, Hutton.
4. *Ancilla lata*, Hutton.
5. *Ancilla hebera*, Hutton.
6. *Natica darwini*, Hutton.
7. *Natica zelandica*, Quoy and Gaimard.
8. *Turritella cavershamensis*, Harris.
9. *Turritella kanieriensis*, Harris.
10. *Turritella rosea*, Quoy and Gaimard.
11. *Cirsotrema browni*, Zittel.
12. *Struthiolaria papulosa*, Martyn.
13. *Genota robusta*, Hutton.
14. *Terebra tristis*, Deshayes.
15. *Terebra nitida*, Hinds.
16. *Crepidula monoxyla*, Lesson.
17. *Dentalium giganteum*, Hutton.
18. *Dentalium mantelli*, Zittel.
19. *Dentalium lævis*, Hutton.
20. *Lima paleata*, Hutton.
21. *Pseudamussium huttoni*, Park.
22. *Glycimeris globosa*, Hutton.
23. *Cucullæa alta*, Sowerby.
24. *Chione oblonga*, Hanley.
25. *Tellina angulata*, Hutton.
26. *Dosinia greyi*, Zittel.

Of the twenty-six species in this list, seven, or 28 per cent., are still living.

TENGAWAI RIVER.

From the limestone on the south bank of the Tengawai River, near Cave, I collected the following molluscs:—

1. *Cirsotrema browni*, Zittel.
2. *Ostrea* sp. (?).

3. *Pecten vellicata*, Hutton.
4. *Pseudamussium huttoni*, Park.
5. *Magellania sufflata*, Hutton.
6. *Terebratula tayloriana*, Colenso.
7. *Terebratula oamarutica*, Boehm.
8. *Terebratulina suessi*, Zittel.

These fossils indicate the upper horizon of the Mount Brown beds.

Kakahu Bush, west of Geraldine.

Stratigraphy.

Before reaching Kakahu Bush the Oamaru Stone and the underlying sandstones and sandy-clay beds are repeated by a fault. Sir Julius von Haast* placed this fault in such a position as to make certain sandy clays appear to overlie the Waitaki Stone. Mr. McKay† followed him in this in 1876, and so also did the writer‡ in 1885, no doubt having at that time been expressed as to the stratigraphical position of the Pareora fauna to the Waitaki Stone.

The Geological Survey maintains that the Pareora fauna occurs in beds overlying the Waitaki Stone, while Captain Hutton contends that the sandy clays and greensands believed by the Survey to be below the Waitaki Stone contain the Pareora fauna. The Survey admits the inferior position of the fossiliferous sandstones overlying the coal at Kakahu Bush, but does not acknowledge that the fauna is Pareora. Captain Hutton, while admitting the Pareora facies of the fauna in the Kakahu Bush beds, contends that the beds which contain it do not underlie the Waitaki Stone, but occur in a narrow valley eroded in that rock. It does not appear, however, that he has personally examined the Kakahu section.

As it was important to determine the stratigraphical relationships of the beds admitted by Captain Hutton to contain a Pareora fauna, I devoted my time to an examination of the Kakahu Bush section, where all the members of the Oamaru series are exposed in vertical succession, from the coal-beds, resting upon the Palæozoic rocks, up to the Waitaki Stone. The section exposed there is as follows:—

* Haast, "Geology of Canterbury and Westland," 1876, p. 310.
† McKay, Reports of Geol. Expls., 1876–77, p. 51.
‡ Park, Reports of Geol. Expls., 1885, p. 170.

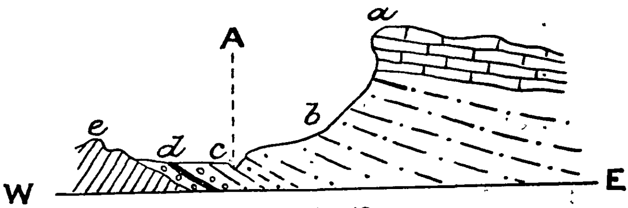


Fig 13.

SECTION AT KAKAHU BUSH.

A. Bush Creek. *a*. Waitaki Stone. *b*. Bluish-green sandstones. *c*. Soft sandstones (greensands) with calcareous bands and masses; fossiliferous. *d*. Quartz grits, brown sands, fireclays, and brown coal. *e*. Claystones and sandstones.

Many sections exactly similar to this are exposed in different parts of the Kakahu Valley.

Fossils.

In the bed of Bush Creek, a few chains above its junction with the Kakahu, I collected from beds *c* the following species :—

1. *Lamna huttoni*, Davis.
2. *Aturia australis*, McCoy.
3. *Terebra tristis*, Deshayes.
4. *Scaphella corrugata*, Hutton.
5. *Siphonalia regularis*, Sowerby.
6. *Siphonalia dilatata*, Quoy and Gaimard.
7. *Ancilla hebera*, Hutton.
8. *Natica darwini*, Hutton.
9. *Struthiolaria papulosa*, Martyn.
10. *Crassatellites ampla*, Hutton.
11. *Crassatellites australis*, Hutton.
12. *Cassidaria senex*, Hutton.
13. *Calyptræa monoxyla*, Martyn.
14. *Turritella rosea*, Quoy and Gaimard.
15. *Turritella cavershamensis*, Harris.
16. *Turritella kanieriensis*, Harris.
17. *Teredo heaphyi*, Zittel.
18. *Dentalium mantelli*, Zittel.
19. *Dentalium lævis*, Hutton.
20. *Ostrea wullerstorfi*, Zittel.
21. *Anomia alectus*, Gray.
22. *Pecten williamsoni*, Zittel.
23. *Pseudamussium huttoni*, Park.
24. *Lima paleata*, Hutton.
25. *Cucularia australis*, Hutton.
26. *Panopæa orbita*, Hutton.

27. *Corbula caniculata*, Hutton.
28. *Chione crassa*, Quoy and Gaimard.
29. *Chione vellicata*, Hutton.
30. *Dosinia magna*, Hutton.
31. *Cucullæa alta*, Sowerby.
32. *Glycimeris globosa*, Hutton.
33. *Leda fastidiosa*, Hutton.
34. *Flabellum radians.*
35. *Balanophyllia hectori*, Tenison-Woods.

There are several species in the Kakahu collection in the Canterbury Museum which were not found by me. They are as follows:—

36. *Scaphella kirki*, Hutton.
37. *Struthiolaria spinosa*, Hutton.
38. *Ostrea angasi*, Sowerby.
39. *Pinna zelandica*, Gray.

Of the thirty-six molluscs in the above list, ten, or 28 per cent., are still living.

Trelissic Basin.

This place was examined by Sir Julius von Haast in 1867, examined and mapped by Sir James Hector in 1872, by Mr. McKay in 1879,* and by Captain Hutton in 1886.† Last April I spent four days examining the section along the course of the Thomas River, which runs through the centre of the basin. Every one had given a different interpretation of the geology of the basin, and for that reason I devoted my time to one section, in the hope that I should be able to arrive at some definite conclusion as to the sequence and relationship of the different beds. In this I was disappointed.

The Cretaceous and Tertiary beds are not folded so as to be involved in the tectonic arrangement of the mountains which surround the basin; but they are faulted, disturbed by volcanic intrusions, and covered over wide areas by heavy deposits of terrace gravels, which make it impossible to get a continuous section in any direction across the basin. It is for these reasons that the sections shown by Sir James Hector‡ are so unlike those drawn by Captain Hutton.§ I agree with Sir James Hector and Mr. McKay in correlating the lower limestone with the Weka Pass Stone. But Mr. McKay goes further than this. He correlates the lower limestone (Weka Pass Stone) with the Ototara Stone (Waitaki Stone), a view

* Reports of Geol. Expls., 1879–80, p. 54

† Hutton, "On the Geology of the Trelissic or Broken River Basin, Selwyn County" (Trans. N.Z. Inst., vol. xix., 1886).

‡ Reports of Geol. Expls., 1879–80, p. xx.

§ Trans. N.Z. Inst., vol. xix., 1886, p. 408.

advanced without evidence, but in conformity with the Cretaceo-Tertiary theory of the Geological Survey.

As will be shown anon, the Weka Pass Stone is the closing member of the Waipara series, and the Waitaki Stone the closing member of the Oamaru series. The former is a hard limestone, often flaky and fucoidal, and practically devoid of molluscous fossils; the latter a soft coralline crag, with well-known characteristic molluscs, corals, and echinoderms.

The lower limestone (Weka Pass Stone) is followed unconformably by a considerable thickness of tuffs, impure limestone, and calcareous sandstones, containing many of the brachiopods, pectens, corals, &c., of the Kakanui limestones and tuffs.

These beds are followed by fossiliferous sandstones, shelly sands, sandstones, and clays with brown coal.

The fossiliferous sandstone contains a number of large molluscs, including *Dosinia magna*, *Tapes curta*, *Cardium spatiosum*, *Crassatellites ampla*, *Glycimeris globosa*, *Cucullæa ponderosa*, *Turritella cavershamensis*, and *Dentalium giganteum*. Many other forms characteristic of the Oamaru series are recorded by Captain Hutton and Mr. McKay, and need not be enumerated here, as there is no means of determining the relationship between the beds which contain them and the Waitaki Stone.

It may be of interest to mention that I discovered a fossiliferous horizon not hitherto recorded. On the west bank of the stream which the coach-road crosses before ascending the sideling cutting leading on to the terrace on which Castle Hill Hotel is situated, at a point about 15 chains below the crossing, there is an outcrop of blue sandy clay containing a band of *Ostrea ingens*, Zittel, in a fine state of preservation, and as large as the examples found at Waitotara. At the same place I collected *Calyptræa scutum*, Lesson.

The oyster-bed appears to lie some distance above the shelly sands and sandstones at the upper end of the gorge of the Thomas River.

So far as I am aware, *Ostrea ingens* has not been recorded from the South Island until now. It is a shell distinctly characteristic of the Te Aute series in the North Island, and its presence in the Trelissic basin suggests the question, Are the Motanau beds present in that area?

WAIPARA AND WEKA PASS.

Stratigraphy.

This district has been examined very frequently, and, although the stratigraphy is very clear and free from involvement, much confusion has arisen through the endeavours of some of the writers, myself included, to interpret the sections in conformity with the Cretaceo-Tertiary theory of the Geological Survey. According to this theory the Weka Pass Stone is the equivalent of the Waitaki Stone. Below the Weka Pass Stone there is a succession of beds closely resembling those found below the Waitaki Stone, and containing a Secondary fauna: therefore the theory was held to be proved. But this contention overlooked the manifest fact that the succession of fossiliferous Tertiary beds which underlie the Waitaki Stone in Otago and South Canterbury overlie the Weka Pass Stone at Weka Pass, forming the Mount Donald and Mount Brown Ranges.

The Geological Survey has always acknowledged that the Mount Donald beds overlaid the Weka Pass Stone, but has not recognised that the Mount Donald, Mount Brown, or Hutchinson Quarry beds underlaid the Waitaki Stone, as I have shown to be the case at Kakanui and Wharekuri.

The resemblance of the sequence and character of the rocks of the Waipara and Oamaru formations was noticed by Sir Julius von Haast. That writer, when discussing the Oamaru formation in 1879, said,* "The beds belonging to the Oamaru formation resemble often in sequence and character of the rocks those of the preceding Waipara formation. They in most instances begin with littoral deposits and end with calcareous strata, the latter formed in deeper water."

In this district there are three easily recognised marine formations—namely, (1) Motanau beds, of Older Pliocene age; (2) Oamaru series, of Miocene age; (3) Waipara series, of Upper Cretaceous age. These formations are met in the order named on the railway-line between Waipara Station and the upper end of Weka Pass.

Motanau Beds.

At 42 miles 30 chains from Christchurch, after the line leaves the gravel terrace of the Waipara, there appear in the railway cuttings brown sands with layers of hard flaggy sandstone, often pebbly and gritty, and generally calcareous. The dip of these beds is easterly at very low angles, and, proceeding along the railway-line, sandstones, sandy clays, and shell-beds succeed each other for a distance of three-quarters of a mile.

In the cutting between the $42\frac{1}{2}$-mile and the $43\frac{3}{4}$-mile posts there are a number of conspicuous oyster-shell beds occurring throughout a thickness of about 100 ft. These marine beds end at a point 10 chains north of the 43-mile

---

* Haast, "Geology of Canterbury and Westland," 1879, p. 305.

post. They are, according to Captain Hutton,* about 370 ft. thick. From the shell-beds above the oyster-beds I collected the following species :—

1. *Purpura textiliosa*, Agassiz.
2. *Siphonalia dilatata*, Quoy and Gaimard.
3. *Siphonalia orbita*, Hutton.
4. *Euthria lineata*, Martyn.
5. *Nassa incisa*, Hutton.
6. *Ancilla australis*, Sowerby.
7. *Scaphella pacifica*, Lamarck.
8. *Lotorium spengleri*, Lamarck.
9. *Natica gibbosa*, Hutton.
10. *Calyptræa calyptræformis*, Lamarck.
11. *Turritella rosea*, Quoy and Gaimard.
12. *Turritella kanieriensis*, Harris.
13. *Ethalia zealandica*, Homb. and Jacq.
14. *Calliostoma punctulatum*, Martyn.
15. *Panopæa orbita*, Hutton.
16. *Mactra discors*, Gray.
17. *Zenacia acinaces*, Quoy and Gaimard.
18. *Mesodesma novæ-zealandiæ*, Chemnitz.
19. *Chione vellicata*, Sowerby.
20. *Chione stutchburyi*, Gray.
21. *Meretrix multistriata*, Sowerby.
22. *Dosinia australis*, Gray.
23. *Venericardia australis*, Lamarck.
24. *Glycimeris laticostata*, Quoy and Gaimard.
25. *Glycimeris globosa*, Hutton.
26. *Pecten zelandiæ*, Gray.
27. *Anomia alectus*, Gray.
28. *Ostrea angasi*, Linné.

Balanus (sp. ?).
Fish-teeth.

Of the twenty-eight species of molluscs enumerated above, twenty, or 71 per cent., are still living.

The species of oyster in the oyster-beds appear to be *Ostrea angasi* and *Ostrea agglomerata*, or varieties of these.

Below the oyster-beds there are loose pebbly shell-beds from which I collected the following species :—

1. *Carcharodon carcharias*, Müller.
2. *Siphonalia dilatata*, Quoy and Gaimard.
3. *Ancilla australis*, Sowerby.
4. *Turritella rosea*, Quoy and Gaimard.
5. *Crepidula monoxyla*, Lesson.

* Hutton's "On some Railway Cuttings in the Weka Pass" (Trans. N.Z. Inst., vol. xx., 1887, p. 257).

6. *Dentalium majus*, Hutton.
7. *Zenacia acinaces*, Quoy and Gaimard.
8. *Chione vellicata*, Sowerby.
9. *Chione stutchburyi*, Gray.
10. *Meretrix assimilis*, Hutton.
11. *Dosinia australis*, Gray.
12. *Venericardia australis*, Lamarck.
13. *Glycimeris globosa*, Hutton.
14. *Pecten radiatus*, Hutton.
15. *Ostrea angasi*, Sowerby.
16. *Anomia alectus*, Gray.
17. *Psammobia lineolata*, Gray.
18. *Mactra æquilatera*, Deshayes.
19. *Tapes intermedia*, Quoy and Gaimard.

Of the eighteen molluscs in this list, thirteen, or 61 per cent., are still living, a percentage which clearly places these and the associated beds in the Pliocene.

The Motanau beds, although correlated by the Geological Survey with the Pareora series, contain none of the shells characteristic of the Pareora fauna. As will be shown presently, the Pareora fauna occurs in the underlying Mount Brown or Mount Donald beds.

The Motanau beds rest upon a denuded surface of the underlying Mount Brown beds. The unconformity between the two series was recognised by Sir James Hector* in 1868, and by Sir Julius von Haast† in 1870. Both writers referred these beds to the Pliocene. The former noted that the beds contained "many specimens of marine shells that are still alive," and had been deposited "in basins excavated in the older Tertiary rocks"—that is, in the Mount Brown beds. After an interval of thirty-four years I am compelled to once more refer the Motanau beds back to the Pliocene.

Mount Brown Beds.

At 43 miles 3 chains from Christchurch the railway-line enters a cutting which is a little over 6 chains long. The bank on the west or Weka Stream side of the line rises from a few feet high at the lower end to 26 ft. high near the north end, whence it drops to nothing somewhat more abruptly. The section exposed in this cutting is of great importance, as here the Motanau beds are seen to rest unconformably upon the Mount Brown beds. The Motanau beds lie on a denuded surface of the Mount Brown beds, and the section is so clear that no doubt can be entertained as to the unconformable

* Hector, Progress Report, p. xii., Reports of Geol. Survey, 1868–69.
† Haast, Reports of Geol. Expls., 1870–71, p. 15.

relations of the two formations. Fig. 14 shows the general arrangement of the beds exposed in the bank on the west side of the cutting :—

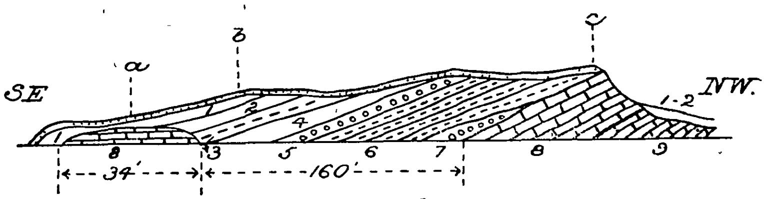


Fig 14

SECTION FROM 43 M. 3 CH. TO 43 M. 9 CH., LOOKING TOWARDS WEKA PASS CREEK.

1. Shelly sands. 2. Brown sands. 3. Shell-bed. 4. Sands. 5. Pebbly shell-bed. 6. Sands. 7. Pale-greenish-coloured sands. 8. Coralline limestone. 9. Brown sandstone with calcareous layers.

Beds 1 to 7 are the Motanau beds; 8 and 9 the upper horizons of the Mount Brown beds. At point *a* the coralline beds rise in the bank to a height of 7 ft. At *b* the cutting is about 20 ft. high, and at *c* about 26 ft.

From bed 8, which is a coralline crag, I collected the following forms :—

1. *Ostrea wullerstorfi*, Zittel.
2. *Pecten hutchinsoni*, Hutton.
3. *Pecten beethami*, Hutton.
4. *Pecten*, 2 sp. nov.
5. *Lima paleata*, Hutton.
6. *Plagiostoma lævigata*, Hutton.
7. *Dosinia greyi*, Zittel.
8. *Magellania novara*, Jhering.
9. *Magellania sufflata*, Hutton.
10. *Magellania parki*, Hutton.
11. *Rhynchonella nigricans*, Sowerby.
12. *Meoma crawfordi*.

Balanus.

Corals and *Cidaris* spines in great abundance.

Many of these fossils distinguish the highest fossiliferous horizon underlying the Oamaru Stone in North Otago.

On passing through the cutting just described, and shown in fig. 14, the line crosses a gully excavated in soft brown sandstones, which are best seen on the back of Mount Donald, a short distance to the north.

Before reaching the 44-mile post the line passes through a heavy cutting in the rubbly impure limestones and sandstones which form the crown of Mount Donald, whence they descend to the railway, cross the valley, and stretch westward to Mount Brown.

This horizon of impure limestone and calcareous sandstone can be traced for miles along the crest of Mount Donald and Mount Brown, forming a steep escarpment facing the northern aspect of these ridges. In some places it is crowded with fossils, in others almost destitute of them.

At Weka Pass fossils are not very abundant, and for some distance along the escarpment going towards Mount Donald very few are seen excepting corals. Some mile and a half north of the pass, near the highest part of Mount Donald, the beds become richly fossiliferous for a stretch of 15 chains. At this place I made a large collection of well-preserved fossils, which included the following species :—

1. *Kekenodon onomata* (?), Hector.
2. *Carcharodon megalodon*, Agassiz.
3. *Aturia australis*, McCoy.
4. *Pleurotoma awamoaensis*, Hutton.
5. *Scaphella elongata*, Hutton.
6. *Scaphella corrugata*, Hutton.
7. *Siphonalia nodosa*, Martyn.
8. *Ancilla hebera*, Hutton.
9. *Natica gibbosa*, Hutton.
10. *Cirsotrema browni*, Zittel.
11. *Crepidula monoxyla*, Lesson.
12. *Calyptræa calyptræformis*, Lamarck.
13. *Cassidaria senex*, Hutton.
14. *Turritella cavershamensis*, Harris.
15. *Xenophora* (sp. ?).
16. *Dentalium mantelli*, Zittel.
17. *Ostrea wullerstorfi*, Zittel.
18. *Ostrea angasi* (?).
19. *Anomia alectus*. Gray.
20. *Lima paleata*, Hutton.
21. *Lima bullata*, Born.
22. *Pecten beethami*, Hutton.
23. *Pecten williamsoni*, Zittel.
24. *Pecten hutchinsoni*, Hutton.
25. *Pecten* (sp. nov.).
26. *Pseudamussium huttoni*, Park.
27. *Cucullæa alta*, Sowerby.
28. *Glycimeris globosa*, Hutton.
29. *Glycimeris striatularis*, Lamarck.
30. *Limopsis insolita*, Sowerby.
31. *Dosinia magna*, Hutton.
32. *Dosinia greyi*, Zittel.
33. *Panopæa orbita*, Hutton.

34. *Psammobia lineolata*, Gray.
35. *Chione vellicata*, Hutton.
36. *Venericardia awamoaensis*, Harris.
37. *Mactropsis traili*, Hutton.
38. *Tellina angulata*, Hutton.
39. *Mytilus magellanicus* (?), Chemnitz.
40. *Bouchardia concentrica*, Hutton.
41. *Bouchardia elongata*, Hutton.
42. *Magellania parki*, Hutton.
43. *Magellania insolita*, Hutton.
44. *Magellania novara*, Jhering.
45. *Magellania triangularis*, Hutton.
46. *Terebratula oamarutica*, Boehm.
47. *Balanus* (sp.?).
48. *Meoma crawfordi*, Hutton.

The fossils enumerated in this list are those found, with a few exceptions, in the fossiliferous horizons below the Waitaki Stone at Kakanui, and include the majority of the species held to be characteristic of the Pareora fauna. Of the *Mollusca*, nine, or nearly 20 per cent., are still living.

In Mount Donald and Mount Brown there is a second band of impure rubbly limestone lying several hundred feet below the band which occupies the summit of the ridges. It is mainly composed of corals and cup-shaped bryozoans, but, unlike the upper band, contains very few distinct molluscs on the slopes of Mount Donald ridge facing the pass. The two bands of limestone form lines of conspicuous escarpment on the northern aspect of Mount Donald. They are separated by soft brown sandstones, which are not well exposed except in the railway cuttings. The lower band of limestone rests conformably on bluish-green and grey sandstones, which are well exposed in the steep banks of Weka Stream below the railway-line. These beds form the "grey marls" of the Geological Survey. In them I found *Amussium zitteli*, Hutton, a small *Dentalium*, and a few small bivalves too indistinct for identification.

In the higher part of the small shallow valley which runs from the viaduct eastward under Mount Donald the slopes are covered with large masses of hard calcareous sandstone and conglomerate often crowded with brachiopods, *Pseudamussium huttoni*, *Cucullæa*, &c. I could not satisfy myself as to whether these masses were derived from the lower calcareous horizon or had fallen from the summit of Mount Donald.

In his section from the Waipara River across Mount Brown, a few miles south-west of Mount Donald, Haast* shows a series of *Cucullæa* beds resting directly upon the

* Haast, *loc. cit.*, p. 18.

Weka Pass Stone at the foot of Mount Brown, in a position that would correspond with that of the supposed lower *Cucullæa* horizon at Mount Donald, Wharekuri, and Kakanui.

In places where the Mount Brown beds are in contact with the Weka Pass Stone the relation existing between the two formations is not very distinct, the upper formation consisting of soft sandstones naturally conforming more or less completely to the surface of the hard Weka Pass Stone. But the mapping of the rocks puts a different complexion upon the question, and brings out the unconformable relations of the Tertiary to the Cretaceous formation in a very clear manner. Thus, at the 45-mile post the lower, but not the lowest, of the Tertiary beds rests upon the Weka Pass Stone and its associate the Amuri limestone; and a short distance before reaching the viaduct the same or even lower Tertiary beds rest against the greensands which underlie the Amuri limestone.

Further, the Weka Pass Stone and Amuri limestone are thrown into folds in which the Tertiaries take no part whatever.

The unconformity between the Mount Brown beds and the Weka Pass Stone was recognised by Sir James Hector* in 1868. The former he referred to the Miocene, and the latter to the Waipara formation of Hochstetter. Haast† was also satisfied, in 1870, as to the unconformable relations of the two formations. In reference to this point he wrote, "That the denudation of the Weka Pass beds [Weka Pass Stone and Amuri limestone] had taken place previously to the deposition of the *Cucullæa* beds No. 11 is well shown in the sections Nos. 6 and 7, where the Weka Pass beds stand as isolated islands between the latter, abutting unconformably against them."

Apart from the stratigraphy, the palæontological break is complete; and I do not think that any one will now seriously contend that a formation which contains a Miocene fauna is conformable to a formation containing saurians and other Secondary forms.

Waipara Series.

(Syn. Waipara Formation, Hochstetter, 1866.)

The sequence of the rocks belonging to this formation in the Weka Pass and Waipara districts is as follows:—

1. Weka Pass Stone.
2. Amuri limestone.
3. Glauconitic greensands.
4. Greensands, often argillaceous with saurian boulders, sometimes covered with a crust of cone-in-cone limestone.

---

* Hector, Progress Report, Report of Geol. Survey, 1868–69, p. xii.
† Haast, Reports of Geol. Expls., 1870–71, p. 16.

5. Black-oyster bed with *Conchothyra parasitica*, McCoy.
6. Quartzose sands with shale and brown coal.
7. Quartzose sands with bands of limonitic sandstone.

The full succession is exposed in the Waipara Valley, between Ram Paddock and the slopes of Doctor's Range; but only beds 1, 2, and 3 are seen in the Weka Pass, the direction of the dip not permitting the exposure of the lower beds.

The general arrangement of the Weka Pass Stone and Amuri limestone on the west side of the stream is very well seen from the railway-line, standing at a point near the 45-mile post. The section from the lower to the upper end of the gorge is as shown in fig. 15.

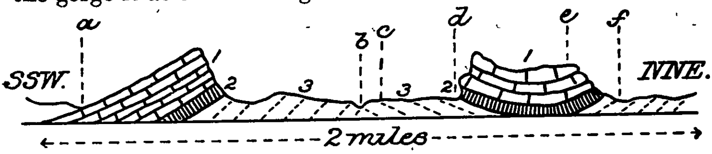


Fig 15.

SECTION ALONG WEST SIDE OF WEKA PASS.

a. Lower end of pass. *b.* Small stream. *c.* Opposite 45-mile post. *d.* 45¼-mile. *e.* Opposite viaduct. *f.* Upper end of gorge. 1. Weka Pass Stone. 2. Amuri limestone. 3. Upper greensands.

The section exposed at the 45-mile post, running from the pass eastward to Mount Donald Range, is shown in fig. 16.

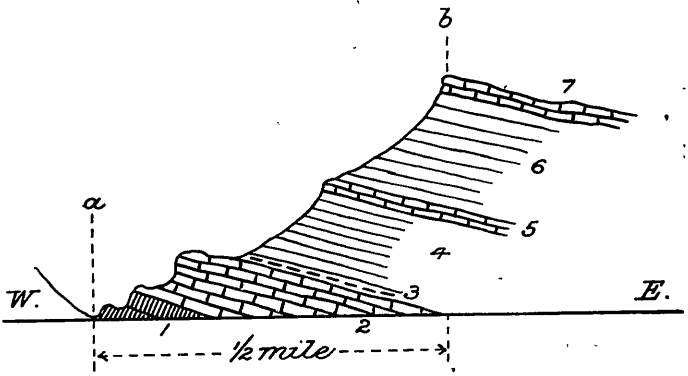


Fig 16.

SECTION FROM PASS EASTWARD.

a. Weka Pass. *b.* Mount Donald Range. Waipara series: 1, Amuri limestone; 2, Weka Pass Stone. Oamaru series: 3, Blue sandy clays; 4, brown and greenish-grey sandstones; 5, band of impure limestone (coralline) about 24 ft. thick; 6, soft brown sandstones, fossiliferous in upper part; 7, calcareous sandstone, richly fossiliferous in places.

Bed 4 corresponds with the grey marls of the Geological Survey and the *Cucullæa* beds of Haast at Mount Brown. The lower coralline limestone occupies the stratigraphical position of the Oamaru building-stone, and is doubtless the local representative of that horizon.

The arrangement of the Waipara and Tertiary beds is very well seen near the upper end of Weka Pass, in the line of section from Waikari Flats across to Mount Donald Range. It is shown in fig. 17 below.

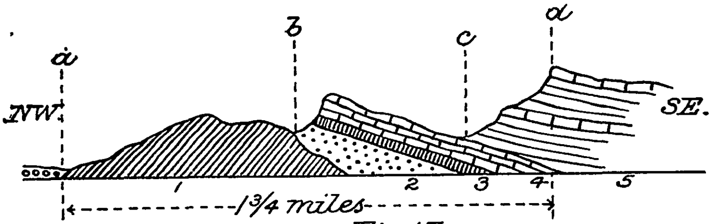


Fig 17.

SECTION FROM WAIKARI FLATS TO MOUNT DONALD RANGE.

a. Waikari Flat. *b.* South-east boundary-line of Section 8198. *c.* Valley opposite viaduct. *d.* Mount Donald Range. 1. Palæozoic or Secondary claystones and sandstones. 2. Glauconitic greensands. 3. Amuri limestone. 4. Weka Pass Stone. 5. Tertiary beds.

Weka Pass Stone.—This is generally a hard grey limestone, sometimes sandy and flaky, and in places crowded with fucoid-like markings. At the north side of the viaduct, at the upper end of the gorge, it is about 125 ft. thick. An average sample of the rock broken from the whole thickness showed the following composition. The analyses of Amuri limestone, Weka Pass Stone, and Oamaru Stone were made by Dr. Maclaurin, D.Sc., Government Analyst :—

	Oamaru Stone.*	Weka Pass Stone.†
Calcium-carbonate ...	93·90	67·60
Magnesium-carbonate ...	1·00	0·80
Calcium-oxide	...	0·80
Alumina	0·51	3·92
Iron-oxide (Fe_2O_3) ...	0·69	2·08
Silica	2·75	22·51
Organic matter and water	1·15	2·29
Undetermined	...	...
	100·00	100·00

* Oamaru Stone from Totara Quarry, near Oamaru.

† Weka Pass Stone from Waikari, end of Weka Pass, from cliffs on north side of stream, a few chains above the railway viaduct.

These are the analyses not of a single rock-specimen, but of average samples selected from the total thickness of the beds. The Weka Pass Stone contains a high proportion of silica and a low proportion of calcium-carbonate, and is a very poor sandy limestone. The Oamaru Stone is a high-class limestone, remarkably low in alumina, iron-oxide, and silica.

The Weka Pass Stone varies considerably in composition, being more calcareous in the higher than the lower portion. Near its junction with the Amuri limestone it is merely a calcareous sandstone, as shown by the analysis of an average sample selected about 2 ft. above the Amuri limestone:—

	Weka Pass Stone (2 ft. above Amuri Limestone).
Calcium-carbonate	47·62
Magnesium-carbonate	1·46
Calcium-oxide	1·50
Alumina	6·44
Iron-oxide (Fe_2O_3)	2·76
Silica	34·95
Organic matter and water	3·50
Undetermined	1·77
	100·00

The following analyses are interesting as showing that the Amuri limestone becomes more siliceous as it approaches the Weka Pass Stone:—

	Average Sample from Thickness of 40 ft.	Sample from 2ft. below Weka Pass Stone.
Calcium-carbonate ...	88·64	81·56
Magnesium-carbonate ...	0·45	0·61
Calcium-oxide	...	...
Alumina	0·66	1·03
Iron-oxide (Fe_2O_3) ...	0·54	0·77
Silica	7·25	14·45
Organic matter and water	2·06	1·58
Undetermined	0·40	...
	100·00	100·00

The Weka Pass Stone seems to be entirely destitute of molluscan fossils. I spent many hours searching acres of its bare weathered surfaces, and only succeeded in finding a few broken echinoderm spines and a thin calcareous tube. The ganger or foreman at the railway quarry near the 45-mile post, in reply to my inquiries, informed me that he had never seen a trace of fossils in the stone, of which thousands of tons had been broken.

Many large masses of the rusty-brown fossiliferous calcareous sandstone which crowns the Mount Donald Range overlooking the railway-line are strewn on the surface both above and below the outcrop of the Weka Pass Stone in the pass in the vicinity of the quarry. I am inclined to think that many of the fossils credited to the Weka Pass Stone were in reality obtained from these masses.

Sir Julius von Haast,* in his report on the geology of Waipara district in 1869, gives a list of fossils purporting to come from the Weka Pass Stone, and then further on admits that the greater part of the fossils came from the Curiosity Shop beds. The species he enumerates are the fossils characteristic of the Mount Brown beds. Nearly all of them are present at Mount Donald, and can be collected from the loose fallen masses lying in Weka Pass, near the railway-line. Certainly none of them occur in the Weka Pass Stone.

The Weka Pass Stone has been correlated by the Geological Survey with the Oamaru Stone† for more than thirty years, and the characteristic fossils of the Oamaru Stone have been credited to Weka Pass Stone. I can find no record of the grounds upon which this correlation was made. It certainly was not founded upon similarity of fossil contents, or even lithological characters.

The Oamaru Stone is underlain by beds containing a Tertiary fauna; the Weka Pass Stone by beds containing a purely Secondary fauna. Further, the Tertiary fauna found below the Oamaru Stone in North Otago and South Canterbury occurs above the Weka Pass Stone in the Weka Pass, thus proving in the most conclusive manner that the Waitaki Stone cannot be the equivalent of the Weka Pass Stone. The correlation was apparently based upon the resemblance of the escarpments and weathered outcrops of the two rocks It gave an erroneous conception of the relationship existing between our Tertiary and Upper Secondaries, and may be held chiefly responsible for the Cretaceo-Tertiary theory of the Geological Survey.‡

Captain Hutton contends that there is an unconformity between the Weka Pass Stone and the Amuri limestone. I carefully examined the line of contact of the two rocks, but was unable to find any evidence of unconformity; and on this point my view coincides with that of Sir James Hector, Sir Julius von Haast, and Mr. McKay.

---

* Haast, Reports of Geol. Expls., 1870–71, p. 13.

† The Geological Survey has always been of the belief that there is only one limestone in the Oamaru district. The Oamaru or Ototara Stone of the Survey refers in nearly all cases to the Waitaki Stone, or closing member of the Oamaru series, and not to the Oamaru building-stone.

‡ Hector, Reports of Geol. Survey, 1866–67, p. 17.

LOWER AWATERE.

The Awatere beds are well exposed on the banks of the Awatere River, both above and below the railway-bridge near the Township of Seddon, and also in the bed of Starborough Creek, which flows through Seddon, and joins the Awatere a little over a quarter of a mile below the bridge. The lower beds consist of blue clays, which often contain large limestone concretions; and the higher beds, of sandy beds and sandstones, which are interbedded with thin layers of harder shelly sandstone, generally crowded with shells. The clay beds contain only a few fossils. The higher sandy beds, on the other hand, are richly fossiliferous, the shells being well preserved and easily extracted.

A collection made from the upper beds as exposed on the bank of the Awatere, at the mouth of Starborough Creek, contained the following forms :—

1. *Siphonalia dilatata*, Quoy and Gaimard.
2. *Siphonalia mandarina*, var. *cordata*, Quoy and Gaimard.
3. *Siphonalia subnodosa*, Hutton.
4. *Siphonalia conoidea*, Hutton.
5. *Struthiolaria sulcata*, Hutton.
6. *Struthiolaria vermis*, Martyn.
7. *Struthiolaria papulosa*, Martyn.
8. *Struthiolaria cincta*, Hutton.
9. *Scaphella corrugata*, Hutton.
10. *Scaphella pacifica*, Lamarck.
11. *Turritella rosea*, Quoy and Gaimard.
12. *Turritella kanieriensis*, Harris.
13. *Cirsotrema zelebori*, Frauenfeld.
14. *Calliostoma selectum*, Chemnitz.
15. *Natica ovata*, Hutton.
16. *Natica zelandica*, Gray.
17. *Ancilla australis*, Sowerby.
18. *Cylichna striata*, Hutton.
19. *Cantharidus purpuratus*, Martyn.
20. *Monilea egena*, Gould.
21. *Dentalium conicum*, Zittel.
22. *Ostrea angasi*, Sowerby.
23. *Anomia walteri*, Hector.
24. *Pinna zelandica*, Gray.
25. *Mytilus magellanicus*, Chemnitz.
26. *Glycimeris laticostata*, Quoy and Gaimard.
27. *Pecten convexus*, Quoy and Gaimard.
28. *Pecten triphooki*, Hutton.
29. *Chione oblonga*, Hutton.
30. *Chione stutchburyi*, Gray.

31. *Dosinia magna*, Hutton.
32. *Dosinia greyi*, Zittel.
33. *Cardium spatiosum*, Hutton.
34. *Cardium striatulum*, Sowerby.
35. *Corbula dubia*, Hutton.
36. *Zenatia acinaces*, Quoy and Gaimard.
37. *Panopæa plicata*, Hutton.
38. *Tapes*, sp. nov.
39. *Diplodonta zelandica*, Gray.

Of the forty-two species enumerated above, thirty, or 71·4 per cent., are still living. There is no difficulty in correlating these beds with the Motanau beds of North Canterbury and the Te Aute series of Wellington and Hawke's Bay.

Port Hills, Nelson.

Stratigraphy.

The Tertiaries of Nelson consist of conglomerates followed by coarse sandstones, which are succeeded by finer banded sandstones and sandy clays. The conglomerates form Arrow Rock, at the entrance to the harbour. The coarse sandstones contain gritty shell and coral beds, and are well exposed below high-water mark as reefs lying between Arrow Rock and the sea-wall. The finer sandstones are best seen in the cliffs facing the harbour.

A few isolated boulders of granite partially water-worn occur imbedded in the upper sandstones. The largest boulder seen by me was about 4 ft. in diameter. The material composing the great conglomerate at the base of the series is said to be mainly granitic.

The beds are tilted towards the south-east—that is, towards the Port Hills—at angles varying from 70° in the lower sandstones to 45° in the higher. They run more or less parallel with the sea-wall, but in places are seen to be faulted and even bent along the strike. The direction of the dip carries them under the Port Hills, themselves composed of gravels which appear to be a remnant of the Moutere gravels of Pleistocene age.

The well-known Waimea, Moutere, and Motueka gravel hills are all that now remain of the great sloping fan or plain formed by the Motueka River at the time when it drained the slopes of the Spenser Mountains and Mount Murchison, and wandered from Richmond to Riwaka, a slow sinking of the land enabling it to carry forward the material by means of which half of Tasman Bay was reclaimed from the sea. The outline of this great river-fan can still be clearly traced from the shores of Tasman Sea south-westward to the sources of the Hope River, where it attains a height of over 2,000 ft. in a distance of little over thirty miles as the crow flies.

By the recision of its head-streams the Buller River has cut its course back into the watershed of its eastern neighbour, thereby diverting the drainage from the Spensers into its own channel. That the recision of the head-waters of the Buller has taken place since the retreat of the glaciers is almost quite certain, but the cause of the recision is not very evident. Whether it was due to the physical condition and favourable arrangement of the rocks for erosion or faulting, or the differential elevation of the land, or to a combination of these causes, is a subject that awaits further investigation.

Fossils.

From the gritty sandstones exposed at low water below the sea-wall about half-way around the Port Hills Road to the Waimeas I collected the following fossils:—

1. *Aturia australis*,* McCoy.
2. *Pleurotoma fusiformis*, Hutton.
3. *Siphonalia nodosa*, Hutton.
4. *Scaphella pacifica*, Lamarck.
5. *Scaphella corrugata*, Hutton.
6. *Struthiolaria papulosa*, Martyn.
7. *Cirsotrema browni*, Zittel.
8. *Natica darwini*, Hutton.
9. *Turritella cavershamensis*, Harris.
10. *Turritella kanieriensis*, Harris.
11. *Crepidula monoxyla*, Lesson.
12. *Calyptræa calyptræformis*, Lamarck.
13. *Teredo heaphyi*, Zittel.
14. *Dentalium mantelli*, Zittel.
15. *Ostrea wullerstorfi*, Zittel.
16. *Pecten williamsoni*, Zittel.
17. *Glycimeris globosa*, Hutton.
18. *Cucullæa alta*, Sowerby.
19. *Solenotellina nitida*, Gray.
20. *Flabellum radians*, Tenison-Woods.
21. *Flabellum sphenodeum*, Tenison-Woods.
22. *Trochocyathus mantelli*, M. Edw. and H.

Besides these, the following forms are recorded by Hochstetter as having been found by him in the Port Hills cliffs:—

* The *Aturia* occurs in a crumbling gritty sandstone, close to the sea-wall, at a point about 18 chains south of the "basin," and worn smooth by the wash of the tide at high water. The exact spot was shown to my old friend Mr. W. S. Curtis, of the Government Survey Department, Nelson, who will be glad to point out the place to any one interested in our Tertiary geology.—J. P.

23. *Siphonalia robinsoni*, Zittel.
24. *Scaphella gracilicostata*, Zittel.
25. *Limopsis insolita*, Sowerby.
26. *Glycimeris laticostata*, Quoy and Gaimard.
27. *Solenella australis*, Zittel.

Of the twenty-four molluscs in the above lists, seven, or 29 per cent., are still living. The fossils clearly refer these beds to the Oamaru series.

About 11 ft. below the *Aturia* bed there is a gritty shell-bed crowded with broken corals and *Cidaris* spines. It varies from nothing to 6 ft. in width, its outcrop presenting the appearance of a truncated lens. It was from this bed that the bulk of the fossils collected by me were obtained.

Résumé.

The conclusions I have arrived at relative to the physical and stratigraphical geology of New Zealand, based upon the foregoing facts, may be summarised as follows:—

(*a.*) That the main orographical features were determined soon after the close of the Jurassic.

(*b.*) That there are three Tertiary marine formations in New Zealand, as under:—(1.) Wanganui series: Newer Pliocene. (2.) Te Aute or Waitotara series: Older Pliocene. (3.) Oamaru series: Miocene.

(*c.*) That the Oamaru series rests unconformably upon the Waipara series of Upper Cretaceous age.

(*d.*) That the Waipara, Oamaru, and Waitotara series are marginal deposits which accumulated during periods of partial submergence of the land.

(*e.*) That the great glacier period of New Zealand was in the Pleistocene, since when the glaciers have been gradually retreating and diminishing in size.

(*f.*) That the Pleistocene great extension of the glaciers was mainly caused by refrigeration due to elevation of the land rather than general climatic conditions.

(*g.*) That the distribution of the Oamaru and Waitotara series, ascending in height from the sea on both coasts towards the interior, is an evidence of differential elevation along the main orographic axis.

(*h.*) That the Pareora, Kakahu, Waihao, Black Point, and Hampden shell-beds belong to the Oamaru series.

(*i.*) That many areas mapped as Pareora are potential coal-bearing areas.

(*j.*) That the Motanau and Awatere beds overlie the Oamaru series unconformably, and belong to the Pliocene.

(*k.*) That the Oamaru series contains two distinct calcareous horizons—namely, the Waitaki Stone and Oamaru Stone, which are separated by the Mount Brown or Hutchinson Quarry beds.

(*l.*) That the Weka Pass Stone has no relation to the Waitaki or Oamaru Stone, but is the closing member of the Waipara series in Canterbury.

(*m.*) That the Weka Pass Stone is always conformable to the Amuri limestone.

CLASSIFICATION OF NEW ZEALAND FORMATIONS.

The classification which my investigations in the past four years have led me to adopt is as follows :—

Tertiary	Recent	River and beach sands and gravels, sand-dunes, &c.
	Pleistocene	High-level gravel terraces, old moraines, old river-fans, &c.
	Newer Pliocene	Wanganui series.
	Older Pliocene	Te Aute or Waitotara series.
	Miocene	Oamaru series.
Secondary	Upper Cretaceous	Waipara series.
	Jurassic	Mataura series.
	Triassic	Shaw Bay series.
Primary	Permo-Carboniferous	Mount Mary series.
	Carboniferous	Kakanui series.
	Upper Silurian	Mount Arthur series.
	Lower Silurian	Collingwood series.
	Azoic	Crystalline schists of Otago.

ART. LVII.—*On the Occurrence of Large Bodies of Ferrous Sulphate in the Gold-mines of Thames Goldfield.*

By MATTHEW PAUL, Mine-manager.

Communicated by Professor James Park.

[*Read before the Otago Institute, 8th November, 1904.*]

SULPHATE of iron is found in large deposits in the old workings on the Thames Goldfields, principally in the Kuranui, Caledonian, Waiotahi, Victoria, and Moanataiari Mines, situated west or seaward of the Great Moanataiari Fault. In No. 3 level in the Kuranui-Caledonian Mine, in an old cross-cut drive (347 ft. from surface) which was driven for the purpose of connecting with the Waiotahi Mine some twenty-five years ago, there is a very large deposit of this mineral. In some parts it has almost filled this drive up, and one would think at first sight that the country-rock had fallen away, but on closer examination the whole of this is found to be sulphate of iron. In this level there is scarcely any moisture to be seen, and the deposit grows on the top,