ART. XXXIII.—*On the Jurassic Age of the Maitai Series.*

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[*Read before the Otago Institute, 9th June, 1903.*]

Plates XXXIII. and XXXIV.

ROCKS belonging to this formation are widely distributed in New Zealand, and play an important part in the structure of the mountain-ranges in both Islands. In the neighbourhood of Nelson, where they are typically developed, they consist of a great assemblage of greenish-grey sandstones, blue, green, red, and grey slaty shales, and limestones, with a few subordinate beds of red and green slaty breccia. The blue or green shales often alternate with thin laminæ of grey shale or sandstone.

The average general bearing is N. 20° E. (true bearing). The arrangement of the strata is displayed to great advantage in the valleys of the Matai, Brook Street, and Roding Streams, which descend from the Dun Mountain region at nearly right angles to the trend of the series. The beds are seen in all three lines of section to be arranged in a great synclinal fold.

The strata on the western side of the syncline — that is, immediately behind the Town of Nelson—are associated with massive sheets and numerous ramifying dykes of a chloritic basalt,* and on the eastern side by a remakable development of altered ultra-basic rocks, principally peridotite and serpentine, the latter often traversed by veins of bronzite, hypersthene, and other pyroxenes.

The eruption of these igneous rocks was probably contemporary with, or at least not much later than, the deposition of the beds with which they were associated.

AGE OF MAITAI SERIES.

The late Dr. Von Hochstetter, who examined these rocks in 1859, referred them to the Lower Trias,† placing them conformably under his Richmond sandstone, the equivalent of the Wairoa series of Sir James Hector. He described them as containing no fossils, and apparently ascribed them to the Triassic period, from their association with the Richmond sandstone, in which he found *Monotis salinaria* var. *richmondiana*, Zittel, a typical Trias form in Europe.

Sir James Hector, in the Catalogue of the Colonial Museum, 1870, in his "Synopsis of the Arrangement of the Formations represented by the Collections of Fossils," also

* Hutton, Proc. Roy. Soc. N.S.W., 1889, p. 152.

† Hochstetter's "New Zealand," 1867, page 57.

placed the Maitai series at the base of the Trias, between the Wairoa and Kaihiku series.

The late Mr. E. H. Davis, in his very excellent report on the geology of Nelson District, referred to the Maitai series as Triassic.* In the limestones at the base of the series he found *Inoceramus* and corals; and in the slates above the limestone numerous annnelid trails, *Inoceramus* in great numbers, a cast of a cephalopod, and casts of fossils not determined.

Captain Hutton, F.R.S., in his "Report on the North-east Portion of the South Island," in 1873, reversed the relative positions of the Maitai and Wairoa formations: thus, while the Wairoa series is still retained in the Trias, the Maitai series, on palæontological and stratigraphical grounds, is placed in the Jurassic system.†

In the same year Sir James Hector examined the sections exposed in the Wairoa Gorge, and in his Progress Report states that in his opinion the Wairoa formation—that is, the Richmond sandstone of Hochstetter—rests unconformably upon the Maitai formation, and accordingly reverses the order of superposition proposed by Captain Hutton. He still retains the Wairoa formation in the Trias, and now relegates the Maitai formation to the Upper Palæozoic, placing it below his Te Anau series.‡

In his classification of 1877 the Maitai formation is placed by Sir James Hector in the Permo-carboniferous period in association with the Nuggets and Mount Potts beds;§ and in his classification of 1878 it is pushed down into the Carboniferous.‖

Mr. A. McKay, F.G.S, in the year 1878, examined the lines of section detailed so minutely by Mr. Davis in 1869, and at the same time extended his observations to the neighbourhood of the Wairoa Gorge and Mount Heslington. In his report he adopts the classification of the Director of the Geological Survey for the Wairoa and Maitai formations, but, unlike previous observers, places the Maitai limestone at the top instead of at the base of that series, and supports this view by stating that he considers the Maitai formation to be overturned.

In the following year Mr. McKay made a further examination of the Wairoa and Mount Heslington districts, and, besides making large collections of fossils from the Maitai and Wairoa formations at different points, discovered what he

* Reps. Geol. Expl., 1869–71, p. 103.
† Reps. Geol. Expl., 1873–74, p. 34.
‡ Geological Map, Hector, 1873; and Reps. Geol. Expl., 1876–77, p. 1.
§ Reps. Geol. Expl., 1876–77, p. v.
‖ Reps. Geol. Expl., 1877–78, p 198.

believed to be an outcrop of fossiliferous Permian rocks in Eighty-eight Valley district, near Wakefield.

Among the fossils collected from the limestone at Sellen's and Wairoa Gorge he says that Dr. Hector identified "*Spirifera bisulcata* and *Productus branchythærus* among the *Brachiopoda*, and the genera *Cathophyllum* and *Cathocrinus* among the corals."* On this occasion he places the limestone at the base of the Maitai series, instead of at the top, as he did in 1878.

In the summer of last year I made an examination of the sections of the Wairoa and Maitai formations exposed in the Maitai Valley, along the Dun Mountain tram-line, at Wairoa Gorge, Mount Heslington, and Eighty-eight Valley, at the same time making collections of fossils at all available places.

In the Wairoa Gorge I observed that the dip and strike of the two formations were the same at every point of exposure. I further noted that the dip of the higher *Mytilus* beds, granitic conglomerate, and associated strata was such as to carry the Wairoa series conformably below the limestone at the base of the Maitai formation.

So far as I could determine after an examination of many sections, the two formations seemed to form a continuous sequence, the Wairoa series occupying the inferior position, as reported by Captain Hutton in 1873.

The result of my observations at the Wairoa Gorge induced me to examine the sections of the Trias in Eighty-eight Valley, more especially those exposed in the vicinity of Well's Creek, where Mr. McKay reported the discovery of supposed Permian (Kaihiku) beds in 1878. A detailed examination of the very clear section exposed along the right bank of Well's Creek showed that the supposed Permian beds occurred at the top and not at the base of the Wairoa series, as reported by Mr. McKay, and this discovery led me to conclude that there was possibly some association between the Wairoa limestone and the so-called Kaihiku beds, which in places are richly fossiliferous and often highly calcareous.

In November of this year I again re-examined these sections, and also extended my observations to the sections exposed at Sellen's run and Roding River. The result of my work on this occasion was to fully confirm my former conclusions—namely, that

(*a.*) The Wairoa series lies conformably below the Maitai formation.

(*b.*) The supposed Permian strata in Eighty-eight Valley are probably the equivalent of the Maitai limestone.

* Reps. Geol. Expl., 1878–79, p. 117.

We have already seen that Captain Hutton, in his report on the north-east portion of South Island in 1873, placed the Maitai formation above the Wairoa series, classifying the former as Jurassic and the latter as Triassic.

In his Progress Report for the year 1873 the Director of the Geological Survey states that, after an examinaton of the sections relied on by Captain Hutton, he had arrived at the conclusion that the relative positions of these formations as reported by Captain Hutton must be reversed, "as the section up the gorge of the Wairoa River shows the latter" [Wairoa] "formation, with its characteristic fossils (*Monotis salinaria* and *Mytilus problematicus*), to rest unconformably on the 'Maitai' formation."* Unfortunately, he omitted to furnish details of the section showing this unconformity, and in the absence of specific data it is impossible to review the evidence on which he based his conclusion.

In his reports of 1877 and 1878 Mr. McKay adheres to the classification of Dr. Hector. He examined the typical sections exposed in the Maitai Valley, Brook Street Valley, Roding River, Wairoa Gorge, Sellen's, and Eighty-eight Valley, and, although in no case do his descriptions possess the elaborate exactness of those of Mr. Davis, I found that his field observations were everywhere carefully noted and faithfully recorded. On the other hand, in his discussion on the relative positions of the Wairoa and Maitai formations his conclusions seem curiously at variance with the recorded facts, while some of his sections are obviously constructed to represent his views rather than the facts observed in the field.

Proceeding from the Waimea Plain through the Wairoa Gorge, and thence along the course of the Roding River, there is exposed a clear section of the Wairoa and Maitai formations in which the dip is continuously to the east-south-east in one unbroken sequence, at angles generally between 65° and 75°, representing in a distance of a mile and a half a thickness of not less than 7,000 ft. of strata. In this section the Trias beds appear first, and are clearly seen to dip under the Maitai limestone.

At a point just above the first bend in the Roding River the beds dip west-north-west at an angle of 75°, and thence, following up the river, the whole sequence of the Maitai formation is repeated down to the limestone and associated conglomerates, beyond which appear the eruptive rocks of the serpentine belt. This synclinal arrangement of the overlying Maitai formation is also observed in the Maitai River and Brook Street Valley sections.

* Reps. Geol. Expl., 1873–74, p. ix.

The Trias formation consists of a great series of claystones, coarse and fine sandstones, and granitic conglomerates, containing a number of well-marked fossiliferous horizons, to which reference will be made later when describing the section in Eighty-eight Valley.

A careful examination of the pebbles and boulders forming the conglomerates shows that they consist principally of diorites, granite, and a great variety of acidic, eruptive, and quartzose material, all of which have been apparently derived from the granitic masses in the Mount Arthur district, lying to the north-west of this, where these rocks occur *in situ*, associated with rocks of Silurian age.

It is a significant fact, and one quite in harmony with the stratigraphical evidence, that the ultra-basic eruptive rocks which occupy so conspicuous a place in the Maitai formation are quite absent from the Trias conglomerates.

The Maitai formation and its colossal pile of basic eruptives form a long chain of broken uplands, on the lower flanks of which the Wairoa beds form a corresponding chain of foot-hills. Hence, if the Maitai rocks were antecedent with the Wairoas resting on their denuded surfaces, as contended by Sir James Hector and Mr. McKay, fragments of the basic eruptives should be largely represented among the coarser sediments of the Wairoa beds; but they are entirely absent, as, indeed, could not be otherwise from their subsequent date.

The Maitai rocks have generally been described as slates of various colours. This is a somewhat loose use of the term "slate." The rocks are not really slates, but bluish-grey claystones, which often occur in thin laminæ of different shades of colour. When these thin laminæ alternate with each other, as is often the case, the rock gets a slaty or flaggy appearance. In places the claystones are slaty and somewhat fissile, with a silky lustre where they have been much crushed. In the lower part of the formation there are thick beds of grey sandstone and greywacke, generally much shattered and jointed, and often streaked with white veins of a hydrated mineral which was determined by the late Mr. W. Skey to be stilbite. Thin veins of grey and brown flinty quartz occur in the harder sandstones in several places.

Beds of red and green slaty claystones and breccias occur interbedded in the formation. They are quite subordinate in extent to the claystones and sandstones, but wherever they occur they are very prominent from their conspicuous colour.

Mr. McKay, referring to the Wairoa section, says, "In the lower part of the Roding River, near its junction with the Wairoa, the junction between these beds is strictly analagous

to that made between the Wairoa and Maitai rocks behind Richmond, already described."* And on the preceding page, after describing the Richmond section, which lies a few miles further north, he says, "Perhaps, upon the whole, it may be said that this section does not favour the theory which aims at showing the Wairoa formation to be the younger of the two."†

Mr. McKay seems unwilling to admit the inferior position of the Wairoa formation no matter how clearly indicated by the stratigraphical evidence, and to get over the difficulty argues that the Trias rocks must be arranged as an "inverted syncline," basing this last supposition on the repetition of the *Mytilus problematicus* beds, which he considers must be due to the complete inversion of one side of the supposed syncline. He mentions, however, that the *Mytilus* bed was the only one which seemed to be repeated, and in this he admits a serious difficulty. An examination of the Mount Heslington‡ and Eighty-eight Valley sections shows that the repetition of the *Mytilus* bed is due not to inversion, but to the simple circumstance that there are two distinct horizons of *Mytilus*, one near the middle of the Trias, and one below the upper granitic conglomerate lying below the Maitai limestone.

In the section at Sellen's run, a few miles south of the Wairoa Gorge, the Trias and Maitai rocks dip east-south-east at high angles, the former again occupying the inferior position. Writing of this section, Mr. McKay says, "On the ridge east of the limestone at Sutton's" [Sellen's] "these beds" [Wairoa beds] "again dip as though they would pass under the Maitai series,"§ and in this instance his diagrammatic section along this line correctly shows the Trias rocks dipping conformably below the Maitai limestone as they are actually seen to do.

The Trias rocks in the section on the north-east side of Well's Creek, in Eighty-eight Valley district, a few miles south of Sellen's line of section, are again seen to dip conformably below the Maitai formation. Here the whole series is clearly exposed in a regular sequence, dipping to the south-south-east at angles varying from 50° to 75° or 80°, the inclination of the beds becoming steeper in ascending order to the eastward.

Speaking of this section, Mr. Mackay says, "Along their junction with the Maitai series the beds" [Wairoa beds] "are much crushed and highly indurated, but a short distance

* Reps. Geol. Expl., 1877–78, p. 156.

† *L.c.*, p. 155.

‡ Mr. McKay, in his reports, erroneously speaks of this hill as Mount Wellington.

§ Reps. Geol. Expl., 1877–78, p. 157.

to the north-west of the boundary-line the strike and dip of the beds are regular in such a direction that the beds appear to pass under the older beds" [Maitai beds] "lying to the eastward."* For "older beds" he should have written "supposed older beds."

Here again Mr. McKay attempts to explain away the very plain stratigraphical evidence in the following words:—

"It is highly probable that what are now the higher beds, as seen in the section along the banks of the creek, are in reality the lower beds, and that they are now in an overturned position."† Thus, while correctly noting and recording the stratigraphical evidence, which shows the inferior position of the Wairoa formation in all the sections examined, in order to support the theory that the Maitai formation is older than the Wairoa formation he assumes that the combined strata of both formations, representing a thickness of 7,000 ft. or 8,000 ft., have been completely overturned; and, having thus overturned the formations, argues that the Maitai formation, which everywhere admittedly occupies the superior stratigraphical position, is Carboniferous, and the inferior or underlying formation Triassic.

The gritty, pebbly, calcareous sandstones and claystones immediately overlying the upper granitic conglomerate in Well's Creek section are seen to dip under the Maitai rocks. They contain a large assemblage of fossils, mostly brachiopods, and, although they occur at the top of the Trias series, they become by the process of inversion the bottom beds, and have been referred by Mr. McKay to the Permian. Disregarding, however, this supposititious inversion of the formations, and reading the sections as they appear, the sequence of the Trias rocks in the different sections is found to be approximately the same as would naturally be expected in lines of section across the same basin of deposition.

In the Wairoa section the beds in descending order are as follows:—

0. Fossiliferous limestone (Maitai—*i.e.*, Wairoa—limestone).
1. Claystones.
2. Upper granite conglomerate.
3. *Mytilus* sandstones and claystones.
4. *Spirigera* sandstones.
5. *Mytilus* sandstones.
6. *Monotis* sandstones.
7. *Spirigera* and *Trigonia* sandstones.
8. Lower granite conglomerate.

* Reps. Geol. Expl., 1878–79, p. 118.
† *L.c.*, p. 118.

9. *Halobia* claystones.
10. *Spiriferina* claystones.

In Sellen's section the sequence is :—

0. Fossiliferous limestone (Maitai limestone).
1. Claystones.
2. Upper granitic conglomerate and grit-stone.
3. Claystones (no *Mytilus* seen).
4. Sandstone and claystone, with *Mytilus* at base.
5. Lower granite conglomerate.
6. Claystones, with *Halobia*.
7. Sandstones and claystones, with *Halobia*, *Rhynchonella*, *Spiriferina*, and corals.
8. Plant beds.

One of the clearest sections of the Trias rocks is exposed in Well's Creek, where the sequence is as follows :—

0. Fossiliferous calcareous gritty sandstone.
1. Claystones.
2. Upper granite conglomerate.
3. *Mytilus* sandstones and claystones.
4. *Spirigera* sandstones.
5 *Mytilus* sandstones.
6. *Spirigera* sandstones.
7. Lower granite conglomerate.
8. *Halobia* claystones.
9. *Spiriferina* claystones and sandstones.
10. Plant beds.

In the Wairoa and Sellen's sections the Trias formation is closed with a limestone (the Maitai limestone of Hector), from which I collected *Spiriferina* (two sp.), *Athyris*, *Rhynchonella*, *Pleurotomaria*, *Inoceramus*, *Pentacrinus*, and corals (three sp.).

In many places the limestone is argillaceous, gritty, and pebbly. It has been broken and shattered into small angular fragments, which have been recemented by white veins of calcite. Fossils are not at all common, and where found are difficult to extract in a complete state on account of the jointed and veined condition of the material. Of the different forms present *Inoceramus* was found to be the most abundant.

Among the collections made by Mr. McKay Sir James Hector is said to have identified the Carboniferous forms *Spirifera bisulcata*, *Productus branchythærus*, and the genera *Cathophyllum* and *Cathocrinus* among the corals.* Considering the imperfect character of most of the specimens and their association with *Inoceramus*, a good deal of doubt must necessarily attach to these determinations.

The large brachiopod identified as *Spirifera bisulcata* seems

* Reps. Geol. Expl., 1878–79, p. 117.

to be related to the peculiar form of *Athyris* called *Clavigera* by the Geological Survey. Should it, however, on examination, prove to be a true Spirifer, it would show that this genus persisted in New Zealand up to the close of the Trias.

A calcareous, pebbly, and gritty sandstone in Eighty-eight Valley closes the Trias sequence, and occupies the same relative position to the upper granite conglomerate that the limestone (Maitai) does to the same conglomerate in the Wairoa sections. From it I collected *Spiriferina* (two sp.), one of these the *Rastelligera* of Hector, *Athyris* (two sp.), *Epithyris*, *Rhynchonella*, *Pleurotomaria*(?), *Patella*, branching corals, *Pentacrinus*, and fragments of saurian remains, which may probably be referred to *Ichthyosaurus*.

Among the *Athyris* (*Spirigera* of D'Orbigny) in this horizon there are two very unusual forms. They have a long straight hinge-line, and a distinct area. They are smooth, gibbose, impunctate, and possess a gentle mesial sinus in each valve, the sulcation being more distinct in the ventral valve than in the dorsal. The ventral valve is provided with strong prominent hinge-teeth, one on each side of the deep triangular notch which in *Spirifera* is closed by pseudo-deltidium.

The two species differ widely in external form. One species has rounded cardinal angles resembling those of *Athyris expansa*, Phillips, or some of the straight-hinged *Terebratula*, such as *Terebratula (Megerlia) suessi*, E. Desl., of the English Lias; the other, sharp cardinal angles like some species of *Argiope*.

The section of the Trias rocks at Roaring Bay, near Nugget Point, in Otago, supplies the most complete confirmation of the reading of the section in Eighty-eight Valley. Along the coast-line there is exposed a thickness of over 2,500 ft. of strata in one continuous sequence, representing the whole of the Trias formation from the base of the *Spiriferina* beds to the summit of the *Athyris* beds. The different horizons represented in this section are as follows, in descending order:—

1. *Athyris* beds—coarse pebbly calcareous sandstones.
2. Coarse sandstones.
3. *Mytilus* and oyster bed.
4. Claystones.
5. *Trigonia* and *Spiriferina* beds.
6. Granite conglomerate.
7. Sandstones, with beds of claystone.
8. Breccia conglomerate.
9. Claystones.
10. Breccia conglomerate.
11. Claystones (*Halobia lomelli* beds).
12. Porphyrite dyke.
13. *Spiriferina* beds—claystones.

The general facies of the Trias in Nelson and southern Otago exhibits a harmony that seems remarkable considering the great distance which separates the localities. Near the base of the formation in each place occur claystones with *Halobia* and *Spiriferina*, and in both places the Trias formation is closed by an *Athyris* horizon, followed conformably by a great series of claystones and sandstones. In Otago the formation conformably overlying the Trias series is known as the Mataura formation, to which a Jurassic age has been ascribed by Sir James Hector and Captain Hutton.

The natural inference to be drawn from the stratigraphical evidence is that the Maitai formation of Nelson must be correlated with the Mataura series of Hutton.

The *Athyris* bed at the top of the series contains thousands of finely preserved *Athyris* and a few *Spiriferina* (*Rastelligera* of Hector). The *Productus* of the so-called *Productus* formation of Mr. McKay at Nugget Point* was found on examination to be a *Spiriferina*.

As there is no reason to believe that the Trias formation in both Otago and Nelson has been overturned, we must conclude, from the stratigraphical and palæontological evidence, that the so-called Permian beds of Mr. McKay in Eighty-eight Valley occur at the top of the formation, and are the horizontal equivalents of the limestone in the Wairoa Gorge.

The characteristic fossil of the Maitai formation in Nelson is *Inoceramus*, which has been found in many places in the lower horizons of that formation on both sides of the great synclinal fold. This form occurs sparingly in the limestone at the base of the formation (*i.e.*, top of the Trias), but is found in great abundance in slaty claystones about 100 ft. above the Maitai limestone in the Maitai Valley and Dun Mountain sections.

I will now review the palæontological evidence bearing on the correlation of the highest fossiliferous zone in Well's Creek with the highest zone in the Shaw Bay section. I have already shown that stratigraphically they both occupy the same relation to the underlying *Mytilus* beds.

Among the *Brachiopoda* from Well's Creek there are two very characteristic genera—namely, a *Spiriferina* with singular comb-like dentition along the hinge-line, and an unusual form of *Athyris*, represented by two species the general features of which have already been described. The *Spiriferina* is the *Rastelligera* of Hector, while the *Athyris* is probably the *Clavigera* of the same author.†

* Reps. Geol. Expl., 1873–74, p. 63.
† Trans. N.Z. Inst., vol. xi., 1878, p. 538.

The *Athyris* bed at the close of the Trias at Shaw Bay contains both *Rastelligera* and *Clavigera*, the latter in great abundance and in a fine state of preservation. The two species of *Clavigera (Athyris)* which occur in Well's Creek horizon are both represented at Shaw Bay.

The sub-genera *Rastelligera* and *Clavigera* are so distinctive in structure and widely distributed that they are of the highest value for the identification of Trias rocks wherever they occur in New Zealand. In my examination of the Trias in Nelson, Nugget Point, and Hokonui Hills I found them only in the highest fossiliferous horizon.

The Director of the Geological Survey, in his "Outlines of New Zealand Geology," 1886, states that *Rastelligera* occurs in the Otapiri and Wairoa series—that is, in both the Upper and Middle Trias. If this is the case *Rastelligera* has no zonal value. But I can find no reference in the Geological Reports to its occurrence below the Otapiri series except at Well's Creek, where the theory of inversion of the Triassic system suggested by Mr. McKay makes the *Clavigera* beds of the Otapiri series appear to be at the base of the Trias.

The genus *Clavigera*, so far as I have been able to discover, occurs only in the highest marine horizon of the Trias, and, having a definite age-limit, it assumes a zonal value. Hence its occurrence in a group of beds in Shaw Bay, in Otago, and in Well's Creek, in Nelson, tends to indicate the correlative age of these distant beds. But the Shaw Bay *Clavigera* beds overlie the *Mytilus* beds, therefore the *Clavigera* beds in Well's Creek should also overlie the *Mytilus* beds, and I have already shown that they do so.

Thus in both districts the stratigraphical and palæontological evidence clearly proves the superior position of Mr. McKay's so-called Permian beds in Well's Creek, and supports the correlation of the conformably overlying Maitai formation in Nelson with the conformably overlying Mataura formation in southern Otago.

An examination of the geological structure of the region between Nugget Point, Waikawa, and Mataura has confirmed me in the belief that the Mataura and Maitai formations of Sir James Hector represent the same series of beds. Both formations follow the Upper Trias conformably, and both consist of a great succession of slaty shales and sandstones singularly free from organic remains. The Maitai rocks contain *Inoceramus*, annelid-markings, and indistinct plant-remains; the Mataura series *Inoceramus*, annelid-markings, and plant-remains.

As the Carboniferous age of the Maitai formation can no longer be maintained, and since the term "Maitai" has grown almost synonymous with "Carboniferous," to avoid

confusion it would, I think, be preferable to drop the term "Maitai" and adopt the name "Mataura" for all rocks of Jurassic age throughout the colony.

Captain Hutton, in his report of 1873, referred the Maitai formation to the Jurassic system; and now, after a lapse of thirty years, it is necessary for me to bring it back to the position then assigned to it. The Carboniferous age of the Maitai rocks imposed many insoluble problems on the geology of New Zealand. The removal of the Maitai formation to its natural position in the Jurassic now paves the way for a systematic subdivision of the Lower Mesozoic rocks of New Zealand.

Conditions of Deposition of the Nelson Trias.

The presence of plant-remains and of *Mytilus* in the finer sediments, and of *Patella* and saurian bones in the coarser sandstones and conglomerates, points to a prevalence of shallow-water conditions of deposition from the beginning to the end of the Trias period in the Nelson basin.*

Mytilus is essentially a littoral shell. In some horizons it occurs in millions, and in a condition of preservation that clearly shows that the shells were buried in the sediments accumulating around the places where their owners had lived. It is therefore certain that the old marine littoral of the Palæozoic land-surface on the shores of which these *Mytilus* deposits formed was where these fossils now abound—that is, along the southern boundary of the Waimea Plain.

The shallow-water character of the fossil shells and the alternating marine muds and river-detritus indicate that the local conditions of deposition were fluvio-marine, or, at any rate, of such a nature that during abnormal floods, or through the formation of shoals causing a diversion of the ordinary currents, river-detritus became mixed with or spread over the finer marine sediments.

Having shown that the southern limit of the present Waimea Plain at one time coincided with the northern limit of the Nelson Triassic basin, our inquiry naturally leads us to an investigation of the character of the old Palæozoic land-surface whose erosion yielded the material for the Trias formed on its shores.

We have already found that the coarser sandstones and conglomerates are principally composed of diorites, granites, felsites, and quartzose material, none of which occurs *in situ* as a land-surface in the vicinity of Nelson. The nearest granite-area lies to the north-west along the flanks of Mount Arthur range and lower course of the Motueka River. In that

* An interesting petrological description by Dr. Marshall of material from the upper granite conglomerate will be found in Article XXXVI.

region the granite and a great variety of related crystalline rocks are associated with Silurian slates, schists, quartzite, and limestone, which are in places richly fossiliferous.

We must therefore conclude that an extension of the Mount Arthur system, with its associated granites, formed the old littoral of the Nelson basin, and now forms the floor of the Waimea Plain, Moutere gravel hills, and Motueka Valley.

The open Triassic sea extended southward into Marlborough, and in that direction the pelagic sediments would be finer and organic remains rarer than along the shores of the Nelson basin.

GENERAL CONCLUSIONS.

Summarising the results recorded in the preceding pages, we find (*a*) that the Trias rocks everywhere dip below the Maitai formation; (*b*) that the Maitai formation is principally characterized by the presence of the Secondary genus *Inoceramus;* and (*c*) that the Trias contains such characteristic Lower Mesozoic forms as *Halobia lommeli* and *Monotis salinaria.*

The stratigraphical evidence alone seems amply conclusive of the subsequent date of the Maitais; but, setting this aside, it seems impossible for any student of geology to seriously maintain a Carboniferous age for a formation characterized by such a truly Mesozoic genus as *Inoceramus.*

The Maitai formation, although typically developed in the neighbourhood of Nelson, is one of the most important rock-formations in New Zealand—its importance lying in the fact that it is one of our principal mountain-builders.

Having shown it to be of subsequent date to the Trias has a wider significance than its local relationships might indicate. The Maitai formation possesses the closest stratigraphical connection with the Trias not only in Nelson, but throughout New Zealand. Where one is present the other is seldom, perhaps never, absent. The two formations form one great stratigraphical system, and are so closely associated in the structural features of the country that a definition of the geographical limits of the one must always include that of the other.

Rocks belonging to the Jurassic system, in association with those of the Trias, form the greater portion of the Tararua, Ruahine, and Kaimanawa Mountains in the North Island; while outlying patches occur in the Upper Mokau, at Kawhia, Raglan, Waikato Heads, Kaipara, and Rodney districts, in the Province of Auckland. And we have no reason to assume a greater age for the slaty shales, sandstones, and greywackes which form the floor of the Hauraki Peninsula.

In the South Island this great Juro-triassic or Juro-

permian system composes the broken mountain-chain dividing Nelson from Marlborough, and its western and southern continuation the St. Arnaud and Spencer Mountains, the Kaikouras, and the greater part of the Southern Alps and subsidiary ranges in Canterbury, which are everywhere distinguished by great slopes of moving shingle.

From Canterbury it stretches into Otago, where it forms a portion of the Kurow Mountains and the high rugged chains which extend southward to central Otago and westward to the sources of the Ahuriri River, reaching even to the main divide.

This system also comprises the rocks forming the Hokonui, Takitimu, and Longwood Ranges; and occupies the area lying between the lower Clutha and Waikawa. The shales, sandstones, and limestones of the Blue Mountains, bounding the north side of the Shag Valley, are in all probability an extension of this system from the direction of Mount Ida.

From the foregoing it will be seen that practically all the rocks throughout New Zealand to which a Carboniferous age had previously been ascribed are now included in the Jurotriassic system of Nelson and Nugget Point, in Otago.

There is, however, still some doubt as to the geological position of the gold-bearing rocks at Reefton, which consist of slaty shales and sandstones, often much crushed, folded, and altered. In Murray Creek, and elsewhere in the Inangahua Valley, the Reefton rocks rest unconformably on a highly denuded surface of grey quartzites, slates, and limestone. The slates and limestone contain a rich marine fauna, including *Orthis, Strophomena, Trilobites,* and other Lower Palæozoic genera. Mr. Cox referred these rocks to the Lower Devonian or Upper Silurian, but Sir James Hector, in his classification of 1887,* placed them in the Upper Devonian.†

The Baton series, like the Reefton series, consists of a great thickness of grey quartzite and slates passing into limestone. The slates contain a large assemblage of marine genera, including a number that appear to be identical with forms found in the Reefton slates. In the above classification the Baton series is referred to the Upper Silurian; but, whether the Reefton rocks are Devonian or Silurian, they afford no clue to the age of the gold-bearing series.

In a paper on the Permo-carboniferous rocks of North Otago I have described the discovery of Permo-carboniferous fossils in the upper part of Hector's Kakanui (Walter and

* Reps. Geol. Expl., 1874–76, p. 63.
† Reps. Geol. Expl., 1886–87, Appendix, p. 256.

Cecil Peak series) formation, thus clearly disproving the Devonian age hitherto ascribed to those rocks.

By correlating the Reefton quartzite series with the Mount Arthur system, which seems the only reasonable and consistent course to follow, we are left without a representative of Devonian age in New Zealand; and the Maitai formation having been shown to be Jurassic, and not Carboniferous, it seems probable that New Zealand is also without a formation truly representative of the Carboniferous period of Europe.

With respect to the age of the Reefton gold-bearing formation, there now remain two courses open to us. We can either consider it an entirely distinct formation and refer it to the Devonian or Carboniferous, or we can refer it to the Mount Mary series in North Otago, to which I have ascribed a Permo-carboniferous age.

The Reefton rocks were first correlated with the Maitai formation of supposed Carboniferous by Mr. Cox as far back as 1875.* They were described by him as resting unconformably on fossiliferous rocks which were referred to the Lower Devonian or Upper Silurian. It seemed, therefore, but natural to refer them to the Carboniferous, and in doing so Mr. Cox had doubtless in his mind the marked unconformity which existed between them and the underlying formation—an unconformity noticed by Sir James Hector in 1873.†

Mr. McKay, in his report on Inangahua County in 1882, followed Mr. Cox in correlating the Reefton gold-bearing rocks with the Maitai formation; but when we examine the grounds upon which this conclusion was based we find the evidence not altogether satisfactory or conclusive. Discussing the age of these rocks, he says, "There is but little resemblance between the Reefton auriferous series and the Permian or Trias rocks of New Zealand, and, as shown, not much with the Te Anau formation as developed nearest to Reefton; so that, in a word, the auriferous series of Reefton can be the equivalent of no other than the Maitai formation."‡

Although I have shown the Maitai formation to be Jurassic, it does not necessarily follow that the Reefton gold-bearing rocks are not Carboniferous, as originally indicated by Mr. Cox. On the other hand, there is nothing to justify the conclusion that they are a separate formation; and until something more definite is known about them I will refer them to the Mount Mary formation of Permo-carboniferous age.

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* Reps. Geol. Expl., 1874–76, p. 77.
† Reps. Geol. Expl., 1872–74, p. 87.
‡ Reps. Geol. Expl., 1882, p. 132.

Besides the Reefton rocks, I think it more than probable that the aphanitic sandstones, breccias, and slates described by Mr. McKay as extending from south of the Greenstone, on the west side of Lake Wakatipu, northward to Lake Harris, and ascribed by him to the Maitai and Te Anau series, in reality belong to the Mount Mary formation.* I also think that the continuation of the same rocks northward to Cascade River, behind Big Bay, described by me as Maitai or Te Anau, should now be included in the Mount Mary formation.†

Generally speaking, it may be said that all the rocks ascribed by the Geological Survey to the Carboniferous system are Jurassic or Triassic, excepting perhaps the gold-bearing rocks at Reefton and the so-called Maitais in the mountainous country lying west and north of Lake Wakatipu.

DESCRIPTION OF PLATES XXXIII. AND XXXIV.

PLATE XXXIII.—SECTION ALONG WELL'S CREEK, EIGHTY-EIGHT VALLEY.

1. *Halobia* and *Spiriferina* beds.
2. Claystones.
3. Lower granite conglomerate.
4. Gritty sandstone, with *Spirigera*, &c.
5. *Mytilus* sandstone.
6. Claystones and sandstones.
7. Claystones, with *Mytilus*.
8. *Pentacrinus* and corals in grits and claystones.
9. Upper granite conglomerate.
10. *Athyris* calcareous pebbly sandstone.
11. Maitai sandstones and claystones.
12. Pliocene gravels, Waimea Downs.

F. Fault.

PLATE XXXIV.—SECTION FROM WAIMEA PLAINS TO WAIROA GORGE AND UPPER RODING RIVER.

A. Waimea Plain.
B. Mount Heslington.
C. Wairoa Gorge.
1. Lower Tertiaries.
2. Serpentine belt.
3. *Halobia* and *Spiriferina* beds.
4. Lower granite conglomerate.
5. Upper conglomerate.
6. Maitai limestone.
7. Maitai shales and sandstones.

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* Reps. Geol. Expl., 1879-80, pp. 140-42.
† Reps. Geol. Expl., 1886-87, p. 132.