ANT. XXXI.—On the Age and Relations of the New Zealand Coalfields.

By Professor James Park, F.G.S., Director Otago University School of Mines.

[Read before the Otago Institute, 3rd December, 1903.]

The geology of the coalfields is a subject of great industrial importance, and for this reason is generally the first problem to engage the attention of the geologist in a new country. Moreover, it is obvious that no reliable advice can be given by any one as to the search for coal until the coal-bearing formations have been determined, and the relations and distinctive features of the different members of each ascertained by careful investigation in the field. At the present time there is no general agreement as to the age of the coalfields of New Zealand, excluding from our present consideration the thin seams of bituminous coal found at Otapuri, Wyndham, and Waikawa, in Southland, and on the West Coast south of Waikato, in the North Island, which are acknowledged to be Jurassic; also the lignites of Kaipara, Manukau Harbour, central Otago, and Southland, which are believed to be Pliocene or later.

The valuable coalfields of Auckland, Mokau, west coast of South Island, Canterbury, and Otago are held by the Geological Survey to be of one age, and to belong to the Cretaceous-tertiary period. The late Ferdinand von Hochstetter,* Sir Julius von Haast,† and Captain Hutton have maintained that there are two or more coal-bearing formations in New Zealand.

Captain Hutton, in a paper "On the Relative Ages of the New Zealand Coalfields," gives an able summary of the views held by himself and the Geological Survey.‡ He discusses the correlation of the Amuri limestone and hydraulic limestone of north Auckland, and, after reviewing the evidence bearing on the stratigraphical position of the latter and its relation to the Oamaru series, arrives at the conclusion that the correlation cannot be sustained. And it seems to me he could form no other conclusion from the conflicting evidence presented to him. In the Geological Survey Report the hydraulic limestone is generally stated to overlie the Whangarei limestone, the supposed equivalent of the Oamaru stone, whereas the Amuri limestone always underlies that

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* "Geology of New Zealand," 1867, pp. 58 and 59.
horizon in North Canterbury and elsewhere. As the Amuri limestone could not both underlie and overlie the same formation, Captain Hutton naturally concluded that the hydraulic limestone had no connection with the Amuri limestone of the South Island.

In 1899 I revisited the north Auckland coalfields, and after a careful re-examination of the old sections and many new, formed the opinion that the Geological Survey was right in correlating the hydraulic limestone with the Amuri limestone, but wrong in placing the hydraulic limestone above the Whangarei limestone.

In 1874 Sir James Hector placed the "grey and chalk marls" [hydraulic limestone] of the Kaipara district at the top of the Cretaceous-tertiary series, in which he also included the underlying greensands and *Inoceramus* clays, in the following order:—

4. Grey and chalk marls.
5. Greensands and coal grits.
6. *Inoceramus* clays, &c.

Mr. Cox, in his report on the Kaipara district in 1880, also refers to the hydraulic limestone and underlying glauconitic greensands to the Cretaceous-tertiary period.† He discusses the stratigraphical position of the hydraulic limestone, and, when speaking of the large boulders incrustcd with cone-in-cone limestone at Batley, says, on page 21, "If these cone-in-cone beds are interstratified with the chalk marls and hydraulic limestones, as they appear to be, it would give a certain amount of evidence in favour of the whole series being older than I have considered it"—that is, than Cretaceous-tertiary. On page 19 he gives a section near Captain Colbeck's, at Pahi, in which the Whangarei limestone and what he calls "Miocene greensands" are shown lying unconformably on the hydraulic limestone.

Mr. McKay, in 1889, in his report "On the Geology of the Coal-bearing Area between Whangarei and Hokianga,"‡ places the Amuri [hydraulic] limestone and chalk marls below the Otorara and Weka Pass stone [Oamaru stone], and it is noteworthy that, while Mr. Cox shows the Whangarei limestone at Colbeck's resting in a narrow gutter excavated in the hydraulic limestone, Mr. McKay states that the hydraulic limestone is underlain conformably by the Whangarei limestone (page 115), which obviously, according to this view, could not be the equivalent of the Oamaru stone.

In his report on Waitemata and Rodney Counties § in the

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† Reps. Geol. Expl., 1879-80, p. 18.
§ Loc. cit., p. 106.
same year Mr. McKay shows that the upper Waitemata beds rest unconformably on the hydraulic limestone at Mahurangi, in this agreeing with the opinion expressed by Mr. Cox in 1880 (Geol. Reps., 1879–80, p. 29). At the end of his report Mr. McKay gives a tabulated statement of the strata passed through in four boreholes put down in that year by the Kawakawa Coal-mining Company in the search for coal, according to which borehole No. 2 is supposed to have passed through 234 ft. 2 in. of what is termed "Amuri limestone, chalk marls, and chalk with flints, VI.d."

In my report on the Kaipara district in 1885 I included the hydraulic limestone in the Cretaceo-tertiary series, and placed it above the Pahi greensands, from which I made a large collection of marine shells having a facies closely resembling the fauna of the Waihao greensands in South Canterbury.* On this occasion I distinguished two horizons of greensand—namely, coal greensands, containing the Tertiary fauna just referred to, and glauconitic greensands (page 169), which I said appeared to occur at the base of the Cretaceo-tertiary series, and were interbedded with a cone-in-cone limestone and a calcareous sandstone, in which I found remains of *Inoceramus*. In this report I described how the Komiti beds (Mount Brown series) lay unconformably on the chalky marls and hydraulic limestone.

In my report on the Kaipara district in 1887† I again described the hydraulic limestone as overlying the coal greensands, but underlying the Whangarei limestone; but when discussing the relations of the hydraulic limestone to the associated beds I stated that "the relation of the hydraulic limestone and underlying marly greensands is not so satisfactory as might be desired" (p. 229).

Mr. McKay, in 1888, examined the Pahi and Paparoa sections, and, while agreeing with me that the hydraulic limestone overlies the coal, continues as follows: "Mr. Park believes that in the sections at Paparoa and Pahi there is an unconformity between the beds with *Inoceramus* and the white clays under the Whangarei limestone, . . . but I must say I could not convince myself of the existence of such unconformity."‡

Mr. McKay still places the hydraulic limestone above the Whangarei limestone,§ but is apparently doubtful of this, as on page 54 he says, "The lower beds, supposed" [by the author] "to be unconformable, are well developed between

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§ Loc. cit., p. 43.
Maungaturoto and Colbeck's estate, and appear in that direction perfectly conformable to the hydraulic limestone; and all over the west of the Bay of Islands County and in the Hokianga district I judged the relations of the hydraulic limestone to the *Inoceramus* beds to be a relationship showing the stratigraphical conformity of the higher and lower beds mentioned."

Mr. McKay, in 1890, in his report "On the Prospects of Coal at Pakaraka, Bay of Islands, Auckland," again affirms his belief that the hydraulic limestone overlies the Whangarei limestone. Speaking of the section at Ngahikunga, he says, "The limestone" [Whangarei] "is overlain by the firestone and hydraulic limestone division of the Cretaceo-tertiary series."*

In the same year Mr. McKay, reporting on the geology of the district around Whangaroa Harbour, states that in the north branch of the Kaeo River the hydraulic limestone forms "the highest member of the " [Cretaceo-tertiary] "series,"† and is, he continues, overlain, apparently conformably, by the Kaeo greensands, that had always been regarded by the Geological Survey as the equivalent of the Kawakawa greensands forming the roof of the coal. As the hydraulic limestone was still supposed to overlie the coal greensands, the Kaeo greensands, since they followed the hydraulic limestone, were now correlated with a horizon in harmony with that theory.

In 1892 Sir James Hector illustrates his Progress Report with vertical sections of the boreholes put down by the Kawakawa Coal Company in 1883, and shows, as did Mr. McKay, the "Amuri limestone, chalk, chalk with flints, VI.d," overlying the Whangarei limestone.‡

Mr. McKay, in his report "On the Hikurangi Coalfield" in 1892, shows the hydraulic limestone as the closing member of the Cretaceo-tertiary series, and, as in former reports, it is shown overlying the Whangarei limestone conformably §

The succession of beds on the south side of Parengarenga Harbour, in the North Cape district, is stated by Mr. McKay to be, in descending order — hydraulic limestone, firestones interbedded with greensand, shales and sandstone with calcareous concretions, often covered with a layer of cone-in-cone limestone, and containing fragments of *Inoceramus* ||. This section, it will be seen, is almost identical with that at Batley, on the Kaipara.

Sir James Hector, in his Progress Report for 1903,

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† Loc. cit., pp. 65 and 69.
‡ Reps. Geol. Expl., 1892–93, p. xii.
§ Loc. cit., p. 87.
|| Loc. cit., p. 86.
page xiii., commenting on Mr. McKay's work in the North Cape district, uses the following significant words. He says, "No fossils have yet been found in this stratum" [hydraulic limestones] "where it overlies the formations next to be mentioned" [i.e., Whangarei limestone and coal greensands] "in the Kawakawa Basin by which their age can be decided. They" [hydraulic limestones] "have been referred to the horizon of the Amuri limestone. If they are the same limestone as that mentioned by Mr. McKay as occurring at the sources of the Waitangi and Kaeo Rivers, and which is associated stratigraphically with sandstones and shale containing Ammonites and Inoceramus, this identification would be justified. Unfortunately, wherever these forms are found the downward sequence does not develop the greensands with coal as at Kawakawa. On the contrary, greensands decomposing to rusty sands, and containing such forms as characterize the cover of the coal at Kawakawa and Hikurangi, and also on the west coast of the South Island, are reported by Mr. McKay to rest on the hydraulic limestone of the Kaeo locality."

Reviewing the foregoing, we find that Sir James Hector, Mr. Cox, and Mr. McKay have always maintained (a) that the hydraulic limestone overlies the Whangarei limestone which was acknowledged to overlie the coal-measures of Kawakawa and Hikurangi; (b) that the hydraulic limestone was the equivalent of the Amuri limestone in the South Island; and (c) that the Pahi and Kawakawa coal greensands containing a Tertiary fauna were the equivalent of the greensands with Inoceramus underlying the hydraulic limestone.

The Amuri limestone is held by the Geological Survey to underlie the Oamaru (Weka Pass) stone conformably; therefore with the hydraulic limestone above the Whangarei limestone, and its equivalent the Amuri limestone below the Oamaru stone, it was found impossible to correlate the Whangarei limestone with the Oamaru stone.

The views expressed by myself were (a) that the hydraulic limestone underlaid the Whangarei limestone, (b) that the latter was the equivalent of the Oamaru stone, (c) that the hydraulic limestone was the equivalent of the Amuri limestone, and (d) that the hydraulic limestone overlaid the coal greensands.

It should be noted, however, that every one, myself included, expressed some doubt as to the true relations of the hydraulic limestone; and it may be mentioned that the many discordant views on this important question were principally due to the obscurity of the sections, caused by the disturbed condition of the strata and the difficulty of obtaining a continuous or complete succession of the beds on account of the
land being deeply intersected by numerous tidal rivers and
ramifying arms of the sea.

The evidence of the Kawakawa boreholes, supplied by
Mr. McKay, seemed perfectly conclusive that the hydraulic-
limestone was superior to the coal-measures; but I found, on
making inquiries from Mr. T. P. Moody, under whose super-
vision the boreholes were put down, that no hydraulic lime-
stone was actually cut in the boreholes. The beds in No. 2
borehole, referred by Mr. McKay to the Amuri-limestone
group of the Cretaceo-tertiary, were as follows:—

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<tr>
<td>Blue clay</td>
<td>80 0</td>
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<tr>
<td>Chocolate-coloured clay</td>
<td>10 0</td>
</tr>
<tr>
<td>Soft clays, no core</td>
<td>194 2</td>
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<td></td>
<td>234 2</td>
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It is obvious from the above that Mr. McKay did not base
his opinion regarding the superior position of the hydraulic
limestone upon the identification of that rock in the material
cut in the borehole, but correlated the above clays with the
Amuri limestone, apparently because these clays occupied
the position relatively to the Whangarei limestone which
the hydraulic limestone was supposed to occupy. *

After an exhaustive inquiry in 1899 as to the position of
the hydraulic limestone, I found (a) that the hydraulic lime-
estone is conformable to the glauconitic greensands and cone-
in-cone beds at Batley and elsewhere, and belongs to the same
stratigraphical system; (b) that the Geological Survey was
right in correlating the hydraulic limestone with the Amuri
limestone, but (c) was wrong in placing the hydraulic lime-
estone above the Whangarei limestone; (d) that I was right in
correlating the Whangarei limestone with the Oamaru stone;
(e) that I was right in placing the hydraulic limestone below
the Whangarei limestone, (f) but wrong in identifying the
white clays interstratified with shelly limestone in the Pahi
section with the hydraulic limestone; (g) that the greens-
sands at Pahi containing a Tertiary fauna occur at the base
of the Lower Tertiary series, and are probably the equivalent
of the greensands forming the roof of the coal at Kawakawa
and Hikurangi; and (h) that the Komiti beds, referred by
me doubtfully to the Pareora series, probably form the lowest
horizon of the Lower Tertiary series—or, in other words, that
the Komiti beds form the lower beds of the Pahi greensand
series.

The stratigraphical connection of the hydraulic limestone
to the Inoceramus greensands was practically admitted by

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* Reps. Geol. Expl., 1888–84, p. 188.
Mr. McKay in 1887 when he wrote, "And all over the west of the Bay of Islands County and in the Hokitika district I judged the relations of the hydraulic limestone to the Inoceramus beds to be a relationship showing the stratigraphical conformity of the higher and lower beds mentioned."

The succession of formations determined by me in 1899 was as follows, in descending order:

Miocene: Komiti beds, Pareora series (?)
(a.) Foraminiferal limestone.
(b.) Volcanic tuffs, with lignite.
(c.) Volcanic breccias.
(d.) Ferruginous sandstones.
(e.) Crassatella beds.
(f.) Sandy clays, with Pecten zittelli.

Oligocene: Oamaru series
(a.) Whangarei limestones.
(b.) Calcareous sandstones.
(c.) Marly greensands, with Tertiary marine fauna.
(d.) Coal-seams and fireclay.
(e.) Grits and conglomerates.

Cretaceous: Waipara series
(a.) Grey chalky claystones.
(b.) Hydraulic limestone.
(c.) Glauconitic greensands.
(d.) Calcareous flaky sandstone and shaly clays, with *Septaria* often incrusted with a layer of cone-in-cone limestone.

Trias:
Slaty shales and sandstones forming basement rock of country.

It is not a little singular that in places outside the North Auckland district the stratigraphical connection of the hydraulic limestone and *Inoceramus* shaly clays with cone-in-cone limestone has never been called in question.

In his first report on East Cape district† Mr. McKay considers them conformable; and in his reports "On the Country between Cape Kidnappers and Cape Turnagain,"‡ and "On the Southern Part of the East Wairarapa District,"§ they are shown to belong to the same series, and are placed in the younger Secondary period.

A re-examination of the country north of Napier in 1896 did not lead Mr. McKay to change his opinion on this.

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‡ Reps. Geol. Expl., 1874–76, p. 44, and see sections on sheet facing page 50.
question.* And, further, when discussing the geology of Waiapu Valley he refers to the rocks representing the Amuri limestone as belonging to the "Cretaceous" period.†

In December of 1874 I made a collection of Tertiary marine shells from certain sandy clays in the lower part of the Maungapakeha Valley. These clays rested unconformably on soft shaly claystones containing fragments of a fibrous shell which, I have no doubt, belonged to the genus *Inoceramus*. On a subsequent visit to this district I found that the *Inoceramus* beds were associated with grey chalky clays, which are now known throughout the North Island as hydraulic limestone.

In 1888, in my report "On the Probable Discovery of Oil and Coal in Wairarapa North County," † after speaking of the occurrence of hydraulic limestone on Ika Farm, I state that "this limestone is associated with the younger members of the Upper Secondary rocks"; and in the argillaceous members of these rocks I found that fragments of *Inoceramus* were not uncommon.

In the South Island the conformable relations of the Amuri limestone to the underlying Secondary beds have been acknowledged by every one, but different opinions are entertained by the Geological Survey and Captain Hutton as to the interpretation of the sections at Waipara and Weka Pass.

The chief point of contention is concerning the relations of the Weka Pass stone (Oamaru stone) to the Amuri limestone.

In South Canterbury and North Otago the Oamaru series consists of the following members in descending order:—

(a.) Oamaru stone.
(b.) Marly and sandy clays.
(c.) Marly greensands, often with calcareous concretions.
(d.) Quartz grits, fireclays, and coal.

At Waipara and Weka Pass the Weka Pass stone, which has always been acknowledged to be the equivalent of the Oamaru stone, rests directly upon the Amuri limestone. The Weka Pass stone forms a sloping plane deeply dissected by streams, and in following round the contours of the valleys is always found resting on a level or nearly level surface of Amuri limestone, thereby presenting at many places the appearance of complete stratigraphical conformity.

Since 1873 Captain Hutton has consistently maintained

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† Loc. cit., p. 218.
that the Weka Pass stone was unconformable to the Amuri limestone and its associated saurian beds.*

After his first examination of Weka Pass district, in 1867, Sir James Hector referred the Amuri limestone and saurian greensands to the younger Secondary period,† but since about 1872 he has referred the Weka Pass stone, and all the beds below it down to the base of the Waipara saurian series, to the Cretaceous-tertiary series.

Thus, according to the Geological Survey the Weka Pass stone in North Canterbury is underlain conformably by beds containing a purely Secondary fauna, and in South Canterbury by beds containing only a Tertiary fauna. Placed side by side the sequence at each place is as follows:—

CRETACEOUS-TERTIARY SERIES OF GEOLOGICAL SURVEY.

<table>
<thead>
<tr>
<th>North Canterbury.</th>
<th>South Canterbury.†</th>
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<tr>
<td>(a.) Oamaru (Weka Pass) stone.</td>
<td>(a.) Oamaru stone.</td>
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<tr>
<td>(b.) Amuri limestone.</td>
<td>(b.) Marly, sandy clays.</td>
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<tr>
<td>(c.) Greensands, &amp;c., with saurians.</td>
<td>(c.) Marly greensands, with Tertiary fauns.</td>
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<tr>
<td>(d.) Quartz grits and lignite.</td>
<td>(d.) Quartz grits and coal.</td>
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The apparent stratigraphical continuity of the sequence at Weka Pass and Waipara has been a puzzle and stumbling-block to all geologists who have examined these places, excepting, perhaps, Captain Hutton. It is well known, however, that in many sections in the south-east of England Eocene beds appear to rest conformably on the chalk— that is, the bedding-planes of the younger beds are conformable to the surface of the chalk, which in many places presents an even or gently undulating plane.

The palæontological evidence of unconformity at Waipara between the Weka Pass stone and the Amuri series is conclusive, and I am of the opinion that the absence of the usual Tertiary members below the Weka Pass stone is due to differential movements of the land as between North and South Canterbury after the close of the Cretaceous period. The Geological Survey, still adhering to the belief that the Oamaru series contains in some places a Tertiary fauna and in others a Secondary fauna, includes all the valuable coalfields of New Zealand in one formation—namely, the Cretaceous-tertiary series.

Up till the beginning of the present year I had not examined the Shag Point coalfield, and, in deference to the opinion of the Geological Survey, had always referred the

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† Reps. Geol. Expl., 1868-69, pp. xi. and xii.
‡ As at Kakahu and Waiho, or Ngapara, in North Otago.
coalfields of New Zealand to one geological period.* Early in this year I examined Shag Valley, Horse Range, and Shag Point coalfield, and found that the Oamaru series rested unconformably on the Shag Point coal series of Cretaceous age in the manner shown first by Sir James Hector in his large geological section of Otago, prepared in November, 1864, and now in possession of the Otago University School of Mines; and afterwards by Captain Hutton, in 1875.†

The late Sir Julius von Haast also identified the unconformity between the Oamaru series and the Secondary coal-measures, but he fell into an error in placing the unconformity below, instead of above, the Moeraki *Septaria* beds †

The geology of Shag Valley disproves the Cretaceous-tertiary theory of the Geological Survey in the most convincing manner. Here the Tertiary coal-measures of the Oamaru series and Secondary measures of the Waipara series exist side by side, the younger abutting against the older with a degree of unconformity not often seen among the younger stratified formations in New Zealand.

The Tertiary coal-measures in the Shag Valley consist of the following members, as shown by various prospecting-works and outcrops:—

Oamaru series—

(a.) Oamaru stone.
(b.) Blue sandy clays (foraminiferous).
(c.) Marly greensands, with Tertiary fauna.
(d.) Quartz grits and conglomerates, with coal (South Palmerston coalfield).

The greatest thickness of this series obtained in the Shag Valley was 780 ft.

The succession of the Secondary coal-measures at Shag Point is as follows:—

Waipara series—

(a.) Shaly clays and sandstones, with septarian boulders incrusted with cone-in-cone limestone and containing saurian remains.
(b.) Greensands (glaucnitic).
(c.) Ferruginous sandstones, grits, and conglomerates, with younger Secondary fossils.
(d.) Quartz grits, with coal-seams (Shag Point coalfield).
(e.) Horse Range conglomerates.

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† Hutton, "Geology of Otago," 1875, p. 44.
In the line of section from Shag Point Coal-mine across Puke-iwi-tahi the thickness of the series is about 2,200 ft., of which the Horse Range conglomerates comprise probably about 1,500 ft.

In his paper "On the Relative Ages of New Zealand Coalfields" Captain Hutton states that in his opinion the coalfields of the colony may be grouped according to their age into four series, as follows:—*

4. **Pareora series**, including coalfields of (a) Mokau, (b) Waihao, (c) Waitaki, (d) Pomahaka, (e) Dunstan(?).

3. **Oamaru series**, including coalfields of (a) Bay of Islands, (b) Whangarei, (c) Drury and Lower Waikato, (d) Nelson and Motupipi, (e) Kakahu, (f) Green Island and Saddle Hill, (g) Tokomairiro and Kaitangata, (h) Nightcaps, (i) Orepuki.

2. **Waipara series**, including coalfields of (a) Malvern Hills, (b) Mount Somers, (c) Shag Point, (d) Mount Hamilton.

1. **Amuri series**, including coalfields of (a) Pakawau, (b) Wangapeka, (c) Westport, (d) Greymouth, (e) Reefton.

Captain Hutton considers that the Mokau coalfield belongs to the Pareora series. But is it so? On the other hand, he places the Lower Waikato coals in the Oamaru series. I am satisfied that whatever is the age of the Waikato coals is also the age of the Mokau coal.

Near Huntly and Taupiri the coal passes below marly greensands containing a marine fauna that seems the same as that overlying the coal at the Bay of Islands and Hikurangi. The greensands are followed by sandy clays, generally foraminiferous, and these are in turn overlain by calcareous sandstones, which pass insensibly into a hard limestone towards the south and west. The limestone contains *Scalaria lyrata*, a *Lima, Pecten hochstetteri*, and *Meona crawfords*, which are characteristic of the Oamaru stone elsewhere. In 1885 I traced it from the Waikato River at Taupiri westward to Raglan and southward to Waipa, Kawhia, Te Kuiti, Upper and Lower Mokau. In the Raglan district it is a yellowish-brown sandy limestone resembling the Weka Pass and Otoraro stone, but proceeding south it passes into a hard shelly limestone. It should be noted, however, that the stratigraphical succession of the underlying beds down to the coal at the base of the series is everywhere remarkably uniform.

This series, which I now refer to the Oamaru series, is everywhere in this region, as follows:—

Transactions.—Geology.

(a.) Limestone (＝Oamaru stone).
(b.) Sandy and marly clays (foraminiferous).
(c.) Marly greensands (fossiliferous).
(d.) Grits, conglomerates, and coal.

Captain Hutton also includes the Waihao and Waitaki coals in the Pareora series, and this at once raises the question, Is there a Pareora series in South Canterbury or Otago? On this point there seems to be no very definite information.

Sir Julius von Haast, in his "Geology of Canterbury and Westland," 1875, page 319, like Captain Hutton, includes the Waihao and Waitaki fossiliferous beds in the Pareora series.

In 1880 Mr. McKay and the author made a collection of fossils from certain sands and sandy clays at Mount Harris, Waihao, including most of the forms which were at that time believed to be characteristic of the Pareora series, such as 

* Cucullaea australa, Dentalium solidum, Dentalium giganteum, Natica solida, Turritella gigantea. Dosinia sub-rosea, Pectunculus laticostatus, and Limopsis zelandica.

At Elephant Hill these supposed Pareora beds rest on marly greensands, and, as these marly greensands form the cover of the coal, Mr. McKay placed an unconformity between them and the supposed Pareoras—that is, he placed the marly greensands below the Waihao (Oamaru) limestone and the supposed Pareoras above.* But this course was apparently followed to conform to a theoretical view, since the supposed Pareora beds wherever they occur in this district, or even in North Otago, are always found resting on the coal greensands, and never, so far as my recent investigations go, on the Waihao or Oamaru limestone.

I agree with Mr. McKay in placing the marly greensands below the Waihao limestone, but I am of the opinion that the supposed Pareora sands and sandy clays are conformable to and form the upper horizon of the greensands, and that both underlie the Waihao limestone.

In March of this year Mr. A. Hamilton and the author made a collection of fossils at Wharekuri, in the Waitaki Valley, from certain sands and sandy clays which contained most of the forms supposed to be typical of the Pareora series, besides many corals, including some fine examples of Trochocyathus mantelli. It was from these beds that Mr. McKay, in 1880 and 1881, collected the remains of Kekenodon onomata, Hector.

The sandy beds lay conformably on marly greensands, from which we collected a large and beautifully preserved example of Aturia zicz. The greensands, as pointed out by Mr.

McKay, pass downwards into greysands and quartz grits and conglomerates, which in turn rest on the basement rocks.*

The sandy Kekenōdon beds and underlying greensands, &c., therefore form the base of the Tertiary beds in the old Waitaki Fiord, and, proceeding westward, they pass under a yellowish-brown limestone, which Mr. McKay calls the Otekaike limestone.

I think that there can be no doubt that this limestone is the horizontal equivalent of the Ngapara (Oamaru) limestone. But, without laying any stress upon the exact correlation of the limestones, we have in the Wharekuri Basin a section of the Oamaru series exactly parallel with that at Waihao River; and there is little to wonder at in this parallelism if these beds, as seems to me likely, were deposited on the floor of the same continuous sea.

The position of the sandy beds at Wharekuri, containing, as we find, most, if not all, of the forms hitherto supposed to be typical of the Pareora series, at once raises a question as to the relations of the Awamoa and other supposed Pareoras in North Otago to the Oamaru stone. But, quite apart from the position of the Pareora beds in South Canterbury and North Otago, I am agreed with Mr. McKay that the coal at Waihao, Waitaki, and west of Oamaru occurs below the Oamaru stone.

In 1866 Sir James Hector distinguished two coal-bearing formations on the west coast of the South Island, an upper or pitch-coal series, and a lower or bituminous-coal series. This subdivision has been pretty generally acknowledged by every one from that time up to the present date, but diverse opinions have been expressed as to the relations of the two series.

The coalfields of New Zealand, in my opinion, may be grouped according to their age into two divisions, as follows:—

**Oamaru series—**

(a.) Kawakawa, Bay of Islands.
(b.) Hikurangi, Whangarei.
(c.) Ngunguru, north of Whangarei.
(d.) Taupiri and Huntly, Lower Waikato.
(e.) Waipa-Hikurangi, Upper Waikato.
(f.) King-country and Upper Wanganui.
(g.) Mokau, Upper and Lower.
(h.) West Wanganui, Collingwood.
(i.) Inangahua, Buller County.
(j.) Kakahu, South Canterbury.
(k.) Waihao, South Canterbury.
(l.) Waitaki, North Otago.

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(m.) Ngapara, North Otago.
(n.) Waikouaiti, North Otago.
(o.) Saddle Hill and Green Island, near Dunedin.
(p.) Kaitangata, South Otago.
(q.) Forest Hill, Winton, Southland.

Waipara series—
(a.) Pakawau, Collingwood.
(b.) Mokihinui, West Coast.
(c.) Westport, West Coast.
(d.) Greymouth, West Coast.
(e.) Malvern Hills, Canterbury.
(f.) Shag Point, North Otago.

[Note.—Since this paper was written the author has obtained evidence in North Otago and South Canterbury which confirms his conclusion that the Pareora beds underlie the Oamaru stone, and therefore belong to the Oamaru series.]


By Professor James Park, F.G.S., Director Otago University School of Mines.

[Read before the Otago Institute, 13th October, 1903.]

Plates XXXII.

The hill forming Waikouaiti North Head, locally known as Mount Cronin, is terminated on its south side—that is, on the side facing the inlet—by a sharply defined escarpment of great height. At the foot of this escarpment there is an immense talus which descends by a series of steep wave-like undulations towards the sea, and terminates against the shoreline in a sea-wall of irregular height, broken at intervals by breaches over which it is possible to gain the rolling surface of the talus downs above.

The talus is principally composed of large and small masses of sandstone that have slipped down from the cliffs above. It seems to owe its origin to a series of landslips in places so extensive that masses of rocks many hundreds of square yards in superficial area have settled down in such a manner as to retain their original position relatively to the horizon.

The fallen masses of sandstone forming the cliffs at the end of the sandy beach are so disposed that the original planes of deposition are nearly horizontal, thereby giving the impression, at first examination, that they are in situ, a decep-