

III.—GEOLOGY.

ART. XLIV.—*On the Relative Ages of the New Zealand Coalfields.*

By Professor F. W. HUTTON.

[*Read before the Philosophical Institute of Canterbury, 3rd October, 1889.*]

IN the Hokonui Hills, Southland, in the country between the mouths of the Mataura and Clutha Rivers, and on the west coast of the North Island south of Port Waikato, thin seams of coal are found which are acknowledged to be of Jurassic age. Also, there are at Lovell's Flat, in Otago; round the Manukau Harbour, near Auckland; at the north head of the Kaipara, and in many other places, beds of lignite in which vegetable structure is often recognizable by the naked eye; and these are allowed to be Pliocene or later. Between these dates lie all the valuable coalfields of New Zealand, and the question whether they do or do not belong to a single geological period is one which has been discussed for a quarter of a century without leading to a general agreement. The Geological Survey holds that all these coalfields belong to its Cretaceo-tertiary period; while the late Dr. von Hochstetter,* Sir Julius von Haast,† and myself have maintained the opinion that there are two or more coal-formations in New Zealand. The discovery of Lower Cretaceo-tertiary fossils in the northern part of the colony, and the reports of Messrs. Park and McKay on the localities, have added a new interest to the question; and Mr. McKay has lately given an able and very fair summary of the views held by the Geological Survey Department. He is, however, in my opinion, mistaken in identifying the hydraulic limestone of the north with the Amuri limestone of the south; and, if this be so, his argument for the equivalence of the northern and southern coalfields altogether breaks down. Before giving my reasons for this opinion I wish, as the subject is one of great economic importance and likely

* "Geology of New Zealand," 1867, pp. 58 and 59.

† "On the Character and Age of the New Zealand Coalfields," Rep. Brit. Association, 1886, p. 643.

to interest persons who are not professional geologists—I wish to make a few remarks on the nature of the evidence by which geologists correlate different strata and ascertain their relative ages.

This evidence is of three kinds—(1) stratigraphical, (2) palæontological, and (3) lithological. Stratigraphical evidence, when complete—that is, when one stratum is seen actually to overlie another without any possibility of this being due to inversion or overthrust—is absolutely decisive as to the relative ages of two sedimentary rocks. Unfortunately, complete evidence can rarely be got. Usually the geologist has to infer the relative positions of two rocks by putting together two or more disconnected sections. This lets in the possibility of an unobserved discordance—that is, a fault or an unconformity—occurring between the sections, and so reduces immensely the weight of evidence. Stratigraphical evidence, to be conclusive, usually requires that a considerable area of country should be mapped in great detail; and this, again, requires a more minutely-accurate topographical map than exists for any part of New Zealand. Until we have geological maps equal to those of the British Islands we must generally receive with caution, and treat as probable, the results arrived at by stratigraphical evidence alone.

With palæontological evidence it is quite different, for here good maps are not necessary, and the fact of two localities being disconnected is of little importance, provided they are both within the same biological province. But palæontology has its difficulties. First, we have the danger of mixing together fossils from different horizons although collected close together; secondly, mistakes may occur from labels having got displaced or mixed, or perhaps forgotten altogether. In these cases the attempt to identify the localities by memory has often led to mistakes. Thirdly, there is the difficulty of correctly identifying species. All these are real difficulties which may prevent accurate results being attained. Still, it has turned out over and over again that when stratigraphy and palæontology have been at variance the mistake has been in the stratigraphy; and this is a clear proof that, on the whole, palæontological evidence is the more reliable. After long and detailed study of the geology of Europe and North America by many geologists, the only case where stratigraphy and palæontology are still opposed is the so-called Colonies of Barrande, in Bohemia; and even here it is thought by many geologists that the stratigraphy is in error.

Lithological evidence is of two kinds—(1) included fragments, and (2) mineral composition. Included fragments of another rock are invaluable for proving relative age when the fragments can be recognized with certainty. Mineral compo-

sition is occasionally very useful in the case of rocks of exceptional composition, such as red sandstones with gypsum; but even here it can only be applied with caution, and in restricted areas. It is a test which decreases in value as the formations compared increase in distance; and when the localities are more than fifty miles apart this kind of evidence is usually of very little weight, especially with the younger rocks, which are rarely widely spread. We know that very dissimilar rocks are now forming round our coasts; we know that one kind of rock can often be traced horizontally into another of quite different mineralogical composition; and we also know that rocks of similar mineral composition have been formed at very different periods of time: consequently lithological evidence has always given way to palæontological evidence whenever they have been opposed—as, for example, with the Old and New Red Sandstones of Britain, which were at first considered as one from similar mineralogical composition, but proved by fossils to be separated by the whole of the Carboniferous period, this palæontological evidence being subsequently confirmed by stratigraphy. In the absence of all other evidence mineral composition is our only guide, untrustworthy though it be; and in the Highlands of Scotland it has defeated the first efforts of stratigraphy. This, however, was with Archæan and Palæozoic rocks, and even here it was palæontology that really overthrew the old stratigraphy.

Bearing in mind, then, the relative values of these three kinds of evidence, we come now to the consideration of the case of the New Zealand coalfields drawn up by Mr. McKay, which will be found on page 55 of the “Reports of Geological Explorations” for 1887–88. Mr. McKay says “that the difficulty is mainly a palæontological one, and that if it were not for the seemingly contradictory evidence afforded by the fossil-collections from different localities, it does not seem that most geologists would doubt the propriety of grouping the coal-bearing beds at various places as the same or equivalent developments of one formation, or of including as part of the same sequence the fossiliferous marine strata that in most cases overlie the coal-bearing beds.” Now, I can quite agree with Mr. McKay that *if* the same fauna had been found over the coal at the different localities there would be no great difficulty in considering the coals as all belonging to one formation; but I differ from Mr. McKay in thinking that, as the faunas differ at different localities, there is no difficulty at all in considering them as belonging to more than one formation. I will state the case thus:—

It is a fact admitted by all that the fossils found in the beds immediately over the coal at Waipara, Malvern Hills, and Shag Point (which I will call the Waipara fauna) are

different from those found in the beds which overlie the coal in south-eastern Otago, Whangarei, and Kawakawa (these I will call the Oamaru fauna). The Waipara fauna has not yet been described and catalogued, but it includes *Plesiosaurus* and other marine saurians, *Ammonites*, *Belemnites*, *Inoceramus*, and an extinct genus of gastropods called *Conchothyra*. There are no living species of Mollusca. The flora has been described by Baron von Ettingshausen, who considers it to be Tertiary. We thus have here a parallel to the Laramie fauna and flora of North America; but our fauna is more closely related to that of the Fox Hills Group, below the Laramie. The Oamaru fauna contains remains of cetaceans, penguins, and turtles, as well as a number of other fossils, which have been catalogued in the "Quar. Jour. Geol. Soc. of London," vol. xli., p. 554; and in the "Proc. Lin. Soc. N.S. Wales," 2nd series, vol. i., page 205. Among them are a few living species, but no extinct genera, of Mollusca. It is acknowledged to be a Tertiary fauna, and, according to Professor Tate, represents the Eocene fauna of Australia ("Jour. R.S. of N.S. Wales," vol. xxii., p. 245). In the Waipara district these two faunas are in superposition, and the Oamaru fauna lies above the Waipara fauna, the two being separated by the Amuri limestone, which contains few fossils, none of them very characteristic.

North of Auckland there is a limestone, called the hydraulic limestone, which lies over the Oamaru fauna at Whangarei and Kawakawa, as well as at Pahi and Paparoa in the northern Kaipara district; but in the upper Waitangi valley, near Hokianga, and at Batley in the Kaipara, this limestone lies directly over the Waipara fauna. It is allowed that the hydraulic limestone always overlies the Oamaru fauna conformably, but Mr. Park states that it is unconformable to the series of beds containing the Waipara fauna at Paparoa, Pahi, &c., for the very good reason that "at different places it is found lying on various members of that series" ("Rep. Geol. Exp.," 1886-87, p. 229). Mr. McKay says that he could not convince himself of this unconformity; but he attempts no disproof of Mr. Park's statement, and in the last paragraph of his report he seems to admit that an unconformity is quite possible. Sir James Hector, who discovered these beds at Pahi, considered them to be of Jurassic age, and Mr. Cox informs me that he is of the same opinion, and this of course implies that they are unconformable to the overlying beds.

Now, the officers of the Geological Survey identify this hydraulic limestone with the Amuri limestone of the Waipara, and if this correlation is correct it follows that the Amuri limestone overlies the Waipara fauna at the Waipara and at Waitangi, while it also overlies the Oamaru fauna at Wha-

ngarei, Pahi, &c.; and in this way it is sought to show that the two faunas are of the same age. But what is the evidence for this correlation? Mr. McKay says, "The Amuri (hydraulic) limestone as seen at Limestone Island, Whangarei, is, to say the least of it, remarkably like the Amuri limestone at Amuri Bluff, and the few fossils that have been found in that rock at Whangarei, so far as they go, prove the identity of the two." So that the correlation rests upon the lithological resemblance of two argillaceous limestones more than three hundred miles apart, and on a few fossils of which Mr. McKay gives no list. Many of the fossils reported years ago as coming from the Amuri limestone—including the sharks' teeth collected by Mr. H. Ingles and reported by myself—probably come from a higher level. At any rate, they are all found at higher levels; and the only fossils I know myself from the limestone are some undescribed *Foraminifera* and *Ostrea subdentata*. Mr. McKay has also added *Pecten williamsoni* and *Rhynchonella squamosa*, both of which also belong to the Oamaru fauna ("Rep. Geol. Exp.," 1886-87, p. 90). But, supposing all the identifications to be correct, and the horizon indisputable, still the evidence is not important, and by no means proves the identity of the two limestones. *O. subdentata* is the only characteristic species, and Mr. McKay does not say that he obtained this at Whangarei; and, if not, there is nothing to prevent the hydraulic limestone from belonging to the upper part of the Oamaru series. Mr. McKay does not say that the fossils from the Amuri and hydraulic limestones are not found at other horizons; but, if they are so found, then they are not exclusively characteristic of the Amuri limestone, and cannot be used for identifying it.

To make my meaning clearer, suppose the following distribution of fossils:—

The Oamaru series contains species A, B, C.
 The Amuri limestone contains species C, D, E.
 The Waipara series contains species E, F, G.

To prove an equivalent for the Amuri limestone we can only use D. A bed in another locality containing E might belong either to the Waipara series or to the Amuri limestone, a bed with C to the Oamaru series or the Amuri limestone. The last is the case with the hydraulic limestone, and, as it overlies beds containing A and B, it is with the Oamaru series and not with the Amuri limestone that we must correlate it. In fact, if all the fossils said to come from the Amuri limestone really do so they would only show that the Amuri limestone forms the base of the Oamaru series in the Waipara district, and would not prove it to be the equivalent of the hydraulic limestone. The palæontological evidence is there-

fore opposed to the view of the Survey. So also is the stratigraphical evidence; for the Amuri limestone, which underlies the Oamaru series in the Waipara, cannot overlie it at Whangarei and Pahi, as the theory of the Geological Survey implies. The same rock cannot both overlie and underlie equivalent series. A simple explanation of the facts is that the hydraulic limestone at Pahi overlaps the lower beds of the Oamaru series, and lies directly on the Waipara series at Batley; and if this is the case in the Kaipara the same explanation will probably hold in the Bay of Islands and Hokianga districts. The lithological evidence, I need hardly say, is worthless, for the rocks are so widely separated; and, as it is opposed to both the palæontological and stratigraphical evidence, it must be discarded.

Mr. Park tries to get over the difficulty by supposing that what I have called the Waipara fauna is, in the northern Kaipara district, at Pahi and Paparua, really an older fauna similar to that of the Amuri series, below the Waipara series, and that the unconformity is really between the Amuri and Waipara series. But is it so? The *Inoceramus* and other forms found at Paparua are said to be confined to the horizon of the "black grit" at Amuri Bluff, and Sir James Hector places the "black grit" at the base of the Waipara series, and not in the Amuri series ("Outlines of the Geology of New Zealand," 1886, p. 59). It is true that in 1874 Sir James placed the "black grit" at the top of his Amuri series (No. VII.), but in the new classification of 1877-78 he altered its position, and made it the lowest marine bed of his Cretaceous-tertiary series (No. VI.), where it has remained ever since (see Appendix to "Rep. Geol. Exp.," 1887-88). Again, an *Inoceramus*, also found in the "black grit," occurs in the upper Waitangi, with saurian teeth, *Belemnites*, &c., which, according to Mr. McKay, are identical with species at Amuri Bluff not more than 100ft. below the Amuri limestone, as well as at Shag Point, and these cannot well belong to the Amuri series. Besides, if the *Inoceramus* beds in the Kaipara do represent the Amuri series none of the difficulties as to the relations between the Waipara and Oamaru faunas are removed; and, as Mr. McKay points out, the real difficulty is to explain the presence of a "Tertiary-looking fauna" under the [supposed] Amuri limestone. Neither can it prove an unconformity between the Waipara and Amuri series unless the Oamaru series at Pahi can be shown to represent the Waipara series, for in an unconformity it is the upper part of the lower series, and not the lower part of the upper series, that has been removed by denudation, and the missing Waipara series would be classed with the underlying, not with the overlying rocks.

Next, as to the explanations offered by the Survey of this supposed palæontological anomaly of two distinct faunas belonging to the same period, and inhabiting the same geographical area: On this subject Sir James Hector says, "It thus appears from the foregoing that the land-surface preceding the great depression during Cretaceo-tertiary times survived to a later date in the north than in the south of New Zealand, the beds overlying the coals in the north being generally of younger Cretaceous age" (*l.c.*, p. 62). From this I infer that he considers the Oamaru series, with its coals, to be younger than the Waipara series, with its coals. So far, of course, I agree, as it is directly opposed to the idea that the hydraulic limestone is the same as the Amuri limestone, and as it supposes that where the hydraulic limestone lies directly on the Waipara series (as in the Waitangi Valley) the whole of the lower part of the Oamaru series is absent. This explanation of the Director agrees with mine; but when Sir James Hector says that both these series belong to one period I can no longer follow him. The difference between the Waipara and Oamaru faunas is probably as great as, if not greater than, the difference between the Oamaru fauna and that of the present day, and the two could hardly be kept in one formation even if it were certain that they formed an unbroken stratigraphical sequence. But if this were the case we should expect to find in the beds now upraised a gradation from one fauna into the other; for, even if we suppose the Oamaru fauna to have been suddenly introduced by immigration, still it must have mingled with the older fauna before replacing it. This is well shown in the Pareora (Miocene) fauna, the older and younger portions of which differ much; but the species are so intermingled in the middle portion that no palæontological break occurs. The acknowledged existence of a great palæontological break between the Waipara and Oamaru faunas seems to me to imply, although it does not necessitate, a stratigraphical break also, and I have elsewhere said that I think there is evidence of this. The fact of the Waipara series covering so small an area in comparison with the Oamaru series, although the former occurs far up the valleys of the Waimakariri, Waipara, and Clarence, is very suggestive of extensive denudation before the deposition of the Oamaru series, while the relative positions of the two series show that it is not a mere case of overlap. Again, it is not only the coal in the north which is covered by the younger series—the same is seen near Nelson and in Otago; and the discovery of the Waipara series at the Bay of Islands and Hokianga has made some modification of this theory necessary.

According to Mr. Park, an attempt is made to explain the

palæontological difficulty by supposing that the two faunas are of the same age, but that the Oamaru fauna represents the shallow seas, and the Waipara fauna the deep seas. But he adds, "How far this theory will meet the stratigraphical and palæontological difficulties of the case, considering that both of these beds are found to exist in the same areas, I do not propose to discuss in this report" ("Rep. Geol. Exp.," 1887-88, p. 23). With reference to this theory I may remark that if it were the true explanation the terrestrial or shallow-water coal-beds ought always to be followed by the Oamaru fauna, and this by the Waipara fauna, which is never the case. On the contrary, the coals at the Waipara are followed by the Waipara fauna, and this by the Oamaru fauna. If we reverse the case, and suppose the Oamaru fauna to be that of the deep sea, we are no better off, for it succeeds the coal at Kawakawa, Whangarei, and other places without the intervention of the supposed shallow-water Waipara fauna. Also, if the two were contemporaneous we ought surely to find them mixed somewhere. They could not have been separated by a broad belt of uninhabited sea-bottom; nor by a land-barrier, for they are both found on the same side of mountains which were in existence before the faunas. Again, as both faunas occur in glauconitic greensands, &c., we cannot suppose that there was any great difference in the depth of the seas in which they lived; and this is confirmed by the occurrence of both faunas high up in valleys denuded out of Palæozoic and old Mesozoic rocks, which, as they now form high mountains, must at the time have formed neighbouring shore-lines.

But the palæontological difficulties do not end here. At Waihao Forks, in South Canterbury, the coal is overlain by greensands, which contain a third fauna, quite distinct from the other two, and which is admitted by the officers of the Geological Survey to be closely related to the Pareora (Miocene) fauna. A list of this Waihao fauna, which I think to be identical with the Pareora fauna, will be found in the "Trans. N.Z. Inst.," vol. xix., p. 431, and more fully in "Proc. Lin. Soc. N.S. Wales," series 2, vol. i., p. 205. It includes *Aturia ziczac*, two species of *Ancillaria*, and *Pecten hochstetteri*, which is found in both the Oamaru and Pareora series. I do not know to what zone of depth the Survey relegates this fauna: but, as it is found in sandy beds, like the others, the difference can hardly be due to station; and, as it is also found over the coal in the Mokau Valley ("Rep. Geol. Exp.," 1886-87, p. 46), it cannot be due to locality. I have heard it vaguely suggested that the Pareora (Miocene) fauna is a recurrence of the more ancient Waihao (Cretaceous) fauna, similar to Barrande's Colonies, previously mentioned. This hypothesis

accounts for none of the difficulties connected with the idea of three different faunas—of Cretaceous, Eocene, and Miocene facies—belonging to the same period, but living isolated in the same geographical area; while it introduces new difficulties of its own making. For this recurrence necessitates an emigration to some unknown land and a subsequent immigration of the fauna which is very difficult to explain, more especially as the explanation must show why the other two contemporaneous faunas did not accomplish a similar feat.

Mr. Park says, "All that now remains to place the Cretaceous-tertiary on a sound basis is to prove that the characteristic fauna of the Waihao-greensands horizon occurs below the Amuri limestone, as until this is done there will always remain a doubt as to whether the Waihao and Waipara greensands represent two distinct formations" ("Rep. Geol. Exp.," 1887-88, p. 34). On this I may remark that in my opinion the Waihao fauna has already been found in the Waipara district, in the Mount Brown beds and their equivalents, which lie above the Oamaru series, and therefore far above the Amuri limestone. A list of these fossils will be found in "Trans. N.Z. Inst.," vol. xx., p. 261. It is true that the actual species recorded from the Mount Brown limestones and the Waihao greensands differ much; but in other localities all the forms are intermingled, and the great difference in the mineralogical composition of the rocks at the two localities will probably account for the difference in the species.

To sum up: the palæontological objections to the views held by the Geological Survey appear to be insurmountable and impossible to explain. Practically, the Survey gets over these difficulties by ignoring them and classing in one formation all the coals, with most of the greensands and limestones, found in the colony. Its opinion is therefore founded on mineral composition; but the stratigraphical evidence is also said to be favourable, while the palæontological evidence is supposed to be delusive. Because in many cases the coal is covered by greensands, and these by limestones, it is supposed that all must be equivalents. But this is a sequence of common occurrence in many parts of the world, and is due to the recurrence of similar conditions—that is, to subsidence causing estuarine to be followed by shallow-water, and these by deeper-water, deposits. It is therefore of hardly any weight in correlating detached series of rocks. But in our case the officers of the Survey have confounded together two different kinds of greensands with very different origins. The greensands at the Waipara (with the Waipara fauna) and those at Curiosity Shop, &c. (with the Oamaru fauna), are glauconitic greensands; but those at Waihao Forks and Hampden (with the Waihao fauna) are volcanic sands—that is, sands derived

from the denudation of volcanic rocks—and owe their green colour to part of the pyroxene having been changed into chlorite. In these cases, therefore, the beds have been correlated by mere superficial colouring, although it is opposed to the palæontological evidence, and, as I think, to the stratigraphical evidence also.

If, now, we dismiss the lithological and accept the palæontological evidence, all palæontological difficulties, of course, vanish, and it merely remains to be seen whether there are any insurmountable stratigraphical difficulties opposed to the view that the three faunas, with their coals, belong to three distinct formations. This question I have discussed in other papers,* and need not again repeat my arguments. I hold that the stratigraphical evidence either agrees with the palæontological evidence or in some places is neutral, and that it is never actually opposed to it. But stratigraphical evidence depends so much on inference that there is often room for more than one opinion, and arguments are interminable. So far as the Kaipara district is concerned, if Sir James Hector, Mr. Cox, and Mr. Park are right the stratigraphical confirms the palæontological evidence; and if Mr. McKay is right it is neutral. Conformity between two series belonging to different periods is not a great nor an unprecedented difficulty. The Cretaceous appears to be conformable to the Jurassic in many parts of England, although really unconformable. The Carboniferous is sometimes conformable, sometimes unconformable, to the Devonian in England and Wales, while in Scotland and Ireland there is an unconformity in the middle of the Devonian. The Silurian is conformable to the Ordovician in Scotland, but unconformable in Wales and Ireland. The Ordovician is conformable to the Cambrian in Wales, but unconformable in Ireland and Scotland. These examples are sufficient to show that in our case there are no great difficulties in the stratigraphical evidence. Nowhere is the Waipara fauna superposed on the Oamaru fauna. Nowhere is the Oamaru fauna actually superposed on the Waihao fauna, although Mr. McKay *infers* that such is the case at Waihao and in the Wai-reka Valley.

It seems to me, therefore, evident that the palæontological evidence can be trusted, and that we have in New Zealand at least three distinct coal-formations, characterized by different faunas. How much these faunas have in common, and, consequently, what are the differences in age between them, is another question which has yet to be determined. The correla-

* "Trans. N.Z. Inst.," vol. iii., p. 244; "Rep. Geol. Exp.," 1872-73, p. 44; "Geology of Otago," 1875, p. 50; "Quar. Jour. Geol. Soc. of London," vol. xli., pp. 207, 226, and 279; "Trans. N.Z. Inst.," vol. xvii., p. 307; vol. xix., pp. 406 and 415; vol. xx., pp. 257, 264, and 267.

tion of these three formations with their European equivalents is a third and quite distinct question, and one far more difficult to settle than either of the other two. Of these three coal-formations the coalfields of Shag Point, Whangarei, and Waihao may be taken as representatives. It still remains to ask, are the Grey and Buller coalfields the equivalents of either of them? This question is difficult to answer, because no marine fauna of any extent is as yet known to be associated with the coal-measures, an undescribed species of *Cardium*, called *C. brunneri*, and an echinoderm called *Kleimia disjuncta*, Hutton, being the only fossils known to me. The fossil flora has been examined by Baron von Ettingshausen, who pronounces it to be different from and older than that from the Waipara and Shag Point, being, he thinks, of Cretaceous age. On the other hand, the Oamaru series lies over these coal-measures, probably unconformably, without the intervention of any rocks with the Waipara fauna or flora. This is at present the only evidence available, and, although the palæontological evidence is the more important, it is not sufficient to form any decided opinion upon.

In my opinion the New Zealand coalfields may be grouped by age as follows:—

4. Coalfields belonging to the Pareora series: (a) Mokau; (b) Waihao; (c) Waitaki; (d) Pomahaka; (e) Dunstan (?).
3. Coalfields belonging to the Oamaru series: (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, Moreley Creek, and Linton; (i) Orepuki.
2. Coalfields belonging to the Waipara series: (a) Malvern Hills; (b) Mount Somers; (c) Shag Point; (d) Mount Hamilton.
1. Coalfields belonging to the Amuri series (?): (a) Pakawau; (b) Wangapeka; (c) Westport; (d) Greymouth; (e) Reefton.

ART. XLV.—Note on the Geology of the Country about Lyell.

By Professor F. W. HUTTON, F.G.S.

[Read before the Philosophical Institute of Canterbury, 6th June, 1889.]

FROM the first geological map of the Provincial District of Nelson (1864), published in the "Geology" of "The Voyage of the 'Novara,'" from observations made by the late Sir Julius von Haast, up to the last (1886), issued by the Geological Survey