1. ON GEOLOGICAL BOUNDARY-LINES.*

By HORACE B. WOODWARD, Esq., F.G.S., H.M. Geological Survey.

The steady progress of geological knowledge leads us from time to time to make important alterations in our Table of British Strata. Fresh subdivisions are occasionally made, and new observations sometimes lead to a different classification of old and recognised divisions. When we compare the tables constructed by geologists in the early part of this century with those now in use, and when we consider the reason why many subdivisions are made, and why certain boundary-lines have been fixed upon, we cannot but discern a tendency to overlook the broad classification by mineralogical or lithological characters, and to adopt as lines of demarcation those essentially of a palæontological nature. The discussion of this subject is all the more necessary when the question of geological mapping is taken into consideration.

All those acquainted with field-work, and the tracing of geological boundary-lines, must be aware that so far as the actual guides are concerned in constructing the map, palæontology plays a very insignificant part. Nor could it be otherwise, as for the proper collection of fossils they must be obtained *in situ*, while the rarity of fossils in some formations, and the paucity of sections in others, preclude any purely palæontological boundary-lines being traced satisfactorily. At the same time the value of geological maps cannot be over-estimated, furnishing, as they do, indexes to the geology of a country; and when they exhibit the chief lithological divisions, without perhaps marking continuously all the deposits of one exact period of time, little more can be expected from them.

There is no need to discuss the variability of geological formations and their included fossils: that any kind of sediment and many varieties of organic remains may be deposited and accumulated at the same time, is patent to every observer; and similarly, that the organic remains are liable to variation according to the nature of the deposit in which they were entombed, this indicating different depths of water and other sedimentary conditions. Thus, in a formation of one age, the lithological characters and fossils may vary to a considerable extent, as in the Woolwich and Reading

* It was suggested during the discussion of this Paper, that its proper title would be "The Difficulties of a Geological Surveyor."

Series. Hence the importance of adopting, as a rule, terms expressing no distinct mineral character. At the same time taking the formations themselves into account, we naturally find that the chief variations are in the shore deposits, and that these are necessarily of small extent compared to those of deeper water, which are more persistent. Further, as the character of the deposits and the depth of water equally affect the organisms existing at the time, they might be expected to coincide with the evidence of the rocks, except that great allowance must be made for the drifting and entombing of organic remains away from the spots where they flourished.

In subsiding areas, where shallow-water deposits are succeeded by those of deeper water, we may naturally expect a repetition of similar forms in deposits of different age, species migrating from one area to another, in order to obtain conditions suitable to their welfare. The identity of organic remains can never afford absolute proof of contemporaneity, whether in the minor divisions at home, or in the grand divisions abroad.

Geologists, familiar with our British rocks, may generally recognise a formation when a good exposure is shown, whether in a railway-cutting, quarry, or cliff-section, or they may determine its age by working out its relations to other rocks in the neighbourhood. But supposing a geologist to be placed without any previous knowledge of the district in a clay-pit, he might very easily be perplexed in determining whether the beds be Gault, or Kimmeridge Clay, or Oxford Clay, and here the discovery of one or more fossils might determine the question at once. In the same way he might be puzzled with certain sections of limestone, sandstone, or slate. From mere hand-specimens of rock or pebbles, it is generally hazardous to express a definite opinion, although, at the same time, many such specimens could be picked out with characters peculiar to the rock, and therefore determinable. Palæontology here would afford often a ready clue. In these cases, as in specimens obtained from well-sinkings and deep borings, both lithology and palæontology must check one another.

In identifying the age of a formation, the test of superposition or its stratigraphical relation to other deposits is, as a rule, decisive. Palæontology must spring from stratigraphy. Show a fossil or a set of fossils (not common species) to a Palæontologist, and he will probably ask whence it comes before naming a specimen.

It must not be supposed that I wish for a moment to detract from the importance of palæontology, but the main facts of palæontology in their application to the identification of strata must first be worked out from the stratigraphical succession of the rocks, before the results can be applied as a key to isolated or disconnected portions of rock. Then geology and palæontology will go hand in hand.

Although strata may be identified by stratigraphical position and by fossils, Professor H. G. Seeley has pointed out that no satisfactory classification of rocks can ever be made by fossils, and that no classification true for any large area can be made on mineral character; but he considers that strata can be identified and correlated by discovering the physical conditions which limited, determined, and changed their mineral characters, and changed the distribution of the fauna and flora of the given geographical area which they occupy.* The value of Palæontology cannot indeed be disputed, and if we cannot identify formations far separated as synchronous when the fossils are similar, as Edward Forbes first taught, we may still parallel successive faunæ as Barrande has done.†

Professor Agassiz once expressed the opinion that the rocks should be regarded merely as the tombs of the fossils, that naturalists should try to find out the animals of an epoch, and establish the limits of faunæ on zoological and not on physical principles.‡ To this Professor W. B. Rogers replied to the effect that faunæ are not unfrequently mingled in contiguous formations, that they do not hold the same precise geological level or vertical distribution at different localities, that they may even become inverted in relation to each other, offering in this and other cases evidence of emigration and re-migration in successive times; and he maintained that the precise and absolute limitation of faunæ to formations, as advocated by Professor Agassiz, if true in any case, is at best but of local and partial application, and can not be the basis of a palæontological arrangement of formations. Even according to the ordinary and much less stringent view of geological faunæ, Professor Rogers observed that only the few great divisional lines of the geological column are persistent over extensive areas, while

* "Annals and Magazine of Natural History," for December, 1867.

† See Barrande, "Observations sur les Rapports de la Stratigraphie et de la Paléontologie." Bull. Soc. Géol. de France, 2e Série, Tome xi., p. 311.

‡ "Proceedings, Boston Society of Natural History," Vol. vii., p. 241.

the numerous subordinate ones, however distinct at the typical locality, lose themselves as they are traced, to give place to other modes of subdivision.*

Our British geological formations have been generally described, and their boundaries defined from so called typical sections, and from such we gain ideas which are not unfrequently confused when the same formation is viewed in a locality removed from the original type. Thus, the terms of Greensand and Carboniferous Limestone, although true for some localities, are calculated to puzzle and foster erroneous ideas. On the other hand, the terms Crag, London Clay, Chalk, Lias, and Old Red Sandstone, are applied to formations whose chief characters, indicated in the names, are persistent over large areas, and no great fault can be found with them.†

When we come to consider some of the subdivisions, many difficulties arise. Some of these have quite a local development, and are yet sufficiently important to require separate designation. It is not always easy, nor possible, to insert them in their proper place in chronological order with the larger divisions, which, of course, they in part replace. We might say that a portion of the Great Oolite was of Fuller's Earth age, or *vice-versâ*; that the Midford Sands were sometimes of Upper Lias age, at others, of Inferior Oolite age; even that the Middle Lias was sometimes of Upper Lias age, and this because Middle Lias conditions prevailed longer in one area than in another, so as to be contemporary with Upper Lias forms of life and deposits in a distant part. The Oolitic series, as a whole, consists of sandy and clayey strata with great lenticular beds of limestone. When traced from Dorsetshire into Yorkshire it is found that three, if not four, different classifications of the rocks, based essentially upon lithological characters, must be made at different localities. It would be difficult, and I should consider it impossible, to correlate these divisions in regard to time with any great accuracy; it is sufficient to say that such and such beds are "homotaxeous."

The Greensand of the borders of Dorset and Devon may represent parts of the Upper Greensand, Gault, and even Upper Neocomian, and yet it constitutes one physically connected series, and it would neither be possible nor profitable to trace out or map the palæontological divisions that have been made in it.

* "Proceedings, Boston Society of Natural History," Vol. vii., p. 234. See also pp. 246, 273.

† See paper by J. W. Judd, F.G.S., "Geological Magazine," Vol. vii., p. 220.

The same might be said of the Speeton Clay, which consists of a series of clays attaining a thickness of over 500 feet. According to Mr. Judd's observations, the beds represent the Upper Neocomian (Lower Greensand), Middle and Lower Neocomian, Portland Beds and Kimmeridge Clay. In his opinion no portion of the series can be identified palæontologically with the Gault; and at the same time he points out the probability of there being an unconformity between the Neocomian and Jurassic portions. Of course, in mapping the beds, it would be advisable to separate the Neocomian and Jurassic strata, but it is questionable whether this or any of the palæontological divisions could be traced out with any great approximation to truth, supposing them to extend over any considerable tract of country; and should there turn out to be no real unconformity in the series, it would be far more just to map it all under the denomination of Speeton Clay; a plan which would not for a moment be calculated to set aside the great importance and interest attaching to the natural history of the beds, which has been so carefully worked out by Mr. Judd.

As an instance of a palæontological boundary-line, the junction of the Lower and Middle Lias may be mentioned. So far as the south-western counties of England are concerned, there really is no line of division at all, as the beds pass into one another without any break. The old divisions, in which the main masses of clay and limestone were separated, were much better, and certainly more important so far as a geological map is concerned.

In Buckinghamshire, Lincolnshire, and Norfolk, and probably in Sussex, the Kimmeridge and Oxford Clays come in direct sequence. Unless we imagine an unconformity—and there is no reason for this supposition—the Coral Rag and Calcareous Grit developed in Oxfordshire, Wiltshire, and Dorsetshire, are represented by portions of the Oxford and Kimmeridge Clays in the districts just mentioned. In these cases the divisional line must be made, if at all, by palæontological evidence, in which no very great approach to accuracy can be expected.

The history of the classification of the Cambrian and Silurian rocks shows how liable to change is any boundary-line fixed by the occurrence of organic remains. Professor Hughes, in discussing a paper by Dr. Hicks on the Arenig and Llandeilo groups, recently read before the Geological Society of London (Dec. 2,

1874), observed that the fossils by which the rocks were subdivided did not occur all through the several groups, but only in widely separated zones, and that between those zones, sometimes one line and sometimes another, had been taken as the arbitrary boundary, often to be shifted in consequence of the discovery of other fossiliferous bands. He is strongly of opinion that geologists should adopt Sedgwick's old classification of the Cambrian and Silurian rocks. A well-marked lithological boundary-line, as the Director of the Geological Survey of England has often remarked to me, cannot be displaced; whereas a purely palæontological boundary-line is ever liable to change.

The Trias of the south-west of England may represent the Bunter, Muschelkalk, and Keuper, and yet it is not possible to mark out these divisions to correspond with any degree of certainty with those made on the Continent, and all that can be done is to map the separate lithological divisions. My colleague, the Rev. J. H. Blake, F.G.S., when carrying on the Geological Survey in West Somerset, came to the conclusion that the Muschelkalk was there represented, and during an examination of the country with him, he pointed to the particular beds which from position and mineral character he classed with this formation. My own opinion is, that it is impossible to say by which particular bed, or set of beds, the Muschelkalk is represented, but that there is no reason to consider its absence as indicative of any break, because in Devonshire the Triassic beds exhibit no unconformabilities, and because the sedimentary conditions must have varied considerably in different areas.

Again, so far as geological mapping is concerned, it would not be possible to identify and make a map of every deposit of Gault age in England, or of Upper Lias age, or of Keuper age, or indeed, strictly speaking, of any deposit, seeing that changes in sediment and in organic remains are not likely to occur uniformly over an extended area, and it is impossible to state with precision where in time one deposit was represented by another dissimilar. In fact, our terms are mere convenient forms of expressing an idea; an observation which has been frequently made.

Our formations, then, must be taken to represent deposits of essentially similar character when looked at in a large way, and characterized by a particular assemblage of fossils. They may become attenuated in places, and there represented in part by

different formations. In the case where a formation thins out, or becomes attenuated, we must still apply its name to it without taking in part of the overlying or underlying deposit, even if palæontology seemed to warrant it; for this latter plan would tend to create endless confusion in our geological maps, and in our tables of strata. It is as hard, I might say as impossible, to determine which is a typical section, as which is a typical species or type from which slightly divergent forms are termed varieties.

It must not be supposed that I should imagine an attenuation to represent necessarily a lesser time for its formation than a greater thickness of a rock. Of course the rate of deposition of sediment in a given area may be liable to much modification, some portions for a time may even be without sediment. Nevertheless there can be no reasonable doubt that many of our geological formations are in part represented by other formations in distinct or distant areas; and yet by palæontological evidence we can seldom draw definite lines of demarcation. Our geological classification, so far as the limited tract of Britain is concerned, must be mainly constituted on lithological evidence; and our formations, as recognised and delineated on our maps, must be simply regarded as the expression of certain physical conditions which maintained over a certain area, and as belonging to a sequence which probably varied to a considerable extent in the extension and duration of its many members. By confining, as far as possible, the use of our geological terms to certain deposits—the evidence of certain physical conditions—we may obtain more uniformity, and a stability in our tables of strata, that will not be found if the divisional lines be fixed by palæontological evidence.

The more we learn of the history of our strata, and those of foreign countries, the less evidence do we see of breaks in the conformity of succession. Of course there are gaps that we can never expect to fill up in our own island. But looking at the general results of geological knowledge, as applied to the succession of strata, and finding many easy transitions in rock-character and fossils, we need not be dismayed that our boundary-lines appear indefinite, and that correlation appears less exact. The case becomes only parallel with that of the organic remains themselves, where species once held to be distinct are now found to merge one into the other by insensible gradation, and not only species but genera also. In the West of England there is a transition from the

uppermost Silurian strata through the Old Red Sandstone and Lower Carboniferous rocks into the Coal Measures—each division may readily be traced out on the ground, and yet it is impossible to point to a particular bed and say, “Here is the junction!” The strata merge one into the other as do the colours in the rainbow, and yet looked at in a large way they are distinct. It may with truth be argued that both lithological and palæontological boundary-lines would be likely to vary in different localities, but whereas the palæontological boundary-line would be always liable to change from fresh discoveries, the line drawn in reference to lithological characters would always hold good.

In conclusion, I may state that, in bringing forward this subject for discussion, I am actuated by the idea that this course will be profitable to myself, and perhaps to many other Members of the Geologists’ Association.

2. ON THE PROBABLE DEPTH OF THE GAULT SEA.

By F. G. H. PRICE, Esq., F.G.S., M.A.I., &c.

Some months ago it was suggested to me by Professor Morris that I should endeavour to discover the nature of the Mollusca, more particularly the Siphonostomes and Holostomes, of the Gault which are peculiar to restricted horizons, as by that means we should be able to ascertain under what conditions the beds were deposited. In this paper it is my desire to shew, as far as is possible, by examining the habits and habitats of existing genera, more especially those which are probably the lineal descendants of the Cretaceous forms, the nature of the Gault Mollusca. At the same time we must take it for granted that their habitats and mode of life, so to speak, were similar, if not identical, with the habitats and mode of life of recent molluscs. I have taken Mr. Gwyn Jeffrey’s “British Conchology” and Woodward’s “Manual of the Mollusca” as my text books and authorities to furnish me with the required data as to the depths and conditions of the sea in which the various genera have been met with. It may be inferred from physical as well as from biological evidence that the Gault was deposited in a sinking area, *i.e.*, in an area which sank more rapidly than the detritus accumulated, whereby the actual sea bed was deepened. We may safely conclude that most deposits