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ON THE

PHYSICAL RELATIONS

OF THE

NEW RED MARL, RHÆTIC BEDS,

AND

LOWER LIAS.

BY

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If we look upon the Rhætic beds of Europe as a whole, it is evident that they were formed under very different conditions in different areas. Thus this formation on the south side of the Alps, as described by Stoppani, contains a large and well-developed marine fauna, whereas in England, Germany, Sweden, and in other parts of the north of Europe, the strata are much less developed, and the fauna has dwindled, containing fewer forms of life, while most of them are small and some distorted in appearance.

In this paper I propose to inquire into the reason of these peculiarities with regard to the English beds, and to show their relations to the New Red Marl and the Lower Lias in a physical point of view.

I have for some years held that the New Red Marl is physically more intimately connected with the Rhætic beds, and, in some respects, even with the Lower Lias, than it is with our own New Red Sandstone. The absence of the Muschelkalk in England probably attests a break in succession in our Triassic series. I say probably, because the opinion is every day growing stronger that our

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Triassic series was deposited in inland waters, partly fresh or salt as the case may have been, whereas the continental Trias was partly, at any rate, deposited in areas connected with the sea. If, between the deposition of the New Red Sandstone and Marl in England, the area in which they occur was not for a time depressed beneath the sea, we have a sufficient reason for the absence of the Muschelkalk. There are, indeed, symptoms of a gap in time between our Bunter and Keuper strata, accompanied by slight indications of disturbance and unconformity; and, at all events, there is in places a very marked overlap of the Marl across the Bunter Sandstone series.

In England there is a perfect physical gradation between the New Red Marl and the Rhætic beds, shown by interstratifications of red, green, and grey marls which, varying in different localities, pass by degrees into limestones, sandstones, and black shales. It is therefore impossible to determine precisely where the Rhætic beds commence in this series; and, indeed, all through the New Red Marl there is a tendency to a repetition of the same sort of deposits as those with which the ordinarily recognized Rhætic beds were ushered in. This is evinced by the frequent local recurrence of green and grey marls, and thin beds of light-grey and whitish sandstones, commonly called the Middle Keuper Sandstones, which, however, occur in many horizons in the New Red Marl.

I have long held, in common with some other geologists, that our New Red Sandstone was probably deposited in an inland lake, and that our New Red Marl was certainly formed in a salt lake*. This belief is founded on the existence of the great deposits of rock-salt common in that formation, on the ground that, such lakes being fed by rivers and having no outflow, concentration of salts ensued by evaporation, and saline deposits were at length formed, in this case consisting chiefly of common salt. To me it seems impossible that solid salt can be deposited in quantity in an ordinary ocean, for the salt in solution cannot be sufficiently concentrated there to permit of deposition. And though wide-spreading cakes of salt have been formed by evaporation in such areas as the Runn of Cutch, yet this seems rather to partake of the nature of an accident than to denote a steady, long-continued train of events like those which marked the deposition of salt in our Keuper series.

Gypsum and other salts accompanying the New Red Marl may also have been formed in like manner; and I consider that the peroxide of iron which stains both salt and marl may also have been carried into the lakes in solution as carbonate of iron, and afterwards deposited as a peroxide through the oxidizing action of the air and the escape of the carbonic acid which held it in solution. It is well

* As far as I know, first proposed by the late Professor H. D. Rogers in an address to the British Association at Glasgow, 1855, p. 5, "On some of the Geological Functions of the Winds, illustrating the Origin of Salt." Only the title was printed; but ever since I have adopted and expounded Professor Rogers's views in my lectures. Mr. Moore mentions "the fresh- or brackish-water deposits of the Upper Trias," Quart. Journ. Geol. Soc. vol. xxiii. p. 458.

known that the peroxide of iron, as a thin pellicle, only incrusts the grains of sand that form the New Red and other red sandstones; and microscopic examination of the New Red Marl proves that the grains or flakes of sandy mud composing it are encased in the same manner*. Both Sandstones and Marls, I believe, have been formed in lakes, and their red colour is connected with this circumstance; for it seems impossible that an oxide of iron could be deposited from solution in an open sea in sufficient quantity to colour sediments red, though common pink mud might be so formed from the mechanical waste of red granite or other rocks. The remains of land-plants in the Keuper series, and the peculiarities of some of the reptiles of the period, tend to confirm the view that the strata were deposited in inland salt lakes. Their footprints prove that they walked over moist surfaces; and if these surfaces had been simply left by a retiring tide, they would generally have been obliterated by the returning flood, in the manner that we see every day on our own sandy shores. It seems to me that the surfaces on which we now find fossil footprints were probably rather left bare by the summer evaporation of a lake; these surfaces were baked by the sun, and the footprints hardened, so as to ensure their perpetuation, before the rising waters brought by flooded muddy rivers again submerged the low flat shores and deposited new beds of silt, just as they do at the present day round the Dead Sea and the Salt Lake of Utah.

The Foraminifera of the Keuper Marls, which are numerous, might just as well have lived in a salt lake as in the open sea†; and the same may be said of *Estheria minuta*. The single fish of our Lower Keuper Sandstone, *Dipteronotus cyphus*, will fall under the same category. The *Microlestes antiquus*, which occurs in the bone-beds of Stuttgart, and in the Red Marls of Watchet, in Somersetshire, according to Mr. Boyd Dawkins‡, proves nothing except that there was land in the vicinity.

* Mr. Ward, of the metallurgical laboratory, Jermyn-street, at my request discharged the colour from fragments of New Red Sandstone and Marl by an acid solution of protochloride of tin. Both became white. Under the microscope the marl appeared as a very fine-grained sandstone composed of perfectly white minute fragments of silica. In both the grains had evidently been simply coated with a thin pellicle of peroxide of iron. In the sandstone the peroxide of iron was 1.89 per cent.

† Species of Foraminifera are exceedingly variable in form; and many of them have a long range in geological time. They are therefore of little value in helping to the determination of stratigraphical horizons. It may be true, for example, that if the Chalk were entirely composed of Foraminifera it might be difficult to distinguish from deposits now forming in the Atlantic; but if these Atlantic deposits were, like the Chalk, half consolidated, heaved up, and denuded, geologists would not feel at a loss regarding their age. They would miss, in the first place, all the genera of Cephalopoda characteristic of the Chalk, besides numerous peculiar genera and species of Echinodermata, and, perhaps with one exception, all the species of Brachiopoda common in the Chalk. Further, over large areas, they would be apt to find Tertiary strata of various ages intercalated between the Old and New Cretaceous beds, which would at once furnish a clue to men experienced in field geology.

‡ Mr. Dawkins considers that these strata belong to the Rhætic beds; but the marine Rhætic fossils have not been found so low.

I have already said that the New Red Marl of England is more closely related physically to the Rhætic and, in some respects, to the Liassic beds, than to the Bunter strata; and I will now state the stratigraphical phenomena that have led me to form this opinion.

South and south-west of the Mendip Hills, the New Red Marl and the Magnesian Conglomerates at its base lie directly on Carboniferous strata. The Rhætic beds and Lower Lias immediately succeed these, the former lying conformably on, and generally passing into the Red Marl by obvious gradations. On the north, between the Mendip Hills and Tortworth, the Keuper Marls and sandstones, with occasional Magnesian Conglomerates, also lie on Carboniferous strata. North of Tortworth, as far as the Severn, the Marl, very thin and without any Lower Keuper Sandstone, lies directly on Silurian strata; and on the north side of the estuary it lies indifferently on Old Red Sandstone and Carboniferous rocks. Everywhere in these districts it is immediately succeeded by Rhætic beds, which graduate downwards lithologically into the Marls; and these Rhætic beds are invariably followed by true Lower Lias. The same is the case north and north-west of Gloucester, where the Keuper beds lie on Old Red Sandstone; and on the east of this area the upper Marls still pass into Rhætic beds regularly overlain by Lias Clay. It is not till we come towards the south end of the Malvern range, that Bunter Sandstones appear beneath the Marl. On the east side of the Malvern and Abberley range, the Bunter beds are thrown out of sight by a fault; but further north they come out in full force, extending along the flanks of the Permian strata that bound the Forest of Wyre, the Coalbrook Dale country, and the South Staffordshire Coal-field, whence they stretch along the eastern limits of North Wales, to the estuary of the Dee and the Mersey. Thence the full Bunter series skirts the Lancashire, Cheshire, and North Staffordshire Coal-fields, lying frequently on Permian rocks, then passing eastward by Ashbourne towards Nottingham, and along the flank of the Magnesian Limestone northward into Yorkshire*.

East of South Staffordshire the case is different. Round the Warwickshire Coal-field, the Keuper strata, where unfaulted, lie directly either on Permian or Carboniferous beds, with one small exception north of Atherstone, where Bunter pebble-beds appear for about a mile. Some very thin Bunter beds appear on and round the flanks of the Leicestershire Coal-field; but generally the Lower Keuper Sandstones lie directly upon Coal-measures; while further east, round Charnwood Forest, the marl lies directly on Cambrian rocks; and the same is the case with respect to the igneous bosses that rise through the marl further south.

Wherever the New Red Marl seems to attain its complete thickness, it passes into Rhætic strata; and these are always succeeded by Lower Lias, as far as the Rhætic beds have yet been observed. Obser-

* Sometimes the Bunter beds are cut out by faults for a space; but this does not affect the general question.

vations, more or less perfect, confirm this, from the south-western parts of England, northward to the shores of the Tees, all on the direct outcrop between the common Lower Lias and the recognized New Red Marl. Two outliers of Rhætic beds, formerly called Lower Lias, also appear at Bagots Park and near Newborough, north-west of Burton-on-Trent; and I do not doubt that the same strata would be found at the base of the outlier of Lias near Whitechurch, in Shropshire, if the rocks of that country were not so much obscured by glacial drift. In Cumberland, round Carlisle, at the mouth of the Vale of Eden, a great tract of Permian strata is directly overlain by Keuper Marls, which are succeeded by Lower Lias, though as yet no Rhætic beds have been noted in that area, which is also deeply covered by glacial débris and other superficial deposits. In fact, wherever the New Red Marl goes, the Lias follows in apparent conformity; and wherever the examination has been complete, the Rhætic beds are found between them, while the Bunter beds, which, were the series complete, would lie beneath the Marl, are often absent, in which case the Marl rests on Permian or any other strata of older date. The Liassic and Rhætic beds, therefore, appear to act in conformity with the New Red Marl, and in connexion with it; while the last seems to have in England less immediate stratigraphical relation to the New Red Sandstone—a fact possibly connected with the absence of the Muschelkalk in Britain.

Having reached this point of the argument, it is time to consider the palæontological part of the question, in relation to the probable physical geography of the time.

In Stoppani's descriptions of the Upper-Trias fossils of Esino* he gives descriptions and figures of a magnificent suite of fossils from beds which, according to his classification, ought to be the general equivalents of our New Red Marl. Only one of these species, *Anatina præcursor*, passes into his infra-Lias or *Avicula-contorta* zone. The Lower St.-Cassian and Hallstatt beds, on the opposite sides of the Tyrolese Alps, are believed by Hauer and Suess to be the general equivalents of the Keuper strata of Germany, France, and England, and, of course, of the beds of Esino. They number from 600 to 800 species of fossils.

In Stoppani's work on the infra-Lias and *Avicula-contorta* zone† of Lombardy, descriptions and figures of about 75 genera and 200 species are given, consisting principally of Mollusca, with a few Echinodermata, Sponges, &c. The fossils are very nearly quite distinct from those of the upper half of his infra-Lias beds, and of our English Lower Lias generally. The thickness of the strata described, the variety and number of the Mollusca and other forms, together with the luxuriant development and proportions of the individual shells, point to the existence in that area, in the south and east of Europe, and elsewhere of a broad open ocean, fitted for the habitation of a large and flourishing fauna—very different in these respects from the development of the British Rhætic beds, whether we regard their thickness or the fossils they contain.

* Milan, 1858-60.

† Milan, 1860-65.

According to lists prepared by Mr. Etheridge for publication in a forthcoming work, the British species in undoubted Rhætic beds may be summarized as follows, omitting the Sutton species. For the substance of the remarks regarding affinities and distribution of the species named I am also indebted to Mr. Etheridge.

Foraminifera, thirteen genera and twenty-seven species; Crustacea 2, viz. *Tropifer lævis* from one of the bone-beds, and *Estheria minuta*, first known in the Keuper Sandstones; one Brachiopod, *Discina Townshendi*, the only one known in our Rhætic strata. Of the forms named in this list, *Lima præcursor* somewhat resembles *L. punctata* of the Lias; *Monotis decussata* occurs at the very top of the Rhætic beds in thin limestone bands, which some writers consider to form the bottom of the Lower Lias. *Ostrea fimbriata* may possibly be *O. irregularis* of the Lias; but oysters are of little value in such an inquiry. *Pecten valoniensis*, also a true Rhætic shell, is a very variable form. *Plicatula interstriata* probably passes into the Lower Lias. *Anoplophora musculoides*, another true Rhætic shell, also occurs with *Monotis decussata* in the thin limestone bands at the top, which some call Lias. *Mytilus minutus* occurs both in the Rhætic and Lower Lias strata. All the Gasteropoda of the Rhætic beds (not including the Sutton species) are peculiar to that formation; and the same is the case with the fish. Of the Reptilia, *Plesiosaurus costatus*, *P. Hawkinsii*, and *P. trigonus* are common to the Rhætic beds and the base of the Lower Lias*. The occurrence of *Microlestes antiquus* in the Keuper Marls is an accident, its remains having been washed into the strata from the neighbouring land†. Of the whole, not more than four species of shells at the most pass into the Lias; and probably this may even be restricted to two. The Saurians have a longer range; and this is very significant.

In this list I do not include the Sutton forms given in Mr. Etheridge's list, fourteen in all, one of which (*Ostrea multicostata*) is also found in the Muschelkalk, and three of which (*Pecten Etheridgi*, *P. suttonensis*, and *Mytilus minutus*) are also Lias species. Few or none of the remaining forms occur associated with the shells of the ordinary Rhætic areas. The Sutton beds lie unconformably on the Carboniferous Limestone, and stratigraphically and lithologically are inseparable from the ordinary Lias limestone. The corals, which Dr. Duncan has examined, occur in small, irregular, broken layers, or rather in occasional white tufaceous limestone patches, at the very

* Since this paper was written, I have been informed by Mr. William Sanders, of Bristol, that he has obtained the centrum of an *Ichthyosaurus* of vast size "in close contact with the thick bone-bed at Aust Passage," apparently identical with *I. platyodon* of the Lower Lias.

† The Mendip Hills and the highlands of South Wales have been recognized as land while the Trias was being deposited, ever since 1846, if not earlier. Sir H. De la Beche ("On the formation of the Rocks of South Wales and South-west of England," vol. i. p. 239 *et seq.*, Mem. Geol. Surv. of Great Britain) considers the dolomitic conglomerates "on the Mendip Hills, for instance," "to have been beaches among islands." See also Ramsay, 'Denudation of S. Wales,' &c. p. 318. Mr. Moore also adopts the island theory, "Abnormal Secondary Deposits," Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 454.

base of the Lias, often crusting the Carboniferous Limestone on which it rests. It is so insignificant in quantity that a few persevering palæontologists might almost carry it away bodily in their bags; and its manner of occurrence has always suggested to me the idea that it was formed in hollows in the rocks, partly by evaporation, between high- and low-water mark. The corals sometimes grew on the Carboniferous Limestone; and the whole by subsidence was afterwards buried underneath the Lias. Mr. Bristow remarks that this mode of formation explains the presence of galena and chert in the tufa*. They have been derived from the Carboniferous Limestone on the land side of the deposit. West of Bridgend, as far as Pyle, the Rhætic beds become sandstones, indicating an approximation towards the margin and shallow water.

Sir Charles Lyell has remarked that "the sandstones and clay of the Keuper resemble the deposits of estuaries and a shallow sea near the land, and afford in the north-west of Germany, as in France and England, but a scanty representation of the marine life of that period†. As regards the scanty marine life, this is true. Mr. Etheridge, in his paper "On the Rhætic or *Avicula-contorta* beds at Garden Cliff" ‡, observes that the Rhætic beds of England and the west and north of Europe, were deposited in shallow seas and in estuaries.

With Sir Charles Lyell's suggestion, as regards the estuarine nature of the Keuper beds of England, I do not agree, while Mr. Etheridge seems to me to be right respecting the conditions under which our Rhætic beds were formed. My reasons for this opinion are chiefly founded on physical considerations, leading to the following conclusions, which form the main object of this paper.

1. The Triassic epoch over a great part of what is now Europe was essentially a terrestrial one; that is to say, the Trias areas of deposition in part, and some of them altogether, were surrounded by continental land. In the latter part of this epoch the Keuper marls were deposited in the British isles in a great lake, fresh or brackish at the beginning; and the same was occasionally true of other areas of northern Europe and its adjoining seas, which lakes were for the most part destitute of outlets to the sea.

2. These lakes gradually got filled with sediments. By and by, through change of amount of rainfall, or through increase of heat, the lake or lakes ceased to have an outflow; that is to say, evaporation was equal to, or greater than, the influx of water.

3. By degrees, through evaporation, the water became salter; concentration of salt or salts in solution ensued; and precipitation of rock salt was one of the results.

* I have examined the Sutton beds with Mr. Bristow, and have no doubt that they are Lower Lias. See "On the Lower Lias or Lias-Conglomerate of a part of Glamorganshire," Bristow, Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 199. See also Mr. Charles Moore, "On Abnormal Conditions of Secondary Deposits," Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 526. Mr. Moore decides the Sutton beds to be of Lower Liassic age.

† Elements of Geology.

‡ Proceedings of the Cotteswold Naturalists' Field Club, vol. iii. 1865.

4. Subsequently by increase of rainfall or decrease of heat, the waters again comparatively freshened, but still remained salt, a fact proved by the occurrence of pseudomorphous crystals of salt in sandy layers interstratified with the marls, up to, and even in, the recognized Rhætic strata. Gypsum also occurs above the bone-bed. These circumstances may be accounted for by the close relation of the Rhætic beds to the ordinary marly series. That Rhætic areas got dried by temporary isolation seems certain; for sun-cracks have been observed in the strata by Mr. Bristow, and also pseudomorphous crystals of salt.

5. During the deposition of the upper part of the Keuper marls, overlaps took place of upper across lower strata. This would necessarily take place in any deep wide lake-basin first half drained by mere evaporation, and again, by a change of conditions, gradually filled with water from which sediments were being deposited across a broader area.

For example, were the rainfall of the area drained by the Jordan to increase gradually, the basin of the Dead Sea would by degrees fill with water, and successive deposits of sediment would gradually overlap each other on the shelving slopes of the lake-basin in which solid salts had previously been deposited. There are examples of this kind of overlap in the New Red Marl of England, in Somerset, Gloucester, Hereford, and Leicester shires.

6. In the British area, sinking of the district took place at or about the time when the lake or lakes got nearly filled with sediment; and the same may have been the case in other European areas. A partial influx of the sea took place over shallow bottoms; and the marine life that accompanied it, and the deposits that ensued, together form the Rhætic beds of England. These marine forms migrated from a true Rhætic ocean, in which the Lower St.-Cassian and Hallstatt beds were deposited. If the Dead-Sea area, by increase of rainfall, got filled up, and if depression of land took place so as to admit the waters of the Red Sea or Mediterranean, analogous results would ensue; for a marine or estuarine fauna would be superimposed in shallow water, on a set of strata containing salt in certain lower deposits. The Dead Sea, like the Keuper, is singularly destitute of remains of aquatic life.

Under these conditions, it is evident that the thin Rhætic beds of North-western Europe might have been deposited in great part in shallow seas and in estuaries, or in lagoons, or in occasional salt lakes of small or great dimensions, separated from the sea by accidental changes in physical geography. Many years ago, while at Lyme Regis, the late Professor Edward Forbes stated to me that the fauna of the White Limestone, at that time called White Lias, reminded him, in its assemblage of forms, of the fauna of the Caspian Sea; and this seems to be a case in point, though not in *all* respects strictly analogous*. The fauna of the Caspian is very small in

* Mr. Moore, speaking of the "White Lias," considers that "the general character of the deposit is such as we might expect to find in a lagoon or inland sea

number of genera and species; and some of the forms are poor and dwarfed. It is a north-sea fauna; and when the area was first separated from the main ocean, it was first freshened by influx of rivers, while it is now again becoming salter by evaporation. The result is the poverty and dwarfing of the forms. In the Black Sea there are misshapen or monstrous forms of Mollusca, stated by Forbes to be due to the freshened state of the water. Both of these cases, relating to what may be called continental seas, bear upon the subject in question, especially since the Rhætic fauna of England is also comparatively poor in genera and species, when compared with the well-developed fauna of Lombardy and other parts of the south and east of Europe.

I now come to a difficult point. It is undoubtedly true in England that the Lower Lias follows the Rhætic beds wherever they go; and though there are symptoms of erosion between them at Penarth and at Curry Rivell, in Somerset*, yet the conformity is, on the whole, so complete, that wherever we meet with the base of the Lower Lias we look for the Rhætic beds below, and as yet we have not been disappointed. The question then arises, how is it that the transition in these areas from the Rhætic to the Liassic forms is so sudden? It is hard to answer this question; but it may perhaps be met by an analogous case. The estuarine and the lagoon beds of the Purbeck and Wealden series commenced in the Oolitic epoch, and ended in the Neocomian or Lower Cretaceous epoch; and the change between the life of the Oolitic and Neocomian and Cretaceous deposits is as great as, and in some respects greater than, that between the Rhætic and Liassic strata; and though the Rhætic beds were not deposited in fresh water, yet, like parts of the Purbeck series, I believe they were formed in shallow water under brackish semi-estuarine conditions which endured for a long period.

In conclusion, I may state that the same kind of reasoning, with differences, applies more or less to other red-coloured and to some calcareous strata of England, including the Permian, Old Red Sandstone, and even the red Cambrian formation. This I hope to treat of in a subsequent memoir. If this idea is true, and if this kind of work be carried out, it must have an important bearing on certain departments of palæontology in a manner already partly indicated by Professor Huxley, and it may throw much light on the distribution of the various forms of animal and vegetable life in time and space. Without it, we must still in great part continue to regard the various formations very much as we might a pack of

in which the beds were being very tranquilly deposited" ("Abnormal Secondary Deposits," Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 470). See this memoir for a great deal of valuable information on these and other deposits. See also memoir by Dr. Wright "On the *Avicula-contorta* beds," Quart. Journ. Geol. Soc. 1860, vol. xvi., and others.

* This kind of erosion was evidently not accompanied by marked unconformity, the result of serious disturbance of the Rhætic beds before the deposition of the ordinary Lias. Estuarine or tidal sea-currents would have been sufficient to produce it when the Lias-sea first came across a slowly sinking area.

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cards arranged in order, 1, 2, 3, and so on up to Knave, Queen and King; so that by their marks we should always be able to mention the cards above and below any given number, unless it happened that one or more had been surreptitiously abstracted from their places. The lacustrine, as distinguished from marine formations, do not strictly follow this rule.

DISCUSSION.

Mr. ETHERIDGE thought the question of the nature of the Rhætic beds was to a great extent palæontological. The main point in connexion with them was as to how the British beds were to be connected with those of the Lombardic and Middle European areas. It certainly seemed probable that in this part of the world the conditions of life were different, the deposits being much less in thickness, and the fauna much diminished; and where represented at all the shells occurred in a dwarfed and stunted form. The exact horizon and nature of the Sutton beds had still to be determined.

Mr. GODWIN-AUSTEN believed that every mass of red sandstone would ultimately be referred to either a brackish or freshwater origin. A comparison of the ancient and present area of the Caspian Sea would tend to remove any doubt that might remain on the mind of geologists as to the possibility of the existence of such vast internal seas as those which had to be called in to account for these formations. He regretted that former observers had not attached more importance to the duration and extent of those freshwater conditions which were found so commonly to have prevailed between the periods of deposit of the great marine formations. There was another fact to be borne in mind, that even in existing lakes the water at the one end was sometimes completely fresh, and at the other end salt, each of course with a different fauna.

Prof. RUPERT JONES said that although there were good grounds for the lake-theory, something might be said for shallow seas. He remarked that sulphate of lime was deposited from sea-water before salt, that oxide of iron might originate from chloride of iron diffused in water whether of lakes or seas, and that the hæmatites of Permian age were probably deposited in the sea. He considered that Foraminifera required great caution when used as criteria, as the varietal forms giving the facies were of more importance than the genera and species. The *Estheria* were never marine, although often occurring in plenty in temporary freshwater pools on the seashore. In his monograph of *Estheria* he had said much to substantiate the notion that freshwater conditions often prevailed during the formation of the Keuper. Both in the Old Red Sandstone of the Baltic provinces and in the Lettenkohle and Keuper of Germany, when *Estheria* comes in, *Lingula* dies out. The repeated set of formations in the Permian and the Trias precludes their contemporaneity, as supposed by Messrs. Godwin-Austen and Marcou.

Mr. BAUERMAN remarked that the Hallstatt beds which had been cited as marine contained large deposits of rock-salt.

M. MARCOU thought that the difficulties in regarding these beds as of freshwater origin were greater than the author supposed. The absence of fossils in gypsum, though almost universal, was not total. He had himself seen three specimens of *Trigonia* in gypsum from Stuttgart.

Mr. TATE mentioned the discovery by Mr. Burton of marine fossils in the Red Marl, in one instance in combination with vegetable remains. He commented on the sharp demarcation observable in Ireland between the Rhætic beds and the marl below, whereas it was almost impossible to separate them from the Lias above. He doubted, however, whether the true relations of the Rhætic beds were to be worked out in this country. As to the fossils of the Sutton Stone, they were all purely Liassic.

Mr. BURTON stated that the fossils from the Red Marl came from a spot about five miles from Retford, in the direction of Gainsborough, but he had not seen them *in situ*. There are, however, no Rhætic beds within some miles.

The Rev. Mr. WINWOOD, in the absence of Mr. C. Moore, from ill health, inquired whether the author regarded the White Lias as Rhætic, or Liassic.

Prof. RAMSAY, in reply, was quite willing to accept marine fossils as coming from the Red Marl. The fact of *Estheria*, a brackish or freshwater form, occurring in certain bands was in favour of his views, as he considered that at intervals the saltness of the water in such a lake as he had suggested must have varied. He could not accept the probability of oxide of iron having been deposited in a large sea-area to such an extent as to colour the sands. All rocks that could be proved to be of marine origin, even when they contained iron, were not stained red unless by infiltration from above. He pointed out that the old area of the Caspian was far larger than the lake in which he had suggested that the New Red Marl had been deposited. If, as was more than probable, there had been during all geological time continental areas somewhat in the same positions as those of the present day, there must have been large areas of inland drainage in which some such deposits as those in question must of necessity have been formed.