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REMARKS UPON THE RELATIONS AND GROUPING OF THE PERMIAN AND TRIASSIC ROCKS.

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THE physical history of the Permian and Triassic rocks of Great Britain has been told by Professor Ramsay, who has pointed out that the beds were deposited in great inland lakes, for the most part salt.[1] Without entering into the consideration of this subject, there seems to be much that requires to be unravelled in regard to the structure of the beds individually, and much that has yet to be explained in regard to the relations and grouping of the rocks.

In their general lithological characters there is a marked similarity throughout the Permian and Triassic series, consisting as they do of red sandstones, conglomerates, and marls, with occasional beds of limestone. Originally, the whole of these rocks were classed as New Red Sandstone, and the name "Poikilitic," subsequently suggested by Conybeare, as an equivalent term, is one that possesses many advantages to recommend it. The ideas that as students we derive from our text-books are that the Permian beds form a group overlain unconformably by the Trias, and sufficiently distinct in their palæontological aspect to be classed as Palæozoic; whilst the Triassic beds (classed as Mesozoic) are divided into Bunter and Keuper, and are regarded as equivalents of the same beds on the Continent—the Muschelkalk being considered to be absent in the British area, and the Keuper beds to rest unconformably upon the Bunter.

The exact evidence upon which these ideas are based appears, however, to be conflicting when it comes to be examined into, and frequently to have but a very local significance, as more recent researches have tended to show. It may therefore be interesting to draw attention to some of the points of the case, and to notice some of the later opinions expressed.

The history of the researches into the Permian and Triassic beds has been given at length by Professor Hull in a work detailing the investigations of the Geological Survey in the midland counties of England: it will suffice therefore to refer to his Memoir[2] in regard to this part of the subject.

[1] Quart. Journ. Geol. Soc., vol. xxvii. pp. 189, 241.
[2] Published by the Geological Survey.

In our tables of British[1] strata we generally find a classification similar to the following:—

Trias	Keuper	Red and Variegated Marl.
		Lower Sandstone and Marl.
		Dolomitic Conglomerate.
		(Muschelkalk wanting in England.)
	Bunter	Upper Mottled Sandstone.
		Pebble-beds.
		Lower Mottled Sandstone.
Permian	Upper or Magnesian Limestone Series.	Upper Red Marl and Sandstone.
		Upper Magnesian Limestone.
		Lower Red Marl and Sandstone.
		Lower Magnesian Limestone.
	Lower, or Rothliegende	Red Marl, Sandstone, Breccia and Conglomerate.

For this series the term "Poikilitic" has been employed by Prof. Phillips; and in his recent work on the "Geology of Oxford and the Valley of the Thames," he has treated all the beds "between the Coal and the Rhætic base of the Lias as one great physical 'Poikilitic' series." He observes (p. 88) that "in some respects and in some districts it is, however, more convenient to adhere to the old established alliance of the Permian many-coloured deposits, with the variegated sandstones and clays of the New Red series; for the *physical history* of these two great groups is, on the whole, one great sequence of natural operations. There are indeed cases, as in Lancashire and Cheshire, and in a less degree in Derbyshire, where a kind of gradation appears between the Coal formation and the Permian sandstones, which are locally conformed to it; so that, in fact, we shall do wisely to adapt our classification to the region which specially engages attention, for local description and limited inference."

In East Yorkshire there is considerable similarity between the beds at the base of the Permian series and those at the top of the Coal Measures, and the beds have been differently classified in places by geologists.[2]

Prof. Hull, however, believes that there is an unconformity between the Permian and Carboniferous rocks in Lancashire and Yorkshire.[3]

It is considered by some that the different members of the Permian formation are not strictly conformable to one another. A most decided instance of unconformity is stated to be in the railway-cutting at Tadcaster. "The Middle Marl has there thinned away to a mere seam, so that the Upper Limestone rests almost directly on the Lower, and at the base of the former there is a thin bed of gravel formed of Lower Limestone pebbles."[4]

In isolated masses, as might be expected, it is not always easy to distinguish between the Permian and Triassic beds. Thus certain

[1] See Mr. Bristow's "Tables of Strata" (published by Stanford.).

[2] See Explanation of Quarter Sheet 98 S.E. of the Geological Survey Map of England, pp. 28, 29.

[3] Quart. Journ. Geol. Soc., vol. xxiv. p. 327.

[4] Explanation of Quarter Sheet 93 S.W., p. 10.

red sandstones in Lancashire, referred to the Permian period by Mr. Binney, have been considered as Bunter by Prof. Hull; although the latter admits that, "isolated as the beds are here, there can be no certainty regarding their age."[1]

The Rev. A. Irving, in an interesting paper upon the Geology of the Nottingham District, remarks that there are clear signs of continuous deposition of the Permian and Lower Bunter rocks; and, so far as the area is concerned, the stratigraphical data seem to point to the Permian and Bunter as but portions of one great unbroken sequence of rocks. Referring to Prof. Hull's Memoir on the Permian and Triassic Rocks of the Midland Counties, he comments upon the meagre evidence on which the great line of demarcation between the Bunter and Permian rocks has been drawn in the northern Permian area.[2]

Turning to the Triassic beds, Mr. Irving refers to the eroded or denuded surface of the Bunter, where overlain by the Keuper, which has been observed in the neighbourhood of Nottingham.

In County Down, according to Mr. J. Anderson, however, the Keuper and Bunter divisions appear conformable.[3]

In regard to the principal cases of unconformity that have been noticed as occurring between the Keuper and Bunter strata, reference may be made to Prof. Hull. He remarks that "there is every reason to believe that the bed of the New Red Sandstone sea over the English area was elevated into dry land during the succeeding period of the Muschelkalk. This elevation, and subsequent submersion at the commencement of the Keuper stage, has left its evidences in the eroded surface, and slight unconformity, which is *locally*[4] observable between the two divisions of the Trias of England."[5] Mr. Hull frequently alludes to the highly eroded surface of the Bunter where overlain by the Keuper; in regard to the unconformity in dip, however, the following remarks of his are important:—"The district around Ormskirk affords several very interesting sections in the Trias, and it is the only one with which I am acquainted where we obtain in one section visible evidence of the unconformity of the Bunter and Keuper divisions. The deep sections opened out by the Ormskirk and St. Helen's Railway, if not everything that could be wished for the purpose of demonstrating the discordance between the two divisions of the Trias, are probably as satisfactory as the nature of the rocks admit of. . . . The basement bed of the Keuper Sandstone consists of coarse light red or brown grit, containing small pebbles of white quartz, and traversed by planes of current-bedding. It rests on a distinctly eroded surface of the Upper Mottled Sandstone of the Bunter series. . . . . Upon a careful examination the Keuper Sandstone will be found to overlap successive beds of the Bunter, which are distinguish-

[1] Memoir on the Triassic and Permian Rocks, p. 41.
[2] Geol. Mag. Decade II. Vol. I. pp. 315, 316.
[3] Proc. Belfast Nat. Hist. Soc., 1873, p. 41.
[4] The italics are mine.
[5] The Triassic and Permian Rocks of the Midland Counties of England. Memoirs of the Geological Survey of England and Wales, 1869, p. 66.

able principally by colour, but also by other mineral characters." Further on Mr. Hull speaks of it, as "this, to all appearance, unconformable overlap of the lower division of the Trias."[1]

In Shropshire, Mr. Hull remarks that "there is some uncertainty as to the exact line of demarcation between the Bunter and Keuper series, as the uppermost beds of the former are sometimes sufficiently hard for building purposes."[2]

It is unnecessary to enter further into a discussion of the relations of the Bunter and Keuper formations, for these quotations will be sufficient to indicate the unsatisfactory evidence of any considerable break having occurred between the subdivisions of the Triassic rocks in England, to warrant the notion that "the close of the Bunter Sandstone period in England was accompanied by a general elevation of the whole of the Triassic area, in which condition it remained throughout the period of the Muschelkalk."[3]

In the south-west of England, or in the country that lies between Bristol and Exmouth, there is a considerable development of the New Red rocks, and these have been generally included in the Trias.[4] In the smaller maps two divisions have been made, namely,

1. New Red Marl and Dolomitic Conglomerate.
2. New Red Sandstone and Conglomerate, as in Greenough's Geological Map of England and Wales. Or

1. New Red or Keuper Marl and Sandstone.
2. New Red or Bunter Sandstone, as in Ramsay's Geological Map of England and Wales.

In the published Geological Survey Maps, two divisions are likewise made, in South Devon, of New Red Marl and Sandstone;[5] the latter including the pebble-beds of Budleigh Salterton and the breccias of Teignmouth. The Dolomitic Conglomerates of Mendip and those of West Somerset were, however, in places coloured distinctly.

Such being the case, there must consequently be some confusion in regard to the classification of these Triassic rocks, and more particularly when no recognized unconformity has been observed to justify the distinctive terms of Bunter and Keuper.

Turning our attention to the coast-sections between Seaton and Exmouth,[6] we find a very clearly developed series. A little east of Seaton, we meet with the lower Rhætic marls, and thence trace their

[1] *Op. cit.* pp. 86, 87. [2] *Idem.* p. 64. [3] Hull, *op. cit.* p. 106.

[4] The name Permian has sometimes crept in through a misunderstanding of the Dolomitic (or Magnesian) Conglomerate.

[5] These Maps include Sheets 19, 20, 21, and 22. The Sandstone is not designated as Bunter, and the boundary between it and the New Red Marl is not engraved in Sheets 21 and 22. The whole area has been undergoing revision, and the new edition of Sheet 19 is now published.

[6] This coast-line has been described and diagrams of the sections drawn by De la Beche, Trans. Geol. Soc. 2nd series, vol. i. p. 40, plate viii. (Bridport to Sidmouth); Buckland, *Idem.* p. 95, Plate xiv. (Portland to Lyme Regis, and Branscombe to Sidmouth); Whitaker, Quart. Journ. Geol. Soc. vol. xxv. p. 152 (Dowlands Landslip to Babbacombe Bay). See also Pengelly, Trans. Plymouth Inst. for 1862–65; Trans. Devon. Assoc. for 1863. My notes on the coast-section (which, however, add nothing to what has been written before) were made in company with my colleague, Mr. W. A. E. Ussher. He has done the greater part of the re-survey

passage downwards into the variegated marls which appear along the cliff, at the base of the Greensand and Chalk. West of Seaton, they form low cliffs of marl, which appear again at Branscombe, dipping gently to the east. Continuing towards Sidmouth, the beds become less calcareous and finally quite loamy, until lower down in the series sandstone crops out at Sidmouth, forming a gentle anticlinal at the town, and being overlain again by loamy beds to the west. Here the sandstone contains seams of red and mottled clay. Continuing westwards the sandstone, containing seams of calcareous conglomerate, forms the low cliff at the mouth of the Otter. The sandstone continues through Budleigh Salterton; and in the high cliff to the west, beneath it, comes the famous pebble-bed, and this again overlies variegated marl, with hard nodules in the lower part, where the beds are less calcareous, although variegated and with marly structure: these beds are interspersed with bands of sandstone, and towards Exmouth there is an alternation of marl and sandstone. In this direction the beds are much disturbed by small faults, which let down the marl at Exmouth: they are found to rest upon breccia.

Crossing over the mouth of the Ex, we come to Langstone Point, and here we find rocks the relation of which to the marls and sandstones of Exmouth is clear, and the dip, which continues on the whole uniform, would place them lower in the series: they form a continuation of the breccia, which just appears at Exmouth.

The Cliffs between Langstone Point and Dawlish show sandstone and breccia interstratified, sometimes the one predominates, sometimes the other. They are much faulted on a small scale.[1] Between Dawlish and Teignmouth the dip continues uniform, and the cliffs display a series of breccias with sandstone interstratified. Between Teignmouth and Babbacombe the beds undulate; the lowest bed, which might be termed a conglomerate, is conspicuous from the fragments of limestone contained in it.[2]

At Livermead and Roundham Head, the beds appear similar to those on the Dawlish coast, and the sections show (1) breccia, (2) sandstone, and (3) breccia, with the conglomerate at base.

There is thus a continuous series of rocks from the breccias and sandstones of Dawlish and Teignmouth up in to the Rhætic beds of Axmouth. The whole of these beds might be termed Keuper; but owing to their great thickness, there is some justification in thinking that the Muschelkalk might be represented, as well as the Bunter, and by sediments of a different lithological character.[3] It seems

of the red rocks between Taunton and Exeter, in which tract he has been enabled to trace out, with marked persistence, the different divisions seen in the coast-section, whilst I have been similarly successful in the smaller areas on which I have been engaged. The details of this work will probably be published on some future occasion.

[1] See section by Godwin-Austen, Trans. Geol. Soc. 2nd ser. vol. viii. pl. xlii. fig. 5.

[2] Here, it may be observed, we approach the Torquay limestone.

[3] See the writings of De la Beche, and Pengelly; also Whitaker, *op. cit.* p. 157; and H. B. W. Science Gossip, No. 115, July, 1874, p. 165. The thickness of the strata has been estimated at from 1850 feet to four miles or more! Probably the former estimate by De la Beche is nearest the truth.

best therefore to term the whole development the Triassic series, without making any subdivisions (which would have no real value) to correlate them with the divisions made on the Continent.

The consideration of the red rocks in the south-west of England, with their many evidences of false-bedding and irregular accumulation, has led me to be rather sceptical of the importance attached to the unconformities observed to the north ; but my knowledge of that district being confined to the inspection of some isolated sections in Cheshire and Nottinghamshire, I have naturally no opinion to offer concerning them.

Whilst the organic remains of the Permian period approach nearer to those of the Carboniferous rocks than to the Trias,[1] it seems important to keep in mind their approximation in physical character to the newer rocks; and when we take into consideration the evidences of unconformity that have been recognized in the Permian rocks themselves, to consider whether they are not equally important with those found locally to exist between the Permian and Bunter beds, and those between the Bunter and Keuper.

The absence of the Muschelkalk in the British area must not of itself be taken as any evidence whatever of an unconformity, considering the different conditions under which the beds were deposited in each area.

Thus it will be seen that there is no very strong evidence for a great break in the Triassic series throughout the British area, but that locally in them, as in the Permian series, there were pauses in deposition accompanied by some erosion of the beds.

The results of further researches may be looked for with interest, and more particularly in regard to the Permian beds.

Lyell has remarked "that nowhere have geologists found more difficulty in drawing a line of separation than between the Secondary and Primary series,"[2] and perhaps future researches may lead to the resumption of the term "Poikilitic" as a general term to embrace the Permian and Trias, especially as it has been used by such men as De la Beche and John Phillips.

[1] The Permian flora is, upon the whole, very nearly allied to that of the Coal-measures, though the Permian species are mostly distinct, and there are some new genera. In the Trias are found some Palæozoic types, as *Calamites*.—Nicholson, Manual of Palæontology, pp. 494, 533.

[2] Student's Elements, 1871, p. 366.

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