

11. *The STRATIGRAPHY and TECTONICS of the PERMIAN of DURHAM (NORTHERN AREA).* By DAVID WOOLACOTT, D.Sc., F.G.S. (Read April 5th, 1911.)

[Abstract.]

THE Permian strata of Durham and Northumberland lie unconformably on a basin of the Coal Measures. They can be divided as follows:—

- (4) Upper red beds, with salt and thin fossiliferous magnesian limestones (only exposed in the south of Durham). 300 feet.
- (3) The Magnesian Limestone.
 - (a) Upper.
 1. Yellow bedded limestone of Roker. 100 feet.
 2. The concretionary limestone of Fulwell and Marsden—a series of concretionary and non-concretionary limestones and marls. 150 to 250 feet.
 3. The Flexible Limestone. 10 to 12 feet.
 - (b) Middle.

Unbedded (as a rule), highly fossiliferous (often) limestone of Claxheugh, Tunstall, etc. Forms a ridge of high ground, and reaches a thickness of 300 feet. Often brecciated and entirely changed in character—rendered more calcareous and fossils obliterated.	replaced on the east by	{ Bedded yellow, non-fossiliferous limestones of the northern end of Marsden Bay and the coast from Hendon to Seaham Harbour. Often highly brecciated 150 feet.
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------
 - (c) Lower. Bedded brown limestones of Frenchman's Bay, Houghton etc. Upper beds often disturbed. 40 to 200 feet.
- (2) The Marl Slate. 3 feet.
- (1) The Yellow Sands, from 0 to 150 feet.

These beds, which vary much in thickness, lie in North Durham in the general form of a syncline beneath Sunderland.

The unfossiliferous Yellow Sands are probably a deltaic formation reassorted by wind, the other beds being the result of deposition in an inland sea undergoing desiccation. The magnesium carbonate existed in the waters of the sea, and was either deposited along with the calcium carbonate, or introduced by seepage when the beds were being laid down.

Great changes in the amount and distribution of these carbonates have, however, taken place since deposition. The cellular structures that occur in the limestone can be classified as follows:—(1) Concretionary-cellular; (2) negative breccia; (3) solution-cavities; and (4) fractured cellular. Most of them have been produced by the leaching-out of the magnesium carbonate (dedolomitization), or of both that and calcium carbonate. In some cases the rock

has been rendered crystalline, as well as more calcareous, and the fossils have been obliterated. They do not afford any proof that the rock has been dolomitized subsequent to deposition. The percentage of calcium carbonate is sometimes over 99, while that of magnesium carbonate is occasionally as much as 50.

The fauna of the Magnesian Limestone is very restricted (about 140 species) and most peculiarly distributed. The marked palæontological features are the profusion of individuals in the Middle Fossiliferous Limestone (which appears to have formed a shell-bank in the Middle Magnesian-Limestone sea) and their sudden disappearance in the Upper Limestone. No corals, echinoderms, polyzoa, brachiopods or cephalopods have ever been found above the top of the Middle Fossiliferous division: only a few fishes, gastropods, lamellibranchs, entomostraca, and foraminifera occurring in the Upper beds. The Lower and Middle Fossiliferous Limestones are marked by the presence of *Productus horridus* Sow. Fish-remains occur at two horizons: namely, the Marl Slate and the Flexible Limestone, and the beds above these deposits.

The Brecciated Beds, which occur at various horizons, chiefly however in the two Middle divisions, constitute the most marked tectonic feature of the Magnesian Limestone of the area. They have been produced by thrusting, which brought about a decrease in the lateral extension of the Permian. Associated with the breccias are other proofs of thrusting: (1) Thrust- or shear-planes; (2) disturbed and displaced masses of Lower Limestone; (3) intruded breccias; (4) slickensided and grooved, horizontal and vertical surfaces; (5) cleavage; (6) folding, both on a local and on a general scale; (7) buckling, thickening, and squeezing-out of beds; (8) phacoidal and other structures; and (9) fissuring. The main thrust at Marsden appears to have acted from a few degrees south of east to a few degrees north of west; there are, however, distinct evidences of movement from other directions in different parts of the district. Experiments, made on the compressive strength of the rocks affected by the thrust at Marsden, indicate that the thrusting reached a maximum of about 300 tons per square foot. Observations made by Mr. S. R. Haselhurst, M.Sc., in the Cullercoats area seem to prove that the thrusting occurred later than the post-Permian movement of the Ninety-Fathom Dyke—some faulting in the area is, however, later than the thrusting—, and it appears evident that the shattering of the strata was produced prior to the pre-Glacial era of denudation. It may have been connected with the Miocene movements that produced such marked changes in the physiography of Britain.

DISCUSSION.

The CHAIRMAN (Dr. C. W. ANDREWS) suggested that perhaps comparison of the Permian dolomititic limestones with those of the post-Miocene raised reefs of Christmas Island (Indian Ocean) might help to throw some light on the question of dolomitization.

Q. J. G. S. No. 267.

z

Prof. E. J. GARWOOD congratulated the Author on the care and perseverance of which he had given proof in working out the Permian geology of an area with which the speaker had been familiar from his childhood. He was glad that the Author had confirmed his own views regarding the original character of the magnesium carbonate present in these beds. He asked whether the Author had been able to determine the general direction of the thrusting over the area to the south of the Tyne Valley, and whether the movement which produced it could be shown to be connected with the thrust described by Prof. Lebour & Dr. Smythe in the Coal Measures farther north; whether any approximate date could be assigned to these movements; and whether they belonged to more than one period. The speaker referred to the difficulties in explaining the V-shaped breccia-gashes, and asked the Author whether he accounted for the uninterrupted character of the overlying bedding-planes on the view that these had been thrust over the gashes as a whole; were the nether surfaces of these overlying beds striated in the manner which the Author had described elsewhere? He agreed with the Author that the marly magnesian matrix had been removed from the beds in which the cellular structure was developed, but thought that this may often have taken place by the mechanical action of water. For this reason he deprecated the use of the term 'dedolomitization' for that process, as the term had now come into general use for cases where the magnesium was not removed, but had entered into fresh combinations.

Mr. E. E. L. DIXON had listened with much interest to the Author's discussion of several points of general importance. He inquired what precisely was the agency that the Author supposed to have deprived a 'dedolomitized' limestone of its magnesium. Under conditions of ordinary weathering a dolomite is undoubtedly more resistant than a limestone, unless, as in the case of some of the dolomites in the Carboniferous Limestone of South Wales, the dissolution of a slight amount of interstitial calcite releases a considerable quantity of dolomite in the form of loose crystals or grains, and enables them to be washed away mechanically. The disappearance of everything, including insoluble impurities, from the cavities in the 'dedolomitized' limestones would seem to demand some such action. Another point raised was the origin of the dolomite. What was the evidence that any of it was an original, chemical precipitate?

The speaker was anxious to hear whether the Author considered that all the masses of breccia in Marsden Bay had originated in earth-movements. Prof. Lebour's explanation—that some of them, the 'breccia-gashes,' had been caused by collapse of material into cavities formed by solution in the limestone—had led the speaker to apply the term 'gash-breccia' to large masses of breccia, up to several hundred yards across apparently, in the Carboniferous Limestone of South Wales. These had undoubtedly originated by collapse into solution-cavities in the heart of the pre-Triassic Armorican mountain-chain; and it would be decidedly awkward

if it were now found that the original 'breccia-gashes' had had an entirely different origin.

Mr. G. W. LAMPLUGH recalled the overthrust in the Chalk on the north side of Flamborough Head, which resembled some of the disturbances described by the Author, and deserved consideration in discussing the age of earth-movements on the north-east coast. He further mentioned that a succession comparable to that of Durham could be traced in the Magnesian Limestone Series of North-East Derbyshire; but the subdivisions in the two districts may represent equivalence of phase, without exact equivalence of time. He enquired whether the Author had observed any dome-like structures among the more massive limestones of Durham, as such structures were conspicuous in parts of Eastern Derbyshire and appeared there to be due to conditions of deposition.

The AUTHOR thanked the Fellows present for the manner in which they had received his paper. He also expressed his thanks to Mr. S. R. Haselhurst, M.Sc., for making the model of the district shown, and to Mr. C. T. Trechmann, B.Sc., for some of the specimens of fossils lying on the table. He agreed with Prof. Garwood's suggestion that sometimes the magnesium carbonate may have been removed by the mechanical action of water; but some of the cellular forms described had certainly been produced by chemical action. In reply to Mr. Dixon, he stated that, under certain conditions of temperature and pressure, magnesium carbonate (in the presence of calcium carbonate) was the most soluble of the two salts. He emphasized the need for a thorough study of the relative solubilities of these two carbonates in presence of one another, and of such other substances as must have existed in the Permian sea. Both these speakers had referred to the 'breccia-gashes': he was convinced that the vertical 'breccia-fissures' had been produced at the end of the period of thrusting; but some of the triangular 'breccia-gashes' may have been caused by the falling-in of caverns, formed by the mechanical removal of softer beds or by their solution.

The thrusting in the Permian appeared to be directed towards a central area; the accentuation of the Coal-Measure basin of North-umberland and Durham beneath East Durham, as also the synclinal form of the Permian strata in the same area, was probably produced by it. That it was connected with some general movement of the North-of-England strata, as suggested by Prof. Garwood, seemed certain. The Author regarded it as having taken place between the Cretaceous and the Miocene Periods.