FAULTED SLATE.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE III. VOL. I.

No. I.—JANUARY, 1884.

ORIGINAL ARTICLES.

I.—A Faulted Slate.

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(PLATE I.)

IT is well known that the slates of the Borrowdale series in the Lake District furnish beautiful illustrations of faulting on a small scale; but so far as I am aware, no description of them, from this point of view, has as yet appeared. The accompanying Plate has been produced in Autotype from one of these slates, the surface of which was first most carefully smoothed and afterwards varnished. Every detail of the faulting is shown in the most perfect manner, and the general tint of the slate is also reproduced. The specimen was purchased at the village of Rosthwaite in Borrowdale; but I was not able to learn the exact locality from which it was obtained. I have little doubt, however, that it came from the Honister quarries. Mr. De Rance tells me that similar slates occur at Tilberthwaite, near Coniston. The plate is of the natural size. The face represented is a cleavage plane, and neither the bedding nor the fault planes are at right angles to this face. The bedding planes make with it an angle of about 40°.

Looking at the plate, the first point that strikes one is the conspicuous fault which slopes downwards from right to left. This will be referred to as the main fault. It produces a displacement of 3½ inches measured along the line of fault as this is shown on the plate. Running parallel with this main fault are several smaller ones, the most conspicuous of which occur in the bottom right-hand corner of the plate. All these form one series which will be described as the *B* series. Crossing this series at an angle of 35°, as measured in the plane of the face, is another series which will be referred to as the *A* series. Owing to the intersection of the two series, a number of typical trough faults are produced, and it will therefore be interesting to examine the different modes of explanation that have been proposed to account for such faults.

According to Prof. Jukes (Manual of Geology, p. 215), trough faults are produced during the bulging upwards of a mass of strata by the action of an upheaving force. Tension must arise in such a bending mass and intersecting cracks may be produced. As the elevation proceeds, the wedge-shape masses may slip down into the opening cracks, and a series of trough faults may arise. When the force of elevation has expended itself, a settling down of the mass will be likely to ensue, great lateral pressure might thus be produced, and any open cracks would become filled up. Such in brief is the theory which Prof. Jukes applies to the trough faults of the South Staffordshire Coal-field, and which Prof. Phillips had previously applied to the Malvern area.

In his work on the Geology of the Weald, Mr. Topley refers to the above theory, and at the same time points out a different mode of explanation, which is unquestionably true for certain faults to which he especially directs attention. He shows that if a district be faulted at two distinct periods, by faults which have the same general strike, but which are inclined to each other, then troughing must necessarily arise. This mode of explanation has one great advantage over that adopted by Professors Phillips and Jukes. It easily explains those cases in which the faults are clean cut; that is, in which there is no considerable thickness of fault rock. If the faults producing the trough were simultaneous, then the angle of the wedge would not usually correspond with that of the space into which the wedge is supposed to slip, and clean cut faults would be the exception instead of the rule. Of course the real test of the accuracy of Mr. Topley's mode of explanation is to examine the point of intersection of the two faults, and trace the earlier fault on the opposite side of the later one. This obviously is only possible when the faults are small.

Such being the two modes of explanation, it is interesting to examine the slate in order to see what light it throws on the question. A momentary glance is sufficient to show that Mr. Topley's mode of explanation gives a perfect account of the appearances there seen. Trace the faults of the *A* series in the top left-hand half of the plate. They terminate abruptly at the line of the main fault. Other and parallel faults occur on the opposite side, but they are not continuous across the slate; the smaller faults of the *B* series shift them again and again. The faults of the *B* series are therefore later than those of the *A* series, and the troughing is the result of the intersection of the two series. It is not necessary to suppose that any long interval of time elapsed between the formation of the two series. Indeed, I suspect that they are both connected with one and the same set of earth-movements, though I do not understand how it is that they are produced successively and not simultaneously.

It will be observed that the faults of this slate appear to be of the ordinary and not of the reversed type. It must be remembered, however, that we are ignorant of the position of the slate in relation to the horizon. If the bedding were horizontal at the time of the faulting, then the effect of the faulting would be to extend the mass in a horizontal direction; but if, on the other hand, the bedding were vertical, then the effect would be exactly the opposite. Whether this particular mass of rock was subjected to horizontal extension or to horizontal compression, or to some other kind of deformation, cannot now be determined. It is interesting to note that instances of what may be called reversed faults are common in these slates. They are described by Mr. E. J. Hebert in the Geol.

MAGAZINE for 1877, p. 441, as being more numerous than those of the ordinary type. A little consideration will show that the two types of faulting might be produced in one and the same bed. Suppose a given stratum of some thickness to be bent into a curve. A state of tension will arise on the outside, and one of compression on the inside. The two spaces in which these opposite conditions exist will be separated by a neutral plane.[1] If the strains be relieved in both cases by faulting—they may of course be relieved in other ways—then ordinary faults will be produced on the outside and reversed faults on the inside.

It would be extremely interesting to study these faulted masses in the field, and to trace the connection between the deformations which they have suffered and the more powerful earth-movements that have affected the rocks. Until this has been done, there are many points that must of necessity remain more or less obscure.

Of course the importance which the reader will attach to the present instance will depend on the view he holds as to the extent to which the general principles of rock deformation are illustrated by minute examples. For my own part, I must confess to a growing conviction that the essential points of both mountain- and low-land stratigraphy, to borrow expressions used by Prof. Lapworth, may be frequently studied in hand specimens.

II.—DESCRIPTION OF A FOSSIL SHARK (*CTENACANTHUS COSTELLATUS*) FROM THE LOWER CARBONIFEROUS ROCKS OF ESKDALE, DUMFRIESSHIRE.

By R. H. TRAQUAIR, M.D., F.R.S.

(PLATE II.)

THE deficiency of our knowledge of the organization and configuration of the Palæozoic Selachii is an unfortunate fact too well known to biologists to render it necessary for me to dilate upon here. Immense numbers of genera and species have been founded upon detached teeth and spines; but as yet very few specimens have occurred, which threw any light upon the general organization and configuration of the ancient possessors of these now scattered relics.

Among the many new and remarkable fossil fishes, which the Lower Carboniferous beds of Eskdale, Dumfriesshire, have recently yielded to the investigations of the officers of the Geological Survey of Scotland, as well as of other collectors, none are more interesting than an entire specimen of a fossil shark, acquired a short time ago by the British Museum. It was found at Glencartholm by Mr. Jex, collector to Mr. Damon, of Weymouth, and for the privilege of describing and figuring it, I am indebted to my friend Dr. Woodward, F.R.S., Keeper of the Geological Department.

The specimen is represented in Pl. II. Fig. 1 (reduced three-fourths), and presents us with a somewhat gracefully shaped fish, laterally compressed, with two dorsal spines, and a heterocercal tail.

[1] See A. Heim, Mechanismus der Gebirgsbilding, Band II. s. 17.