

median and anal are the only branched veins, and the former occupies almost the entire wing; its lowest branch originates close to the base of the wing (not seen in the specimen), and although it runs at a wide distance from the simple internommedian vein, it is only shortly before the middle of the wing that it throws off its first offshoots, which part from the branch at a wider angle than elsewhere in the wing; for nearly all the subordinate nervules are closely crowded together. The anal area extends far beyond the middle of the wing, is comparatively narrow, and filled with very longitudinal branches. Moderately distant cross-veins fill the wing, mostly straight and transverse, but in the broader interspaces irregular and often branching. The length of the fragment is 75 mm., and its width 40 mm. The outer margin is everywhere broken by reaching the end of the nodule, but the probable length of the wing was 130 mm., its breadth hardly, if at all, greater than is preserved. The expanse of wings of the living insect must have been somewhere from 250 to 300 mm., or somewhat more than ten inches.

The exact locality from which the specimen was obtained is not known, but Mr. Higgins says that it certainly comes from the Liverpool Coal-field. The rapidly increasing number of Carboniferous winged insects in other parts of the world should stimulate search in Great Britain, for the actual number of forms known to-day is probably double what it was fifteen years ago. These are the first *Protophasmida* recorded from Great Britain.

#### V.—ON THE SUCCESSIVE STAGES OF SLATY CLEAVAGE.

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SINCE a "shear" is mathematically the same as a compression in one direction with a *compensating* expansion in a direction at right angles to it, the consideration whether slaty cleavage can be ascribed to movements of this character resolves itself into the question whether the cleaved rocks have or have not suffered a total diminution of bulk. The most convenient way of treating the question is by discussing, as I did in my former paper (p. 15), the form of the "ellipsoid of distortion." The ellipsoid produced by a pure shear would be one of three unequal axes, of which the second or mean axis would be a geometric mean between the other two: whereas, if the expansion did not compensate the compression, the second axis would be greater than this geometric mean, and if the expansion were slight, the second and greatest axes would be nearly equal. The facts seem to accord with the latter supposition, and the diminution of bulk thus indicated agrees with what might be *a priori* expected.

Consider, for instance, the probable behaviour of a rock composed largely of fragments of long and flat forms, having initially no cleavage structure, and operated upon by a continued longitudinal pressure which for clearness we may imagine as operating in a horizontal direction. It appears manifest that the first result of such pressure would be a horizontal compression of the rock, involving

a corresponding decrease of bulk, and effected by the closer packing of the constituent fragments, accompanied by the expulsion of the greater part of the interstitial water. Such packing, facilitated no doubt by the fragments slipping over one another, would tend to arrange them in vertical planes perpendicular to the direction of the pressure, thus setting up a cleavage structure. The ellipsoid of distortion would be one in which the greatest and second axes would be nearly equal. This is the case in the Devonian slates investigated by Dr. Haughton.

But there must evidently be a limit to the process of packing just described, and when this was reached, since there could be no further decrease of bulk, continued pressure would give rise to a vertical expansion of the mass compensating the horizontal compression. The movement in this second stage of the process might be justly described as shearing. It would increase the greatest axis of the ellipsoid of distortion and proportionately decrease the least axis. At the same time it would produce a more perfect cleavage structure by arranging the long and flat-shaped fragments more exactly in vertical planes perpendicular to the direction of pressure. This is the case in the Llanberis and Borrowdale slates observed by Sorby and Sharpe.

As a still further result, a more intense pressure would probably bring about mineralogical and chemical as well as merely mechanical changes, the rock losing its eminently fissile character by becoming foliated. This connection between cleavage and foliation was long ago pointed out by Darwin in South America. The obliteration of fossil remains in such foliated rocks leaves us no means of testing the precise character of the distortion they have undergone, but the ellipsoid expressing such distortion would doubtless be excessively elongated and flattened.

The difference between the processes sketched above and the ideas developed in Mr. Fisher's papers in this *MAGAZINE* is evident. He maintains, in effect, that the whole movement which produced slaty cleavage in a rock was one of shearing. As regards Mr. Fisher's paper in the April Number, there is one point raised, to which, as he says, I have hitherto made no allusion, viz. the relation of cleavage to the folding of the strata in which it occurs. Mr. Fisher would argue that since the direction of the cleavage-planes seems to be almost independent of the varying dip of the beds, the origin of the cleavage structure must be posterior to the folding of the strata. Granting this, however, it does not follow that the two things were independent. As Mr. Fisher points out in the same paragraph (p. 177), they are two distinct modes of satisfying compression, and therefore we need not expect to find them proceeding simultaneously. That contortion of the strata should precede cleavage is a matter of no surprise, if the latter involve an actual condensation of bulk while the former is a mere change of position. In accordance with this we frequently find contortion without cleavage, but cleavage without contortion never. In many cases also there is clear evidence that contortion on a minute scale

is a first step towards a cleavage structure, which is rather different in character from that described at the beginning of the present article, though similar in its effects. This has been studied by Dr. Sorby in the slates of Liskeard and other places, and is described and figured by Heim under the name *Ausweichungscleavage*. I suppose Mr. Fisher refers to something of the same kind when he speaks of a frilled schist passing into a rock showing schistose cleavage (p. 176).

In conclusion, I should like to correct a misapprehension of Mr. Fisher's with reference to my former paper. I have always supposed the direction of cleavage to indicate the plane perpendicular to the maximum compression (*i.e.* the principal diametral plane of the ellipsoid of distortion), and not the direction of shearing (which would be, on Mr. Fisher's hypothesis, one of the circular sections). For a great amount of shearing, however, the two planes would make only a small angle with one another.

My diagram, like that of Mr. Fisher to which it corresponded, was not intended to have any relation to the surface contour of the land.

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## R E V I E W S.

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- I.—LITHOLOGICAL STUDIES, A DESCRIPTION AND CLASSIFICATION OF THE ROCKS OF THE CORDILLERAS. By M. E. WADSWORTH. (Memoirs of the Museum of Comparative Zoology at Harvard College, vol. xi. pt. 1, pp. 208 and xxxiii. plates viii.) Cambridge, Mass., Oct., 1884.

THE science of petrology, or petrography,<sup>1</sup> as Dr. Wadsworth would prefer to call it, has been cumbered, more perhaps than any other, by crude hypotheses and wide generalizations founded on slight bases of facts. To students weary with this kind of literature Dr. Wadsworth's *Lithological Studies* will be a welcome refreshment. The method of treatment is logical, which must command respect even if it failed to convince; the style is clear, and not seldom incisive. Dr. Wadsworth in controversy "calls a spade a spade," and bursts the bladders of tumid hypothesis with scant ceremony.

The present volume is but an instalment of a work which must extend to a considerable length. Its basis, as implied by the title-page, is the lithological collection accumulated by Dr. Whitney in the process of the (uncompleted) Survey of California, but in dealing with the more basic portion of these rocks in the present part Dr. Wadsworth has found it needful to carry his investigations far beyond the limits of the Cordilleras. The opening chapter treats briefly of the structure of the earth. The author thinks it probable that the inmost portion concerning which we have any data is composed of iron, with

<sup>1</sup> On the analogy of the names of all the other sciences there can, we think, be no question that this use of the term petrography, whatever may be the authority in its favour, is wrong. Dr. Wadsworth uses petrography as inclusive of lithology and petrology, the latter dealing with the characters of rocks observed in the field only: but surely this is merely petrography; the science is petrology.