33. Résumé du Tom. 2 de mon Ouvrage sur les Brachiopodes des Iles Britanniques. Bull. Soc. Geol. de France. 2nd series, vol. xix., 1862. 18 pages.
34. On the Lower Carboniferous Brachiopoda of Nova Scotia. Quarterly Journal Geol. Soc., 1863. 16 pages. 1 plate.
35. On recent and Tertiary Species of the genus *Thecidium*. GEOL. MAG., 1864. 10 pages. 2 plates.
36. On Maltese Tertiary Brachiopoda. Annals and Mag. of Nat. Hist., 1864. 10 pages. 1 plate.
37. Notes on the Carboniferous and Jurassic Brachiopoda collected in the North-Western Himalayas, Thibet, and Cashmere. Quarterly Journal Geol. Soc., vol. xxii. 1866. 10 pages. 2 plates.
38. On the Brachiopoda from the Carboniferous Limestone and Shales of the County of Cork, in the Museum of the Geological Survey of Ireland. Description of sheet 192 of the Map of Ireland. 1866. 4 pages.
39. Notes on recent Brachiopoda from Jamaica, etc. Proc. Zool. Soc., 1866. 3 pages. 1 plate.
40. On the Genus *Syringothyris*. GEOL. MAG., 1867. 5 pages. 1 plate.
41. On *Terebratulula venosa*. Annals and Mag. of Nat. Hist., 1867. 3 pages, and woodcut.
42. On the Earliest Forms of British Palæozoic Brachiopoda. GEOL. MAG., 1868. 14 pages. 2 plates.
43. On the Upper Silurian Brachiopoda from the Pentland Hills, etc. Trans. Geol. Soc. of Glasgow. Pal. series. 1868. 21 pages. 3 quarto plates.
44. Notes on Continental Geology. GEOL. MAG. for April, May, June, and July, 1869. 38 pages.
45. Note on the Age of the Rocks containing *Ter. viator* or *Diphyia*. Quart. Journ. Geol. Soc., vol. xxv. 1869. 3 pages.
46. Notes on Recent Mediterranean Brachiopoda. Annals and Mag. of Nat. Hist., 1869. 3 pages.
47. Notes on the Brachiopoda hitherto obtained from the Pebble Bed of Budleigh-Salterton. Abstract printed in Proc. of the Brit. Assoc. for 1869. The entire paper in the Quarterly Journal Geol. Soc., vol. xxvi., 1870. 19 pages. 3 plates.
48. On Italian Tertiary Brachiopoda. GEOL. MAG., 1870. 27 pages. 5 plates.
49. On Japanese recent Brachiopoda (ready for press), with 2 plates. 1871.

NOTE.—So that he has published up to this date some 2220 pages and 244 plates!

ORIGINAL ARTICLES.

I.—REMARKS UPON INVERSIONS OF CARBONIFEROUS STRATA IN SOMERSETSHIRE.

By HORACE B. WOODWARD, F.G.S., of the Geological Survey of England.

DURING the past few years Mr. Charles Moore and Mr. J. McMurtrie¹ have called attention to a remarkable inversion of strata, which was indicated by the working of coal under the Mountain Limestone near Vobster, on the north of the Mendip Hills. And this fact renders necessary an important modification in the geological sections of the district.

This inverted structure seems generally to be attributed to a

¹ C. Moore, GEOL. MAG. for July, 1866, p. 331, and Quart. Journ. Geol. Soc., vol. xxiii., 1867, p. 453. In the latter publication, referring to his interesting discovery of a trap dyke, near Stoke Lane, on the Mendip Hills, Mr. Moore remarks that, by its protrusion, the Old Red Sandstone and Carboniferous rocks have been carried forward in a northerly direction, and are not only left standing vertically, but

folding-over of the main ridge or anticlinal of the Mendip range, but no one, so far as I am aware, has been bold enough to represent the idea in diagram.

The subject is to a great extent theoretical,—the facts connected with it are not sufficient to render possible a definite solution of it,—but the strata are so remarkably disturbed, that it could hardly be otherwise. I have for some time been puzzled to draw a section that would satisfactorily account for the phenomena, and being led to differ from the prevalent notion, I venture to publish one, which I think will explain the general structure of the district. Or, perhaps, by exciting discussion, it may be the means of eliciting further information, and of thus obtaining more correct information upon the subject.

At Luckington and Vobster, near Coleford, three patches of Mountain Limestone appear in the midst of the Coal-measures. When originally mapped by the officers of the Geological Survey,¹ they were considered to be due to upheaval, bosses of the rock being represented in their Horizontal Sections as thrust up through the Coal-measures.² With the facts then observed, this was the safest theory to adopt, but now that coal has been worked beneath the Limestone a different theory is necessary to account for their position, and an inversion of some sort must be the correct explanation.

Inversions of strata are by no means new features in this district. In 1824 Messrs. Buckland and Conybeare pointed out that in the Nettlebridge Valley the coal-strata are sometimes in a vertical position, for at Pitcot a shaft was sunk in one bed of coal to a depth of eighty fathoms, while towards Mells they noticed the strata to be actually inverted, and occasionally so disturbed that at Vobster the same bed of coal was thrice passed through in a shaft.³

In reference to this subject, by far the most important contributions are those of Mr. McMurtrie.

In his paper on the "Faults and Contortions of the Somersetshire Coal-field," he mentions the folded and contorted strata of the Nettlebridge Valley, and he remarks that the amount of confusion

are in some instances folded over upon themselves. In illustration of this he mentions the working of coal beneath the Mountain Limestone of Luckington.

J. McMurtrie, "Faults and Contortions of the Somersetshire Coal-field," a paper read before the Bath Nat. Hist. and Antiq. Field Club, 24th Feb., 1869.

Mr. S. W. Brice, in his "Essay on the Coal-field of North Somersetshire," 1867, mentions that at Vobster branches have been driven right under the Mountain Limestone in search of coal. And he suggests that when the Mendip range was considerably higher than it is now, masses of the Limestone might easily have been dislocated from their parent rock, and have rolled down a species of inclined plane into the positions they now occupy.

¹ Two of these, the one at Luckington and the other at Upper Vobster, were laid down on the Geological Survey Map, sheet 19. During a re-survey of the ground, Mr. W. A. E. Ussher has carefully traced out the boundaries of the three. They were very accurately laid down by Mr. W. Sanders, F.R.S., in his "Map of the Bristol Coal Fields, and country adjacent," 1864.

² A similar section was given by Buckland and Conybeare. *Trans. Geol. Soc.*, series 2, vol. i.

³ *Trans. Geol. Soc.*, series 2, vol. i., p. 255. See also Conybeare and Phillips, "Geology of England and Wales," 1822, p. 428.

which the Coal-strata present is such as to baffle description.¹ From Holcombe to Mells the beds are inverted, and dip to the south at various angles, and he states that "at Nettlebridge every yard of the ground has been proved, and the gradation traced from the point at which the true northern inclination exists to where the abnormal southern inclination shows itself." From this he infers that the same disturbance which folded the Coal-measures back upon themselves carried with them masses of Limestone, of which the patches in question are traces.

He does not, however, attempt to explain this in the section he gives, merely drawing a patch of Limestone resting unconformably upon the inverted Coal-measures.

In attempting to account for these vestiges of Limestone, two theories suggest themselves. One, to which allusion has been made, is that the Mendip anticlinal was so folded over to the north as to bring the Mountain Limestone above the Coal-measures. But a serious difficulty at once presents itself. What has become of the Millstone Grit, which should occur between the two? No trace of this has been observed around any one of the three patches of Limestone.² The Grit is present in its regular position, but a mile off, thoroughly conformable, as there is a gradual passage between it and the Mountain Limestone below, and between it and the Coal-measures above.³ The thought occurs that it might have thinned out. That probably the area in which it was deposited was shallowing, and that this is not to be accounted for by increase of sediment alone, but must have been aided by elevation. That the elevation being of unequal intensity over the whole area, the Mountain Limestone might be raised above the sea-level in places, leaving the Grit to be deposited in patches. Afterwards the Coal-measures would entirely cover it, and overlap in places so as to rest directly upon the Mountain Limestone.⁴

But this is not a happy thought; there is no evidence whatever to support a notion that any portion of the Mendip area was above water whilst the Millstone Grit was in process of formation. Again, the Millstone Grit near Coleford has been estimated (by Mr. McMurtrie) to have a thickness of 500 feet; therefore, it could not well have thinned out in so short a distance. And it is no doubt persistent along the Mendip Hills, although the greater portion of it is concealed by the Keuper Marls and Conglomerates. It is

¹ It has been remarked that the disturbances in the Somersetshire Coal-field furnish "our nearest approach in Great Britain to the abrupt foldings which are so remarkable in the Coal-field of Belgium." (W. W. Smyth, etc.)

² And Mr. McMurtrie kindly informed me in a letter dated March 8th, 1870, that so far as he was aware the Millstone Grit has never been detected between the Limestone and the Coal-measures at Luckington and Vobster.

³ This gradual passage is clearly shown in Vertical Sections (sheets 11 and 12) published by the Geological Survey of England. Indeed, it is well known that from the Old Red Sandstone to the Coal-measures in this area, there is no physical break whatever.

⁴ On this subject, see also the remarks of Professor Ramsay, *Mem. Geol. Survey*, vol. i., p. 312.

exposed from Mells to near Ashwick; it was probably reached in a boring at Chewton Mendip;¹ Mr. Sanders has noticed a trace of it near Compton Martin;² and in the summer of 1869, I mapped traces of it near Wells, on the southern slope of the Mendips, where, however, it had previously been observed by Mr. Williams, of the Geological Survey. Being unaware of this at the time, I was much pleased to find my work corroborated.³

Having come to the conclusion that the Millstone Grit has not died out, we have still to account for its absence, and the aid of faults must be invoked in order to get rid of it.

But are there any facts to show that the main ridge of Mendip was folded over? Now, although the Coal-strata present every variety of disturbance, this is decidedly not the case with the Mountain Limestone and Old Red Sandstone. On the northern side of the Mendips they attain a much higher general inclination than on the southern side, and in one locality (near Stoke Lane) Mr. Sanders has observed the Limestone in a vertical position. But never, so far as I am aware, has it been noticed to be inverted along the borders of the Nettlebridge Valley, the average dip being between 60° and 70° in a northerly direction.⁴

The Coal-measures must not be taken as affording a type of the amount of disturbance which the district has suffered—the whole series of rocks would be bent and folded, but whilst under pressure the Mountain Limestone and Old Red Sandstone would be hard and unyielding, the coal-shales would be squeezed up and contorted in all manner of ways, as, indeed, they are now found.⁵

Mr. McMurtrie remarks that the "New Rock series," being chiefly composed of strong sandstones, does not present so much distortion as the other beds in the Coal-measures.

There seems to be no evidence in favour of the theory that the Mendip anticlinal was folded over, and the facts observed are against such a notion.

By introducing a fold further to the north, and by calling faults to our assistance, the position of these Limestone masses may, I think, be satisfactorily accounted for—and without resorting to any form of structure which is not already known in the Mendip area.

The accompanying section shows my attempt to explain the general structure.

¹ McMurtrie—Lecture on the Carboniferous Strata of Somersetshire, 1868, p. 14.

² Map of the Bristol Coal Fields, etc.

³ De la Beche, Mem. Geol. Survey, vol. i., 1846, p. 413.

⁴ *Vide* Sanders' Map. The only locality where anything like an inversion has been observed, is by the road-side at Churchill's Batch, at the western edge of the Mendip range. Proceeding along the high road in a northerly direction, the Mountain Limestone is seen dipping at a high angle to the north, then it becomes vertical, and a little further on the beds dip to the south. The whole is seen clearly in one section, and it forms an excellent example of "fan-shaped" structure. This was originally noticed by Buckland and Conybeare, who regarded it as a sharp synclinal. Mr. McMurtrie admits that the Mountain Limestone has not as a rule been folded back, regarding the Vobster patches as exceptions.

⁵ I find that the same idea is expressed by Conybeare and Phillips, *op. cit.*, pp. 347 and 360.

DIAGRAM-SECTION TO ILLUSTRATE MR. HORACE B. WOODWARD'S PAPER ON THE INVERSION OF
CARBONIFEROUS STRATA, SOMERSETSHIRE.

DIAGRAM-SECTION TO EXPLAIN THE OCCURRENCE OF MOUNTAIN LIMESTONE AT UPPER AND LOWER VOBSTER,
SOMERSET.

Scale about two inches to one mile.

The relative thicknesses of the formations, and their general dip, have of course received attention.

The fan-shaped anticlinal would have exerted sufficient force to produce any amount of contortion in the Coal-measure shales; the twisted beds to the south and the inverted strata on the north are well accounted for. The beds of course would not have stretched across the entire distance represented by the dotted line; great rents and fractures must have occurred, and while the beds, as is well known, were very much faulted, there is not much difficulty in imagining the little patch of Limestone at Lower Vobster to be the relic of a mass faulted into such a position—along with the Coal-measures which have been let down between the masses of Limestone.¹

In regard to the origin of the Limestone at Luckington, a similar and probable continuation of the same disturbance would account for it. As "reversed" faulting has been introduced, it should be mentioned that cases of this are not uncommon in the Mendip area. In the last volume of the *GEOLOGICAL MAGAZINE* attention was re-directed to a reversed fault at Uphill, near Weston-super-Mare, while in the Radstock Coal-field there are numerous "overlap faults," as they are termed, where seams of coal have been forced over one another, so that pits sunk on the spot pass twice through the same seams.²

The Millstone Grit has been inserted conformable to the Mountain Limestone on its northern side at Upper Vobster. This is purely hypothetical, for the surface is obscured by a covering of Inferior Oolite. As the beds are known to be inverted to the north, the Grit might very well come in between the Coal-measures and the Mountain Limestone. The explanation at any rate is as satisfactory as one that would cut it off again with the aid of another fault.

And now as regards the plan: two at least of the patches must be surrounded by faults. But considering the great disturbances to which the beds have been subjected, the dislocations must have been very numerous. Faults are known to be common; on the original theory the bosses of Limestone were surrounded by faults; therefore one need not be scrupulous about retaining them.

Of several varieties of structure I have drawn, the one now given appears to me the most satisfactory. The problem is as full of difficulty as it is of interest. It seems to me that the isolated patches of Limestone could not have been thrown over from the main anticlinal; the explanation I have drawn seems to accord with the known facts. And here I leave it, in the hopes that it may tend, in some degree, to the elucidation of the phenomena.

¹ This is the kind of structure so characteristic of the Alps—as noticed by Studer, Desor, Lory, and others.

² G. C. Greenwell, "Notes on the Coal-field of East Somerset." *Trans. North of England Inst. of Mining Engineers*, vol. ii., 1854, p. 255.

Greenwell and McMurtrie, "On the Radstock portion of the Somersetshire Coal-field." 1864. p. 17.

McMurtrie, "Faults and Contortions," etc.

The faults in the Somersetshire Coal-field are worthy of much study from their variety and remarkable characters. Mr. McMurtrie mentions an instance of beds thinning out towards a fault, a fact that may sometimes be noticed in the *Lias* where it is similarly affected.