18. *On the S.W. EXTENSION of the CLIFTON FAULT.* By PROF. C. LLOYD MORGAN, F.G.S., Assoc. R.S.M. (Read December 17, 1884.)

ON the right bank of the Avon, somewhat below the Suspension Bridge and a little beyond the Clifton station of the Bristol Port railway, the Clifton fault cuts across the strata somewhat obliquely. On the southern side of the fault is massive Mountain Limestone, forming the bold bluff of the Observatory Hill. On the northern side are much contorted red grit and limestone shales (see Map, p. 147).

Viewed from the opposite side of the river, the right bank, from the Suspension Bridge for half a mile northwards, shows the following features. The eastern tower of the Suspension Bridge is built on a solid mass of limestone, the western face of which fronts the river as an almost perpendicular wall of rock. At right angles to this, and parallel with the bridge-road, there is a second face due probably to a joint plane, or a minor dislocation of the strata parallel with that caused by the Clifton fault. This vertical face forms the southern boundary of a little recess in the rocks, in which lies the Clifton station. On the northern side of the station rises the somewhat dislocated mass of limestone which forms Observatory Hill, and which, on its southern side, abuts against Millstone Grit and Upper Limestone Shales brought down by the Clifton fault. The whole appearance of the side of the ravine now changes, and in place of vertical limestone cliffs there is a wooded slope. Close to the river, however, the rocks are well seen in section, and show bands of hard grit characteristic of the Upper Limestone Shales. These bands, passing under the Avon at the point marked *a* on the map, have hitherto caused a shallowing of the river at this point. Blasting operations are at present in progress by which this obstruction will be removed. Some 370 paces from the fault, solid limestone rises from the river-side (at *c*), but is, a little further north, cut into by a wooded notch (*b*) in which runs the path, known as the New Zigzag, which joins the road near Proctor's Fountain. This notch starts from the point of junction, at the surface of the downs, of the solid Mountain Limestone and the Upper Limestone Shales, which are, however, here unconformably overlain by the dolomitic conglomerate of the Trias.

The throw of the fault on this Gloucestershire bank I estimate at about 1150 feet vertically, which is some 350 feet greater than that given by Buckland and Conybeare (Trans. Geol. Soc. 2nd series, vol. i. p. 241), and by W. Stoddart (Proceedings of the Bristol Naturalists' Society, new series, vol. i. p. 328). On the Somersetshire bank I make the throw 50 feet less. This difference may be due, in part at least, to the dying-out of the fault in that direction. Taking as a datum-point the intersection of the line of fault and that of high water on the Gloucestershire side, the rocks which have been relatively shifted downwards are Mountain Limestone, about 710 feet, and Upper Limestone Shales about 440 feet. If we take

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Sketch Map to illustrate the Western Extension of the Clifton Fault.
(Scale about $2\frac{1}{2}$ in. to 1 mile.)

Mr. Stoddart's estimate (Geol. Mag. vol. ii. p. 83) of the thickness of the Upper Limestone Shales at 600 feet, which I think is a fair one, there will be 160 feet or so of these beds above high-water mark, above which the Millstone Grit will be brought down. This accords very well with the facts, that contorted grits and shales are seen from the new road some 50 or 60 feet above high-water mark, and that above this little but grit is to be found. It must be remembered, however, that the beds in the immediate vicinity of the fault on the down-throw side are exceedingly contorted.

A curious effect of the general squeeze by which the rocks here are literally "in one red burial blent," is well shown in the immediate neighbourhood of the line of fault on the Gloucestershire side of the river. Here, over a face of limestone dipping 18° N., has been thrust a semicircular mass of rock with an external layer of grit, then a band of limestone, and internally a core of grit.

Further eastward on this same Gloucestershire, or Clifton, side of the Avon, the effects of the fault on the physical features of the country are well marked, causing the well-defined depression in which lie Triassic beds between the Clifton Downs (with its tongue-shaped mass of limestone stretching westward from the Suspension Bridge) on the south, and the northward-trending limestone mass of Durdham Downs on the north. (See map.)

Passing now to the opposite, or Somersetshire side, we find the following features, as seen from such a standpoint as the Observatory Hill. A little to the north of the Suspension Bridge is the deep indentation of Nightingale Valley, the southern side of which is here precipitous, and answers to the vertical face which forms the southern boundary of the station-recess on the Gloucestershire side of the river. The northern side of the valley is less precipitous, forming, in fact, more or less of a dip slope of limestone. A hundred and fifty yards or so further north is another precipitous face of limestone, that caused by the fault. After this, as we pass northwards, there is, on this side of the river as on the Clifton side, a wooded slope. The solid limestone rises from the river-side at a distance of some 240 paces from the faulted limestone face.

Owing to the fact that the fault cuts across the strata obliquely, lower beds of the Mountain Limestone are intersected on this side of the Avon than were cut on the Clifton side. Hence the rocks relatively shifted downwards at the point of intersection of the line of fault and the line of high water here are Mountain Limestone, about 780 feet, and Upper Limestone Shales about 330 feet, making a relative displacement of 1100 feet. Remembering that the Upper Limestone Shales are some 600 feet in total thickness, this leaves 270 feet of these rocks, which would thus just extend to the top of the cliff. Under these circumstances we should not expect to find Millstone Grit faulted down on this side of the river. Nor have I on careful search been able to discover any beds of this rock. At the point marked *b* on the map, however, I have found well-defined bands of grit interstratified with limestone, showing that we here have beds of the Upper Limestone Shale.

In Messrs. Buckland and Conybeare's paper on the S.W. Coal-district (Trans. Geol. Soc. 2nd series, vol. i. p. 242), attention is drawn to the fact, "that the fault may be traced up the gully which bounds the northernmost of the two Roman camps in Leigh Wood." Beyond this suggestive observation I am not aware of any published account of attempts to trace the further south-western extension of the fault. But since the Upper Limestone Shales faulted down are softer than the solid limestone, we might very probably, so it seemed to me, find a *line of depression* marking the line of fault and running south-westward from this gully. Such a line of depression actually exists; and I have ventured to mark it in the accompanying map as Upper Limestone Shales. It runs from the neighbourhood of Hill Farm across Beggars' Bush Lane, through the northern corner of the Ashton Park estate, across the Abbots Leigh road, in which the depression is well marked, and so to the head of Nightingale Valley, along which this natural line of drainage then passes, deserting the line of fault, which crosses Nightingale Valley about halfway up, and so passes to the gully mentioned by Messrs. Buckland and Conybeare. It is interesting to notice that the point where the fault crosses the Nightingale Valley is indicated by a well-marked change in the physical features. Up to that point the ascent is steep; beyond that point it is much more gradual. Up to that point the southern (left hand) side is precipitous, beyond that point it has a more gentle slope. Up to that point the valley is a deep notch, beyond that point it widens out. These changes result from the bringing in of the softer rock by the downthrow of the fault.

Another point is of interest. West of the point I have just alluded to, a triangular wedge of limestone is cut off by the line of fault and the line of the valley, which intersect at this point. (See map.) This triangular wedge of limestone formed too marked a natural feature to be missed by the Britons, who accordingly strengthened it by building a vallum along its faulted side; so that the line of this Stoke Leigh Camp (marked "camp" on the map), as suggested by Buckland and Conybeare, shows roughly the line of the fault.

I have before mentioned that beds of grit belonging to the Upper Limestone Shales are found on the Somersetshire bank at the point marked *b* on the map. Where the Upper Limestone Shales come in on the north side of Nightingale Valley, I have, however, not succeeded in finding any definite bands of grit, though fragments of siliceous rock are abundant. Near the head of Nightingale Valley, at *c*, beds of clayey shale are exposed. And in the Ashton Park grounds, across the north corner of which I have been able, through the kindness and courtesy of Sir Greville Smyth, to follow the line of depression, there are some quarry-pits, at *d* (see map), in which white clayey bands are interstratified with bands of limestone. And, yet further to the south-west, in the fields that lie between Beggars' Bush Lane and Hill Farm House, there are many sandstone fragments mingled with stones of Mountain Limestone.

Before reaching Hill Farm the depression ceases or widens out somewhat indefinitely. This is what we should expect. For since the line of fault cuts across the strata obliquely, thus cutting lower and lower beds of the Mountain Limestone, and since the fault shows signs of dying out in this S.W. direction, a point must be reached when, instead of Upper Limestone Shales being faulted down against limestone, beds of Mountain Limestone are faulted down against lower beds of the same rock. And since it is only by the bringing in of the softer beds that the line of depression is produced, when these beds are no longer brought down to the present surface-level by the fault, the line of depression ceases.

I thought it worth while to calculate the distance at which the fault would cease to bring down Upper Limestone Shales to the present surface-level, on the supposition that it shows no tendency to die out in this direction. Supposing that the 600 feet of Upper Limestone Shales are just faulted down in the Leigh Woods, on the Somersetshire bank of the Avon, the breadth of surface covered by these beds, at a dip of $27\frac{1}{2}^{\circ}$, would be about 1300 feet. The strike of the strata is 65° east of north, and the direction of the fault is 70° east of north. The fault therefore cuts the strata at an angle of 5° . At such an angle the 1300 feet of Upper Limestone Shales would gradually thin out, wedge fashion, as we pass westwards along the line of fault,—the point of the wedge, where the Upper Limestone Shales cease to come to surface, being about 4300 yards from the Avon. But Hill Farm, where the depression before alluded to ceases, is, according to Mr. Sanders' map, not more than 2200 yards from the Avon. The difference I believe to be evidence of the dying-out of the fault in this direction.

Beyond Hill Farm there is no means of tracing the fault. A quarry a little beyond the farm, at *e* (see map), shows no sign of shaly or sandy beds. But it is worthy of note that if we produce the line that is marked by the Upper-Limestone-Shales depression, in a west-south-west direction, until it cuts the junction of Mountain Limestone and Lower Limestone Shales, we find at this point a great confusion of dips. Within a couple of hundred yards or less we find 42° E.N.E., 25° S.S.E., 22° S., 10° W., 10° E.N.E. Still this represents but poorly the 1150 feet of throw on the Gloucestershire bank of the Avon. If the fault have not practically died out as such, we should expect, here in the neighbourhood of the junction of the softer Lower Limestone Shales and the harder Mountain Limestone, some more marked evidence of its existence. The only further evidence of this kind which I have found, and I do not wish to lay any great stress upon it, is this: that at a point a little to the north of the confused dips, in the midst of the line of depression that marks the Lower Limestone Shales, there is an island of Mountain Limestone, at *f* on the map. Owing to its existence Mr. Sanders, in his map, has carried his Mountain Limestone boundary-line outside this, so as to include it in the Mountain Limestone. But I would suggest, as possible, that this island of Mountain Limestone in the depression is the remnant of a wedge of this rock faulted into the Lower Lime-

stone Shales, there being also a corresponding wedging of the Lower Limestone Shales into the Mountain Limestone as indicated by the S-shaped boundary-line in the map. And I may mention that I have some evidence of the prolongation of the Mountain-Limestone wedge still further westward into the Old Red Sandstone.

In conclusion, I would draw attention to the fact that the marked north-east trend of the Mountain-Limestone uplands from the point of confused dips just alluded to, is undoubtedly, in part at least, caused by the Clifton fault; and to the further fact that the line of this fault is, roughly speaking, parallel with that of the great Clapton-in-Gordano fault. Messrs. Buckland and Conybeare suggested that "it is not improbable that the two may be connected;" but of this there is no direct evidence.

DISCUSSION.

Dr. EVANS thought the paper was one of great value; he asked if there were not proof of the existence of more than a single fault.

The AUTHOR said that at present he could find no proof of the existence of a fault in the line of the Avon gorge; the principal fault is nearly at right angles to the line of the river. In answer to the Chairman he said that to the east the fault was obscured to some extent by the overlying Trias.