But the above tree-like form was not the whole of the discovery. Imbedded likewise in the ironstone, and occurring for the most part near the walls of the place, and low down, were numerous twig-(?) like remains. These are of a harder nature than the trunk mass—they are in better preservation—and in some specimens exhibit beautiful minute striation, with what seem to me to be little scars arranged in a uniform pattern. They are well worth collecting, are not very scarce, and the miner's hammer will bring out good examples.

The cleft, whence all that was of interest has long been removed, is now partially filled with mining refuse and rock debris. In the eastern end of it a shaft was sunk upwards of forty feet further, passing through decomposed limestone containing one bed of ore. From the shaft, adits have been driven beneath the floor into sound limestone generally, with here and there decomposed portions tinged with the mineral. The marketable product, associated with the fossils, was the soft red oxide, found in layers of from one to seven or eight inches thick between the hard beds of ironstone, several hundred tons of which had been gained. Lamination is sometimes finely shown in blocks from the hard beds, and cleavage-planes, at right angles to the bedding, set with glittering crystals of iron-stained quartz.

Narrow fissures in the limestones near, open to the drift, have revealed other curious forms of hæmatite, but whether they also are of vegetable origin, I am unable to say. Their chief peculiarity is a kind of foliation, ascribed by some observers to heat, but which I would suppose might be the result of great pressure: they are unlike any varieties I have ever seen in Furness.¹

V.—ON FAULTS IN STRATA.

By W. T. BLANFORD, A.R.S.M., F.G.S.

MY friend and colleague, Mr. H. B. Medlicott, published, in the August (1869) number of the GEOLOGICAL MAGAZINE, a paper "On Faults in Strata," in which he endeavoured to show that the evidence usually accepted for faults, in the true geological acceptation of the term, is insufficient; that a large number of the lines of junction between rocks of dissimilar age, usually mapped by the Survey of Great Britain and other Surveys as "faults," are, in truth, natural junctions, due to deposition against cliffs or other steep surfaces; and that direct evidence of friction is necessary to establish the existence of a fault. The latter is rather left to be inferred than positively asserted; nevertheless it is very clearly intimated that it is the writer's opinion.

I have expected in vain that some member of the Geological Survey of Great Britain would have defended the system of mapping adopted in that Survey, but hitherto no one has replied to Mr.

¹ Two articles on the subject appeared in *The Grange Visitor*—a weekly newspaper for 1868, D. Atkinson, printer, Ulverstone—by Mr. J. P. Morris and Mr. Samuel Salt.

Medlicott's remarks. The subject is one of very great interest and importance, indeed it may be said to be a fundamental question in Geological Surveying; and, as I differ in opinion from Mr. Medlicott, I wish to offer a few remarks in defence of the faults.

The first point upon which I should join issue with Mr. Medlicott is his demand for direct evidence of friction surfaces or *slickensides*. I have not myself noticed these, as a rule, in undoubted faults—I mean faults exposed in cliff or mine-sections, in which the beds are distinctly seen at different horizons at the opposite sides of the fault—and I believe that my experience in this respect will be corroborated by most field-surveyors. Mr. Medlicott refers to the parallel case of glacial action, but to this I object entirely, for two reasons:—

1st. The circumstances under which friction-surfaces produced by glaciers become visible involve the partial or total disappearance of the glacier—a process not necessarily attended by any important weathering of the rock-surfaces against which the glacier impinged; but the removal by denudation of a large portion of the rock from one side of a fault, without any weathering of the opposite surface, is almost an impossibility. In ninety-nine cases out of a hundred, the rocks on both sides of a fault weather evenly, or nearly so; the harder rock rising from the line of fault gradually. In order to find the parallel to this, the rock bounding a glacier should be removed *pari passu* with the glacier itself, no bergschrund or fissure intervening. Under these circumstances it would be rather a difficult matter to find *roches moutonnées*, or grooved and polished surfaces.

2nd. The polished and grooved surfaces, which prove the former existence of glaciers, are invariably on the hardest and least easily weathered rocks, and are, geologically, of recent origin. No one supposes that any such evidence could now be found, even of Pliocene glaciers; but faults are of all ages, the vast majority being Pre-tertiary at least. Again, every field geologist, who has worked in countries where granitic and other crystalline rocks occur, must have noticed the remarkable manner in which smooth surfaces, freely exposed, resist weathering. Blocks of granite may often be seen, the upper exposed surfaces of which are fresh and unaltered, whilst the sides and lower surfaces, which have been in contact with turf soil or other masses of rock, are much disintegrated. The former, free exposure, is the condition of the glacier-worn surfaces, most of which are on crystalline rocks; they have never been exposed to any more destructive influence than that of pure water in the shape of rain: the latter, that of contact with other rocks, is the condition of the polished or grooved surfaces in a fault. Moreover, a fault is usually more or less a plane of percolation for waters, often, if not invariably, charged to a certain extent with gases and salts in solution, and thus capable of effecting a chemical change in the rocks percolated, which will certainly destroy friction-surfaces; and these destroying influences have, in the vast majority of faults, been at work, not since the glacial epoch merely, but through the countless ages of geological time which have elapsed since the Mesozoic or even the Palæozoic formations were consolidated.

For these reasons I believe that friction-surfaces in faults rarely exist, and can still more rarely be seen ; and I believe a false principle will be introduced into geological surveying if their existence be demanded as the only *direct* proof of faulting.

The next point upon which I differ from my friend is the confusion which, in his opinion, exists between lines of fault and abrupt boundaries caused by deposition against steep surfaces of older rocks. In my opinion these can but rarely be mistaken for each other, and for this reason ;—

Scarps and cliffs, throughout the world, rarely, if ever, are either straight or composed of a series of straight lines. Almost invariably they are much curved, indented, and cut back every here and there by valleys. Now the essential character of a fault is that its direction approaches a straight line, or is formed of a number of straight lines meeting each other at angles, usually open or obtuse, rarely or never in deep curves. The straightness of a line of boundary is, I think, by most geologists considered far more important evidence of faulting than friction surfaces ; and it has the enormous advantage of being more easily demonstrated. Now this most important point is entirely omitted by Mr. Medlicott, who does not even refer to it ; and yet it is by this character that the great abrupt lines of boundary, which are so remarkable a feature in certain Indian deposits, and which almost invariably limit the principal Indian coal-fields, on one side at least, have been by myself and several of my fellow-surveyors attributed to faulting—a view which Mr. Medlicott disputes. Unless I am greatly mistaken, this character is also considered essential by Professor Ramsay and the officers of the Geological Survey of Great Britain.

Unquestionably Mr. Medlicott's warning against carelessness in assuming all abrupt boundaries to be faults, merely because there is evidence of crushing, is just ; and I believe that many instances have occurred, where the boundaries in question are obscure, and their length and the apparent throw inconsiderable, in which mistakes have been made ; but these mistakes will, I believe, usually be found to be of small practical or scientific importance. It is not at all my intention to enter into the question of the great lines of abrupt boundary on the flanks of the Alps and Himalayas. Mr. Medlicott's evidence is, in the latter case, for a portion at least of the boundaries, incontestable. But I object to his illustration from the Garo hills. Because he in one spot found a natural boundary, it does not seem to me a logical inference that there is no fault at all. He admits there has been great and abrupt "relative movement." It should not be forgotten that observations at the base of the Garo hills are made in pathless jungle-forest, of a kind of which European geologists can have but a faint conception—where an elephant may be standing within two yards, and yet be utterly invisible—in the densest of under-wood beneath thick high trees, where, as a rule, rocks are only to be seen in stream sections. In such ground, especially, the presence or absence of a "master-fault" would, to my mind, be entirely dependent on the form of the boundary, straight or curved ; and if the

boundary were straight, I should conclude that the discovery of such a natural junction as that described by Mr. Medlicott proved, not the absence of a fault, but simply that in that spot the newer rocks had been denuded away from the neighbourhood of the fault, and the natural boundary exposed. I do not mean for an instant to assert that this is the case at the foot of the Garo hills; all I contend is, that the evidence offered does not, to my mind, disprove the existence of a fault.

Chanda, Central Provinces of India, Jan. 3rd, 1870.

VI.—ON FAULTS IN STRATA.

By G. H. KINAHAN, M.R.I.A., F.R.G.S.I., &c.

THE acute observation of the late Professor J. Beete Jukes, combined with his power of reasoning from Nature, and by Nature's laws, enabled him at once to be capable of explaining the relations of complicated strata, over which others might puzzle for months: neither was he unwilling to impart his knowledge to others, for nothing seemed to give him greater pleasure than teaching and explaining away difficulties, by pointing out the similarity between the former and present agents at work fashioning the surface of our earth.

In Mr. Medlicott's paper "On Faults in Strata,"¹ similar arguments to many of those of this eminent geologist, against the indiscriminate use of faults, are given. Moreover, Mr. Jukes often impressed on his assistants that which is here so well put forward by Mr. Medlicott—"The result may look very well, but it will leave us no wiser as to the natural history of the rocks."

At the present day, the marginal rocks of groups, now in the course of formation, are as often being deposited at the base of, or against, a cliff as elsewhere; and if now, why in the ages long past should not similarly placed rock have been formed? That they should exist seems probable, and the following instances in Ireland, worked out under the superintendence and with the able assistance of Mr. Jukes, may be mentioned. In the county of Limerick, limestone and other rocks of the Carboniferous age are deposited against masses of contemporaneous Igneous rocks.² In Slieve Bloom, the mountains at the border of the Kings Co., in the hills southward of Nenagh, Co. Tipperary, in Slieve Aughta, the mountains at the junction of Clare and Galway, &c. &c., the basal sandstones and conglomerates of the Carboniferous period [or the Old Red Sandstone] were deposited against cliffs of Lower Silurian rock³; while in the promontory of Dingle, Co. Kerry, the basal bed ["the Inch conglomerate"] of "the Dingle beds" is deposited against and at the base of ancient cliffs of Silurian rocks⁴; and in the country adjoining the north part

¹ GEOL. MAG., Vol. VI., p. 341, August, 1869.

² Memoirs of the Geological Survey, Maps and Explanations of Sheets 143, 144, 153, and 154.

³ *Ibid*, Maps and Explanations of Sheets 118, 124, 125, 126, 127, 134, 135.

⁴ *Ibid*, Maps and Explanations of Sheets 160, 161, 171, 172.