

## ON THE NEW GEOLOGICAL SURVEY OF DARTMOOR.

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IN the course of my occasional geological communications to the Devonshire Association, especially since 1889, I have often sincerely regretted the general avoidance of criticism and mutual correction; as one result of this seems to be that geological literature tends towards becoming more and more an undigested record of independent and often discordant opinions.

Last year the Memoir of the Geological Survey, on the Geology of Dartmoor, was published; compiled from the notes and observations of eight distinguished geologists.

This new Survey Memoir, on the Geology of Dartmoor, provides for me the long-desired opportunity of comparing my own local observations with those of more experienced and specially trained workers.

There are, however, one or two special advantages enjoyed by those resident in any particular locality. An immense amount of detailed, and often trivial, evidence is repeatedly brought before them, which visitors in the district will probably not have the chance of seeing at all. This evidence is occasionally exceptional and apparently conflicting, not to say contradictory.

I have always received the greatest assistance and courtesy from the officers of the Survey, both officially and individually, and any comments I may have to make will be offered in the friendliest spirit possible. Indeed, my interest in the subject is largely owing to the fact that Dr. Teall, when petrologist of the Survey, lent me a collection of the Jermyn Street slides to study at my leisure.

I will first refer to a somewhat important slip due to a pure oversight.

In describing the Normal Granite, Messrs. Flett and Dewey write—"It is remarkably rich in inclusions, which have been described by Sorby and Hunt. They contain a mobile bubble, one or more cubical crystals and sometimes two distinct fluids one within the other" (*loc. cit.* p. 40). Reference is made to my paper in the *Geological Magazine*, 1894, p. 97.

In that paper, p. 103, I figure in one illustration five groups of inclusions, viz. (1) Quartz in Culm state; (2) quartz in Trowlesworthite; (3) quartz in granite trawled in the English Channel; (4) Normal Dartmoor Granite, Heytor quarries; (5) liquid inclusions in Apatite, enclosed in quartz in Trowlesworthite. Of these five specimens, only one is of Dartmoor normal granite; and No. (3), the one with two liquids, is specifically stated to be figured "*for comparison*" (p. 104).

I have always maintained that two characteristics of Dartmoor granite are: first, the very general *presence* of common salt throughout the whole district, and second, the apparent *absence* of any trace of carbonic acid, which is the only second liquid I have ever myself seen in an inclusion.

Dr. Sorby no doubt laid great stress on double liquids and saline inclusions, but I do not remember that he recorded any occurrence of double liquids in the Dartmoor area.

The precise significance of the presence or absence of gases and liquids, still remains to be ascertained. At present the facts may be recorded for possible future use.

My own connection with the Dartmoor problem is very much that of an outsider. As such I have endeavoured to obey, and follow the trumpets; but they have given forth sadly uncertain sounds. In recounting my own experience, I do not wish to seem unduly frivolous when dealing with so serious a subject. But I feel like a bewildered puppy quite unable to locate the direction whence the whistle comes. To explain. When Mr. W. A. E. Ussher was surveying the district south of the Moor in or about 1888, he was very much perplexed as to the relation of the granite to the sedimentary rocks, and, in a paper to this Association, he suggested a laccolithic origin, just as a working hypothesis, until further information could be obtained by others who might not suffer like himself

from "a lack of light on the subject" (*Trans. Devon. Assoc.*, Vol. XX, p. 157).

By the time he had got other geologists well in tow after his laccolitic tug, Mr. Ussher entirely abandoned the idea as untenable; and he openly scouted it on the occasion of the Geologists' Association's Dartmoor excursion in 1899, when I had the privilege to act as guide.

Now, in the Memoir on Dartmoor, we read:—

"This granite probably forms a gigantic laccolite or intruded lake of molten rock, of which the upper surface was no great height above the present surface of the Moor . . ." (p. 27).

As the elvans penetrate the adjacent, and the assumed overlying, carboniferous rocks, and the Permian sandstones were not in existence, I cannot understand myself how that single rock-formation avoided falling into this liquid lake: for very liquid it must have been if we may judge from the way that the granitic material occasionally penetrates the culm rocks, through joint planes apparently in contact. To avoid this difficulty I suggested the possibility of an ancient foundation-granite, reconstituted in Carboniferous times. The idea being to obtain some foundation on which to deposit the sedimentary rocks, and also to account for the fine granites which invade both the normal granite and the sedimentaries. I am not myself sufficiently conversant with stratigraphical geology to understand why the Geological Surveyors have adopted the hypothesis which their former surveyor deemed inadequate. But in addition to the laccolitic and foundation-granite ideas, Mr. R. N. Worth proposed his well-known suggestion that the Dartmoor granite was the source of supply of a great volcano of which the present granitic area is the basal remnant.

Lieut.-General McMahon, in 1893, while criticizing Mr. Ussher, suggested that the marginal fine-grained granites were caused by "traction and friction against the sides of the vent [which] broke up the larger crystals and increased the heat, and consequent fluidity" (*Q.J.G.S.*, Vol. XLIX, p. 393).

This purely volcanic explanation is to my mind summarily vetoed, by the evidence of the liquid inclusions that the temperature of the granitic magma was not volcanic; at any rate on the eastern side of the granite exposure.

However, "be as't will," as Devonians say, the Survey Memoir makes no attempt to judge betwixt Mr. R. N. Worth, Lieut.-General McMahon, and myself, or to combat any difficulties; but falls back on a probable laccolite. We are thus officially where we were five-and-twenty years ago.

Some of the suggestions made in the Survey Memoir seem to me most illuminating and explanatory, such, for instance, that of snow-slides: but many of the conclusions seem to me at variance with those I have arrived at and expressed since 1889.

As this Association may reasonably call me to account for the views I have published, I will endeavour to review a few of those of most importance.

The report of the excursion of the Geologists' Association, for which report I am partly responsible as the sole guide mentioned, will afford a concise basis to start from.

In the Memoir we are told, at the outset, that "in no case do the later veins and masses appear to have been intruded after the earlier masses had cooled. They therefore blend and pass into each other at the margins in a very characteristic way" (p. 27).

Now the occasional absolutely sharp contacts have always been a strong point with me; and the following note will be found in the excursion report:—

"Leaving Water Rock the party proceeded by . . . the Rev. Preb. Wolfe's private drive . . . noticing on the way a remarkable contact of fine and coarse granite in a roadside block . . ." (*Proc. Geo. Assoc.*, 1900, p. 430).

The above is one of the cases of absolutely sharp contacts without any blending or passage whatever. Both in the Dartmoor and Cornish granites these contacts are sometimes sharp even in microscope-sections.

They are sometimes practically as sharp in the granites as in the culm slates, and also as in the single elvan dyke I discovered in the greenstone south of Lustleigh, on Rudge Farm. Which was the newer in the aforementioned case, coarse granite or fine, did not appear.

The report of the Lustleigh Excursion occupies just under two pages of print, but in that limited space attention is called to the following points of interest, viz. :—

1. Abrupt contact of elvan with culm rock.
2. Contact of fine and coarse granite.

3. No distinct evidences of glacial action (Mr. Somervail).
4. Rounded rubble in Peck Pits.
5. Felspar-quartz-schorl vein : the minerals being those of the elvans, but the structure not granitic.
6. Two small and deep rock basins ; formed by the solvent action of rain-water, probably acidulated by the decay of lichens and other vegetation.
7. Split block displaying (a) concretions of two sorts, (b) latent planes of weakness, (c) dissolution of orthoclase crystals, (d) twin crystals of orthoclase, and (e) rearrangement of minerals.

One fact, not recorded, was the 'fine-grained crystalline rock at "Water Rock," with the perfectly idiomorphic microscopic tourmalines ; figured in my Devonshire Association paper in 1889, p. 260.

Here we have a round dozen of Dartmoor problems submitted to the Geologists' Association in 1899. My undertaking on that day was solely to act as guide. I selected a picturesque walk, and pointed out facts of interest ; but without comment.

So long as geologists absolutely denied the original character of Dartmoor tourmaline, and the low temperature crystallization of granites, I had no common basis from which to start. After indicating the split block of granite, displaying the five features enumerated under 7, I resumed my rôle of timekeeper and guide, and sat on a rock till the moment arrived to start for the station. There was nothing else to do under the circumstances : absolutely nothing. My views were unorthodox and would be considered absurd, but seeing that my welcome guests would scarcely have been free to express their feelings in adequate terms, I avoided all expression of heresies.

One of my contentions, and perhaps the most important one, has been that in both the veins and in the granites tourmaline occurs as an original mineral.

So late as 1909 my friend Mr. A. Harker, F.R.S., wrote :

"A well-known type of pneumatolysis in granites is tourmalinisation" : and further, that, "more usually it is produced at the expense of the mica and felspar" (*The Natural History of Igneous Rocks*, p. 301).

In the Memoir Messrs Flett and Dewey remark on "the scarcity on Dartmoor of those minerals that imply the pneumatolytic action of vapours . . . of these the prin-

incipal are white mica, tourmaline, topaz, and fluor spar" (p. 38). They point out the scarcity in the typical Dartmoor granite of white mica, topaz, and fluor spar. *Per contra* we may point to the ubiquity of tourmaline, as evidence that it is not in this case the product of pneumatolysis, whatever that conventional term may exactly mean; for it certainly does not mean what it says, as gases do not dissolve solids.

I have never myself seen a case, in the typical Dartmoor granite, of tourmaline replacing mica, but it quite satisfies me to find the Survey Memoir stating categorically, with reference to the "Eastern area," that, "Schorl, however, is common in many of these veins and appears to be an original constituent: it also occurs as an original constituent in the normal granite" (p. 32).

### *Tertiary and Drift.*

Under the above heading, the Memoir explains the presence of "tumbled rocks," at a little distance from their source, by the former presence of snow-slopes. This suggestion seems to me most illuminating; and it will dispose of one or two very knotty problems.

The large area, amounting to acres, of immense masses of granite between Foxworthy Bridge and Horsham Steps (where, except when in flood, the river passes entirely out of sight) has been to myself absolutely inexplicable.

Our member Mr. Harford J. Lowe is quoted as having suggested that the rocks were swept together by a rush of water when a small stream then passing through the Lustleigh Cleave Valley "captured" the Bovey, then passing in a different direction: but these acres of loose rocks, both in the river-bed and buried in the adjacent slopes, occur at the commencement of a rapid drop in the stream, which drop succeeds a nearly level stretch of valley-deposits. There seems nowhere whence the rocks could come from up the valley, and no imaginable current that could propel them along the valley-flats. Further, a still more exaggerated collection of blocks is that at Becky Falls, where there was no neighbouring river to capture. Now the whole course of the Bovey, from a little above Foxworthy to nearly the bottom of the Lustleigh Cleave Valley, is at the foot of the much-jointed and

shattered granite of the Lustleigh "Cliff," which is the meaning of Cleave. Snow-slopes would exactly supply the machinery to deposit these blocks at the bottom of the valley, and on the way there: just exactly as and where we see them to-day.

Reference is made to a small patch of gravel (which has been mapped), lying between Hunter's Tor and Barnecourt Farm. I believe I was the first to call the attention of geologists to this gravel, which is quite near Foxworthy. In the report of the Dartmoor Excursion in 1900, the following record will be found: "The Director, with the vanguard of the party, pressed on to examine some large mounds of rounded rubble in Peck Pits . . ." (*Proc. Geo. Assoc.*, 1900, p. 431). I may mention incidentally that as about forty were expected to tea, and about seventy-five came, that diversion was a device to lessen the strain on the hot water and teapots!

This gravel seems rather over one hundred feet above the level of the Bovey, where the rubble is of exactly the same character. The Memoir states that "the deposit has been worked to a depth of about thirty feet for stream tin, but the diggings are now full of water" (p. 65). There is a large and picturesque pond there, once termed by a countryman "a ghastly place." It has occurred to me that this pool may have been adapted and arranged as the chief watering-place for the great "British" Camp on the top of Hunter's Tor. So long as that bulwark held out, the watering-place would be quite safe.

The Survey have independently come to a similar conclusion as to the rubble as myself. They can neither accept the two views proposed, nor put forward any alternative. "We [the Surveyors] can only say that the gravel exists, bears every appearance of being due to river action, and is situated at the margin of a well-marked portion of the 800-foot platform" (p. 66).

This is true philosophy: to resist the temptation of expressing a view, when the evidence is entirely inconclusive and perplexing.

#### *Glaciers.*

We are told that "there is no evidence whatever to support the popular idea that there were glaciers in this part of Dartmoor" (the eastern side) (p. 64).

At the Dartmoor Excursion "Mr. Somervail drew attention to the fact that in the great expanse of Dartmoor, where there were no distinct evidences of glacial action, there were no tarns, whereas such sheets of water were common in the glaciated regions of Scotland" (*Proc. Geo. Assoc.*, 1900, p. 431). I was not aware there had been a popular idea prevalent that glaciers had existed on Dartmoor. The absence of evidence has been repeatedly noticed by different geologists.

### *Kaolinization and "Rotting."*

The Memoir draws a distinction between the decomposition of felspar by kaolinization, and by "rotting." Miller describes clay as "the result of the combined action of air and water upon felspathic and siliceous rocks" (*Chemistry*, 1864, Vol. II, p. 508). This is an adequate explanation, if we recognize the gases (or airs) which, dissolved in water, so greatly increase its solvent action.

Describing the plateau south and south-west of Moretonhampstead we are told that "the stone is rotten to a considerable depth, but this seems due to superficial weathering; the resultant material is nowhere clayey, but consists of quartz-grains, broken felspars, and fragments of granite . . . this exceptionally deep superficial weathering is probably connected with the Tertiary contours described in Chapter VII. To the south-west of the valley of the Bovey River this deep rotting ceases and the granite weathers into bold tors . . ." (p. 31).

At the present moment, as I write, a length of hedge north of Narramoor Farm is being removed for widening the road. This is on the plateau under consideration. The exposure several feet deep is not only absolutely disintegrated, but I noticed strata of apparently pure sand, such as might be distributed on flooded flats, rather than by river action. I happened to be driving from Moretonhampstead to Foxworthy, and saw this interesting exposure by chance. Every trace or vestige of clay seemed to have been removed. The resultant material is truly *not here* clayey; but, elsewhere, it may be found in all stages of decomposition and distribution.

In the deep cuttings of the old lanes, and on steep valley sides, one may sometimes see the components of the

ing. The tors came into existence because the subterranean chemical attack was more active than the ordinary

aerial weathering of rain and frost : against which indeed some granites are quite proof.

Colonel MacMahon in 1893, in one of those holiday excursions which great men are so fond of making in difficult districts, ignored the chemical evidence entirely, and assumed that only the aerial weathering of the tors was effective. He also not only accepted the volcanic character of the Dartmoor granite, but suggested that certain feldspars were broken by traction against the vent of the volcano.

These frequent holiday trips, with no reference to, or consultation with, the local workers, who if noticed are too often treated with contempt, make one despair of the progress of geology. I referred to the General's explanation of tors in a paper in 1897 ("The Dartmoor Granite," *Trans. Devon. Assoc.*, Vol. XXIX, p. 419). Other questions raised by General MacMahon are also weighed and considered.

#### *Rock Basins.*

In the Survey Memoir the formation of Rock Basins is attributed entirely to the action of wet and dry conditions, and "frost and thaw." The freshness of the granite surface is noticed. The presence of lichen is also referred to as tending to prevent the moisture running away (p. 72).

In the Dartmoor Excursion of the Geologists' Association I called attention to two deep little cups in the granite of Lustleigh Cleave. They are described in the report as "two small but deep rock-basins . . . these basins were clearly formed by the solvent action of rain-water, probably acidulated by the decay of lichens and other vegetation" (*Proc. Geo. Assoc.*, 1900, p. 432). I may explain that their similarity to pot holes in streams, referred solely to their form, and not of course to their origin.

In the case of water trickling through turf and then over a slab of granite on the ground level, the "exceeding freshness" of the granite surface affected is most marked.

The energetic action of water charged with carbonic acid from decaying vegetation has long been recognized in the case of limestones, but in the case of orthoclase feldspar it seems to have been entirely overlooked. I feel sure that

it is a most important agent in this superficial disintegration and decomposition of granite, and extending as far as the water can penetrate soil and rock.

### *Basic Segregations and Inclusions.*

Basic segregations are described as occurring as "spherical and spheroidal masses ranging in size from one inch in diameter to as much as six inches" (p. 41). Their origin is considered doubtful. The explanation that they "crystallized as scattered lumps of small size before the consolidation of the rest of the magma" is considered as "perhaps the most probable that can be advanced." These "contain more biotite than the normal granite" (p. 41).

Besides these biotite segregations, segregations of schorl and quartz are common, and these are apt to assume the hexagonal form of quartz. Of quite a different nature are the inclusions in the granite of fragments of other rocks.

An inclusion of diabase near Widecombe is mentioned, and a section figured (Plate I, fig. 4). In 1909 I recorded the occurrence of an inclusion of culm grit in coarse granite near Lustleigh, with details of composition by Dr. Flett (*Trans. Devon. Assoc.*, 1909). This specimen was imperfectly united to the granite, and was very obviously a foreign fragment. However, the segregations and inclusions are sometimes so very much alike, that I have never discovered any ready way of distinguishing them. For instance, I have seen an apparent segregation exactly replacing a large orthoclase crystal, which if of fragmental outline would be indistinguishable to myself from an inclusion. A similar grey, fine-grained crystalline stone, I have seen replacing coarse granite in so irregular a way that a fragmental origin was rendered impossible.

The hypothesis of an early crystallization in an original magma, seems to break down in the case of replacements. The hypothesis of a secondary partial aqueous solution and recrystallization seems to meet the case of the segregations better, and will at the same time account for replacements.

“*The Granite Roof*” of Dartmoor.

Mr. G. Barrow calls attention to patches of altered sediment on Leusdon Common, “that formed part of the original top or roof of the granite.” Also to the “comparative absence of . . . forms of pneumatolytic action even in specimens within an inch of the granite . . .” (p. 51).

Mr. R. Hansford Worth has often mentioned to me the occurrence of such patches in other parts of Dartmoor; and I hope that he will find time to benefit the science of geology with further details of his unique knowledge of the petrology and rocks of the district.

The proving of this “roof,” though often suspected, is a fact of crucial importance on the question of the origin and character of the Dartmoor granite. The Memoir asserts categorically that “Culm measures extended right across the granite, at no great height above the present surface” (p. 12).

I will now briefly recapitulate the modern controversy over granite in general and Dartmoor in particular.

In 1894 I submitted an article to the *Geological Magazine*, for which the late Mr. R. N. Worth generously lent me his process block illustrating his theory of the Dartmoor volcano. I showed that there had been four theories of Dartmoor, viz. the ordinary plutonic, Mr. Ussher’s laccolitic, Mr. Worth’s volcanic, and lastly an hypothesis first suggested by myself, and then adopted for entirely different reasons by Mr. Ussher, viz. that “the genesis of the Devon and Cornish granites . . . resulted from the metamorphism *in situ* of pre-existing rocks of pre-Devonian age. . . .” (cited by Gen. MacMahon, *Q.J.G.S.*, Vol. XLIX, p. 385).

General MacMahon’s hypothesis was far more extreme than Mr. Worth’s view of a great plutonic reservoir of molten matter; which of course might assume a granitic character in the course of plutonic cooling. General MacMahon predicated a volcanic vent, against the sides of which the plutonic granite crystals were broken up by traction and friction (see *loc. cit.*, p. 393).

No objection to this astounding theory was raised in the discussion at the Geological Society, though the honest attempts of myself, supported independently by

Mr. Ussher, to find a possible explanation of the problem were treated with marked contempt.

One great petrologist, while taking exception to General MacMahon's explanation of bedded structure, is reported as saying, that, "In all other points he quite agreed with the author" (*Q.J.G.S.*, Vol. XLIX, p. 396).

I am thankful to say that I have protested all along, though Mr. Ussher and I stood absolutely alone. The unqualified assertion of the Geological Survey that "Culm measures are extended entirely across the granite" topples over General MacMahon's volcanic cone and lavas completely, though it does not to the same degree dispose of Mr. Worth's Dartmoor volcano. Mr. Worth did not rely on orthoclase granites having ever been eruptive lavas, but maintained that the volcanic rocks and evidences had been almost entirely swept away.

However, I may submit from my own strictly personal point of view that the volcanic theory is not so strong as it once was, while the view apparently then accepted by the Geological Society is absolutely pulverized.

What view, then, now holds the field? The Surveyors have returned to the laccolite theory; the one which after having been tentatively suggested by Mr. Ussher in our *Transactions*, was by him formally repudiated, for stratigraphical reasons, as already mentioned. In short, Mr. Ussher formulated the laccolite: Mr. Ussher abandoned the laccolite: General MacMahon formulated the volcanic cone: the Geological Surveyors ignore the volcano and readopt the laccolite, without, however, reviewing either Mr. Ussher's objections to that view or my own; objections which were so independent of each other that I am not fully clear as to Mr. Ussher's reasons; nor did Mr. Ussher ever meddle much with petrological and physical reasons.

Were I asked why the Geological Surveyors have adopted the view which Mr. Ussher abandoned, after long years of puzzling over the stratigraphical evidence on the borders of Dartmoor, I must honestly affirm that I do not know: I have no idea.

The Geological Survey Memoir is a most valuable contribution to the study of Dartmoor, and not the less so because it is the joint contribution of many minds, and not the cast-iron decision of a final court of appeal.

Moreover, it gives a very full list of papers on the subject.

The members of the Geological Survey have always been most kind and friendly towards myself in every possible way; and I have noticed that owing to their being always in contact with nature and tackling new work, there has been very little indeed of that professional contempt for amateur efforts which I have so much deplored in other directions. However, there is one thing I must say, and that is that I greatly regret that our great London geologists have apparently made a practice of not conferring with local workers. The Devonshire men have for generations, as father and son, or master and pupil, striven with Devonshire problems. Their work has usually been ignored, or rather perhaps their own existence.

It was unfortunate that General MacMahon should spend a few weeks near Tavistock, and then write merely, "Notes on Dartmoor," promulgating new views on many different points, and not only not associating himself with the local men, but giving rise to a rather depressing style of criticism of third parties; and now again, in this recent Survey, the local men have had no opportunity even to call the attention of the Surveyors to their own particular difficulties, in their own particular neighbourhoods; yet two independent points discussed in the Memoir, viz. Horsham Steps and the gravel north of Hunter's Tor, are, the one close to my farm of Foxworthy on the south, and the other hard by on the north. I should have liked to have met the Surveyor at each place, as I believe that in both cases the explanations entertained, though not necessarily endorsed, are rather against the evidence. A stranger to any district is bound to miss much collateral evidence which local men may, in course of years, take note of, and store up in their minds. What seems obvious at first sight may often seem less certain when collateral evidence comes along.

Before closing I must plead one word in self-defence. A letter in the May number of the *Geological Magazine* commences with the sentence—"If Mr. A. R. Hunt desires to be an effective critic and not a mere needless fault-finder, he should not base an argument on ancient history and ignore modern research" (*Geo. Mag.*, 1913, p. 236).

Fault-finding rather implies personal censure ; but as in the case of the practice of the law, scientific opponents may well challenge alleged facts, and even disagree with conclusions without the smallest implication of censure. For instance, in my present examination of the observations and conclusions of my friends of the Geological Survey, I am not conscious of any desire to censure them, nor even to influence their opinions. My desire is rather to check and test my own conclusions : to hold fast that which is good and to abandon everything else.