NOTES ON THE TORS AND THE CLITTER OF DARTMOOR.

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(Communicated by R. Hansford Worth.)

(Read at Princetown, 26th June, 1930.)

[*Transactions of the Devonshire Association for the Advancement of Science, Literature, and Art.* 1930.—Vol. lxii, *pp.* 373-378.]

THE following little composition is due to observations that the author made on Dartmoor and Exmoor in August and September, 1929. Although the inquiry into the tors and the clitter was not the chief aim of the excursions, the curious forms of both attracted the author's attention very much. In the following, he has tried to give some contributions to the solution of the problems arising from both these phenomena.

The tors and the clitter are a well-known appearance, a minute description of which is not necessary. But some particular features may be hinted at. Most of the tors exhibit the characteristic horizontal pseudo-bedding, by which these outcrops of granite are disintegrated into slabs, lying atop one another. In addition to the horizontal fissures, producing the pseudo-bedding, the tor is interspersed with vertical fissures in a far lesser degree. Another characteristic feature of the tors is the nearly vertical slope, by which they stand out against the sky with sharp contours. The foot of the outcrop of granite is surrounded by a scree of blocks, obviously tumbled down from it. This scree, which does not exhibit any regular arrangement of the boulders, is, further down, followed by a zone of blocks, known as clitter. In most cases, the boulders have a characteristic shape ; according to the pseudo-bedding of the tors they are flat slabs, about one foot thick. The mode of the deposition of these slabs is of great importance. In places where only a few slabs are scattered over the slope, they lie flat on the surface of it. But this arrangement is changed in places where the clitters are so closely packed, that they touch each other. Here they are piled upon each other in the following manner.

There are many examples in which the lower part of the slab, not lying flat on the slope, is raised a little, to such degree, that the slab takes an horizontal position. In other

cases, the angle formed by the direction of the long axis of the slab and that of the slope increases, so that the slab dips against the slope. Even a vertical position has been observed. These conspicuous positions of the slabs are accounted for by their resting on boulders underneath, by means of which their lower part is supported. In a few cases, the lower part of the slab rests on the slope and the upper part is supported. It is very probable that this position has developed out of that described above, the slab being pushed downhill by forces that will be mentioned later, till, at last, it tipped over, and now the lower part rests on the slope.

The positions of blocks in the clitter may be observed best in a little recess or niche on the southern slope of Great Mis Tor, which has an almost vertical back wall and a level bottom, where huge masses of slabs are piled up. The flat sides of them lie one on another, their long axes are parallel, forming nearly a right angle with the vertical back wall of the niche.

The strange arrangement and position of the clitters, and their extension beyond the foot of the hill, were early observed. It is evident that the blocks have not simply slipped from the tor, nor have they been left by the decomposition of softer portions of the bed rock, in this case they would have rested upon it, as Belt has pointed out in his paper "Drift of Devon and Cornwall" (*Quart. Journ. of Geol. Society*, 1876). This author explains the clitters by the supposition of floating ice with presence of water, a theory that seems to be abandoned now. In the *Memoir of the Geological Survey*, explanation of sheet 338 (Dartmoor), similar observations are given. The appearance of the clitter is accounted for in the following manner: "Such banks (mounds of tumbled rock running parallel to a tor) seem to have originated when the climate was colder and snow drifted deep against any projecting tor. As long as the snow-drift lasted, any blocks loosened by the frost would shoot down the slope, to be deposited some distance away at its foot, even though the foot of the snow drift stretched over level ground or perhaps up an opposing slope. Thus small ridges of granite blocks were formed parallel to the length of the tor, the stones often standing on end or piled on the top of each other as they were left when the snow melted."

In both explanations it is admitted, that the formation of the clitters does not result from agencies at work to-day, but by such as were active during the Ice Age, when, at its maximum, the glaciers were stretching to the Bristol Channel. The climatic conditions of the S.W. of England in that time very much resembled those now existing in the tundra

of Siberia and similar areas (Cf. Geikie, *The Great Ice Age*, 1894).

But the explanations advanced in the *Memoir of the Geological Survey* seem unsatisfactory for the following reasons :—

(1). The shooting down of the blocks on the snow slope would not bring about the strange position of those apparently pushed atop of one another ; moreover, they would be expected to accumulate at the foot of the snow slope.

(2). The flat form of most of the boulders would not be favourable to shooting down.

(3). It is most difficult, according to that theory, to explain the fact that the slightest changes of the gradient of the slope result in a different thickness of the accumulation of the boulders ; for, in proportion to the rise of the gradient, the number of the blocks increases. A snow slope could not reflect to that degree the slight changes of the gradient.

(4). Finally, there is no explanation for the blocks strewn over the slope of flat, gently swelling hills, down which a snow slope would not be sufficient to make the stones travel.

These arguments make the explanation given in the *Memoir* very improbable. For the explanation I now suggest, the ideas concerning the movement of the soil should be remembered, which first were advanced in England a long time ago. The papers of Fisher, " On the Warp " (1866) ; of Wood, " On the Newer Pliocene Period in England " (1882) ; of Davison, " On the Movement of the Scree Material " (1888); all published in the *Quart. Journ. of Geol. Society* ; the summarizing chapter in *The Great Ice Age* by Geikie (Chap. XXVII, 3rd Ed., 1894) ; and other papers seem to show the right line toward the explanation of the problem. As for Dartmoor, the paper, " Some Phases of Devonian Detrital Geology," by the late R. N. Worth, published in the *Transactions of the Plymouth Institution* (1898), is of great interest and importance, for the first time applying the movements of the soil and the solifluction to the formation of the tors and the clitter of Dartmoor. Pursuing the ideas put forward in that paper, I shall try to give an explanation of the questions before us, utilizing the observations of the Swedish scholar, Hoegbom, who has described the agencies acting and forms arising in Spitzbergen to-day (B. Hoegbom, *Uber die geologische Bedeutung des Frostes*, Bulletin of the Geol. Instit., Upsala, XII, 1913-14).

The above described distribution and arrangement of the clitter, its extension over level ground, and the manner of piling up, convey the strong impression that the boulders have been pushed downhill by some force. All the detailed form of the clitters is easily accounted for by the agency of that.

solifluction, which acts an important part in Spitzbergen to-day according to the statements of Hoegbom. The soil containing the clitter was by it made to flow and was checked on level ground and on the lower part of steep slopes. In consequence of that check, the blocks accumulated, as is very obvious in the niche at Great Mis Tor above mentioned. That an intensive movement of the soil has taken place becomes most evident, when one is looking from the eastern side of Tavy Cleave westwards to the opposite side of the river. There, a stream of blocks is to be seen, extending downhill between two cliffs of bare granite, in a curved line like a fan, small in the upper part and getting broader in its lower. The aspect of that stream, with its sharp lateral boundaries, at once suggests the movement of flow; it bears a striking resemblance to the descriptions and photographs of the streams of blocks given by Hoegbom in the paper above mentioned. This stream is one of the best examples of this kind that as yet have been described from the non-glaciated parts of Europe.

A further evidence of soil-movement is afforded by the following observations: In two quarries on the southern slope of the Holdstone Down on Exmoor, the terminal curvature of the beds of slate may clearly be observed. In one of the quarries the beds strike N.W.—S.E. and dip at an angle of about 45 deg. south-westwards. The heads of the strata are broken and turned over at an angle of 180 deg., dipping south-westwards. It is very interesting, but not important for our purposes, to see that the layers are not turned over to the southern direction of the slope of the Down, which very likely is that of the solification, but to a S.W. direction, which corresponds with that of the layers. The tendency of avoiding a contortion is evident.

What agencies have brought about these movements? They are frost and regelation, i.e., the alternating freezing and thawing; the snow and the melting of it being the chief forces of the weathering in the tundras. The severe frost produces the permanent frozen soil, called 'tjaele' by the Swedes, reaching a thickness up to 400 feet. At the beginning of summer, the surface thaws to a depth of a few feet. The underlying frozen soil prevents the water resulting from the melting of the snow, from soaking into the ground. It has to flow off within the depth of the surface layer, which gets water-logged and converted into sludge, the tendency of which is to slide horizontally from higher to lower ground, carrying the boulders downhill. At certain times the surface of the thawed layer freezes again, the water congealing between the boulders expands, by which the blocks are pushed down a little further. In that way, in Spitzbergen, blocks that are

not bedded in an earthy matrix, are pushed downhill, so that a movement downhill may take place without solifluction. By these two forces, the solifluction and the pushing down by the frost produced regelation, the arrangement and distribution of the clitters on Dartmoor may easily be explained. According to observations of Hoegbom, blocks can be moved by either force or by both on nearly flat ground. This would give an explanation of the clitter on such ground, e.g., east of Merrivale Bridge and on other similar parts of Dartmoor.

As to the origin of the tors, it is presumed that they have been existing for a long time, at least since the Tertiary uplift. Thus the *Memoir* says: "Long continued subaerial erosion, commencing in all probability in early Tertiary times, has turned the higher parts of Dartmoor into an undulating country, with no ravines, and flowing curves, except for the isolated tors."

The possibility that the tors originated in Tertiary or pre-Tertiary times cannot convincingly be refuted. Yet for the following reasons it is very probable that the formation of the tors is in the main due to agencies at work during the Ice Age.

The cold climate of that time produced an intensive mechanical weathering, chiefly brought about by the frost, which affected the sound rock very strongly by its splitting-up action. These ideas have been put forward by the late R. N. Worth in the paper above cited. The rock is exposed to this splitting-up action of the frost exceptionally during summer, when the temperatures move round the freezing-point. The angular debris thus created was transported downhill by the solifluction and the downward push by frost, whereupon it was carried away by the melted snow. In that way, fresh rocks were always exposed to the frost, so keeping up the supply. The rock was not splintered equally, but sounder parts of it have been left; particularly granite, diabase, gneiss, porphyry, and gypsum are very capable of offering resistance. The outcrops of the sounder rock left are called "ruins" by Hoegbom. These "ruins" of Spitzbergen, consisting of granite and diabase, look completely like the tors of Dartmoor. This coincidence of the outward appearance makes it very probable that the tors of Dartmoor and the "ruins" of Spitzbergen are of the same origin, since the climatic conditions of Devon during the Ice Age correspond to those in Spitzbergen to-day, and the "ruins" there mostly occur associated with moving angular debris and streams of blocks.

The tors are limited to hills with rather steep slopes, the clitters are wanting on flatter ones, as the transport of the

debris here was much slower, the latter beginning to protect the bed rock from the frost. The absence of any tors on Exmoor, where the same climatic condition as on Dartmoor must have been existing, corresponds to the observations of Hoegbom that sedimentary rocks are too weak to be able to offer resistance to the frost. Attention may be drawn to the aureole and the sedimentary rocks of Dartmoor, which only in a few cases are weathered to tors. There is, e.g., no tor on the Homerton Hill at the West Okement and other hills of similar steep slopes where they should be expected. The form of the White Tor and Cox Tor, consisting for the greatest part of contact-altered diabase, is very different from that of the granite tor. They are irregular heaps of decayed bed rock and debris, partly grown over by the vegetation. Viewed from a distance, they do not exhibit the sharp contours of the granite tors, but scarcely rise above the summit of the hill, forming a jagged line at the horizon. Thus there seems to be a difference between the granite and the contact-altered diabase as to their reaction to frost.

One may be inclined to think that there have been agencies at work in the postglacial period, continuing to the present that might form both tors and clitter. I refer to the "creeping" of the soil, an imperceptible downward movement without the tearing up of the covering layer of the vegetation; and to the effects of the frost during winter. As to the former, there are strong doubts whether such a movement really exists. The latter may possibly be at work, but with no effect in any way comparable to that of the Ice Age.

Thus the evidence would point to the tors and the clitters of Dartmoor being due to the splitting action of frost, and to movement occasioned by solifluction.