

## ON GLACIAL CONDITIONS IN DEVON.

BY R. N. WORTH, F.G.S.

(Read at Dawlish, July, 1881.)

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OF late years the current of geological enquiry and research has run strongly in the direction of the more recent formations, stimulated largely by the interest which attaches to everything associated with the question of the antiquity of man. Apart from this special connection, no period of recent geology has attracted so much attention as that which is commonly known as the glacial. The relation of Devonshire to this period, or rather the conditions contemporary in Devon with the glacial era of Britain generally, have had their share of notice, but without leading to any very definite conclusions. There appears indeed to be a general agreement that neither in Devon nor in Cornwall are the more pronounced marks of the glacial era to be found. We have, so far as known, no distinctly identifiable scratched or *moutonnees* rocks, no unquestionable moraines, no certain boulder clays; and therefore it is generally assumed that, during the glacial epoch, the conditions of our land surface were not such as to favour the formation of glaciers. This, however, is a very different thing from assuming that we have no evidence of the existence here of glacial climate; and I wish to bring together what seem to me to be abundant proofs of glacial conditions in this county, quite apart from the more marked phenomena of glaciation, which may, or with greater likelihood, may not, exist. There are two ways of accounting for this absence of striæ, moraines, and boulder clays. First, the non-existence of a mountain range of sufficient magnitude to develop a glacier system; second, the submergence of what is now Devon during the glacial epoch. The latter hypothesis is untenable for two reasons. First, because there are, as I hope to show, proofs of glacial conditions incon-

sistent with the idea of submergence. Second, since in the case of submergence we should hardly fail to have had a number of erratics scattered over the county, whereas only in the North of Devon, in the neighbourhood of Barnstaple, is there any erratic block which can be conclusively attributed to the agency of floating ice.

The class of phenomena to which my attention has chiefly been directed as affording proof of former glacial conditions in Devon, is that connected with certain terminal curvatures of our slate rocks. There are many places in the south of Devon (to which these observations specially apply), and particularly in the neighbourhood of Plymouth, in which the slates are seen to be bent over in the opposite direction to their dip, for two or three feet, and sometimes more, from their upper edges, preserving at the same time in many instances so much cohesion and regularity, that if the upper part of the section only were visible, the rocks would be read in reverse order. This is no merely isolated phenomenon, but one which occurs at frequent intervals over a large area, and generally under closely allied conditions. The best examples I have seen are on the slopes of hills (where our deep sunken Devonshire lanes afford excellent opportunities of observing surface sections), the slates dipping with the hill, and having their edges turned forward, as if by the action of a force which was exerted down the slope, and yet was modified so far—so slow and steady in its operation—that the laminae were simply curved, rarely broken, and left pretty much *in situ* instead of being carried to the hill-foot.

That such an effect could not be produced by any violent, still less by any cataclysmal action was evident; and this at once disposed of the idea that there had been any torrential rush of water. Such a rush would not have simply curved and then passed over the laminae, but would have swept the surface smooth and clear of all loosened portions. Moreover, the main pressure of the water would be exerted down the valleys—along the axes—and not transversely, towards them. Much the same reasoning would apply to what is commonly understood as glacial action. The pressure of a glacier would also be chiefly exerted in the line of the valley, but its force would be such that instead of merely bending or breaking the slaty laminae, it would crush and grind them into mud. Neither to the action of water, nor to that of ice, in its more usual form, can this phenomenon be attributed.

So far back as 1867, Mr. D. Mackintosh, F.G.S., called the attention of the Geological Society to “some striking in-



stances of Terminal Curvature in West Somerset." In his paper he pointed out that among the Quantocks and upon Exmoor he had found numerous instances in which "the laminae of the . . . slate" were "very regularly and distinctly curved backwards;" the most important fact in connection with these sections being: "The bending and curving-back over extensive areas has taken place on perfectly level ground, with a depression instead of an elevation on the side whence the movement must have come. There are indeed instances in which the curving-back has been forced up a slight acclivity." Mr. Mackintosh traced this phenomena "to a powerful and uniformly operating cause," but did not indicate his opinion as to the actual nature of that cause beyond the statement: "It is sometimes difficult to resist the impression that a great weight of *solid* matter, powerfully propelled in a southerly direction, must have curved back the slaty laminae, and, with an almost geometrical exactness, rounded the forms of the limestone and other eminences of the South-West of England." The natural inference is that the word "solid" points to a preference in Mr. Mackintosh's mind for some form of ice action. The progression southward was deduced by him from the fact that he only found the phenomenon affecting summit levels or southern declivities. He suggested also that the "uniform curving-back would only occur when the laminae leaned toward the moving agent (or at least did not lean away from it), so as to afford a certain degree of resistance to its action. In other places the planing-off of the edges of the laminae would either leave them cleanly cut or very irregularly shattered."

In a paper on "The Evidences of Glacial Action in South Devon," read at the Honiton meeting of this Association, Mr. E. Vivian, reasoning on the same lines, cited in evidence "a section of the Devonian slate near Torquay, with the deposits in the Torwood valley;" and also "the condition of the stalagmitic floor and successive fillings in Kent's Cavern." The section was in the Torwood valley. In a deep excavation for buildings "on the summit the laminae are curved over to the uniform depth of about six feet, in the line of least resistance. . . . This has been assigned by Mr. Godwin-Austen, and other writers, to the action of ice during the last glacial period." The deposits in Kent's Cavern Mr. Vivian suggested had been acted upon by flood water, "on the breaking up of the last glacial period, when the valley . . . was filled with a glacier or compact snow, the water being derived from the bursting of debacles or ice lakes, and heavy rains at

higher levels."\* I think, however, the evidence of torrential glacial action in Devon generally of a doubtful character; at all events so far as South Devon is concerned.

The arguments of Mr. Mackintosh were examined by Mr. Ussher, in a paper read before the Geological Society in 1877,† in which, accepting the evident leaning of Mr. Mackintosh towards a land-ice theory, Mr. Ussher assailed it on three principal grounds. First, because the hypothesis ignored the great Pleistocene surface waste of the South-West; second, because instances of terminal curvature occurred in situations which during the glacial epoch must have been too far removed from the suppositional ice bed to have sensibly felt its pressure; third, because the survival of glaciated shales would be inconsistent with the absence of hard rocks presenting *moutonnees* or striated surfaces.

Nevertheless, Mr. Ussher was "inclined to think, that the absence of deposits commensurate with the great Pleistocene denudation experienced by the South-Western Counties may be due in the first place to some powerful denuding agent in the form of a local ice sheet or glacier system, and, in the second, to the great force and volume of surface water likely to be liberated at a close of Arctic severity."

It seems to me that in these suggestions Mr. Ussher himself thus admits the possible existence of sufficient glacial conditions for the production of the phenomenon under review. I agree with him in believing that the glacial epoch in Devon was not one of total submergence.‡ Indeed if it had been, as already noted, we should have had no terminal curvature, assuming that curvature in any way to be due to land ice action.

I agree with Mr. Ussher, too, in rejecting the idea that this phenomena was produced by any oceanic current, water-rush or land slips; for reasons which have been already stated.

Mr. Ussher's own hypotheses of the origin of terminal curvature are three in number.

First he instances "the great and oft-repeated internal movements to which the Palæozoic rocks were subjected." The cause is adequate to produce the most gigantic distortions; but the peculiarly exterior character of terminal curvature, its regularity, and its general correspondence

\* *Trans. Devon. Assoc.* vol. ii. pp. 357-60.

† *Quarterly Journal Geo. Soc.* xxxiv. pp. 49-55.

‡ The granite boulder at Saunton and its neighbours prove the submergence in glacial time of part of North Devon; but the absence of similar erratics elsewhere in the district is good negative evidence that this submergence was not general.



with contour, point to a less deeply-seated and less remote origin.

The second cause assigned is "the intrusion of wedging frosts between the laminae of shales, leaving earthy matter filling up the gaps between them, on the approach of summer."

The third "the intrusion of roots acting as wedges."

As I believe the first of these three causes to be too remote; so I must consider the second and third inadequate to account for a phenomenon of such a persistent and extensive kind. They are too partial and irregular in their operation to explain physical changes so extensive and so consistent. I accept Mr. Ussher's arguments against floating ice, ocean current, or cataclysmic action as conclusive. There is left, therefore, only the "land ice" theory; and as Mr. Ussher does not "deny its applicability to some instances of terminal curvature within three or four feet of the surface in glaciated districts," its adequacy is admitted. His objections to its wider acceptance seem to me rather to rest upon a tacit assumption that glacial phenomena invariably proceed in sequence or companionship; and in part may be met by chronological considerations. The relation of terminal curvature to Pleistocene waste depends very much upon the portion of the glacial epoch to which it belongs.

While I use the phrase "land ice theory," it is in a certain modified sense. Many of the objections which apply to the attribution of "terminal curvature" to bodies so ponderous as glaciers, apply also to "ice caps" as usually understood. They do not seem, however, to militate against the operation of a consolidated snow cap slowly moving down the faces of the hills, as the climate of the glacial period gradually ameliorated. I am, therefore, disposed to find in "terminal curvature" a phenomenon allied to some described by Dr. Geikie in his *Prehistoric Europe*.\* Noting the fact that "sheets of coarse gravel and detritus . . . spread often continuously over wide districts in Southern England," with little or no relation to present drainage systems, "frequently very coarse and rudely bedded . . . confused and troubled," he quotes the suggestion of Mr. Darwin, that during the commencement and height of the glacial period, great beds of frozen snow accumulated, and that during the summer gravel and stones were washed from the higher land over its surface, and in superficial channels, the larger streams cutting through the snow, and leaving their gravel in lines. Each autumn

\* pp. 140, 141.

the lines of drainage would be filled up, and it would be a mere chance whether the next deposit would follow the same course. Thus, he proceeds, "alternate layers of frozen snow and drift in sheets and lines would ultimately have covered the country to a great thickness, with lines of drift probably deposited in various directions at the bottom of the larger streams." These beds would melt slowly, and the elongated pebbles arrange themselves more or less vertically, and the drift "be deposited almost irrespective of the outline of the underlying land."

I am not at all sure that I have not seen deposits on certain South Devon hill sides—somewhat akin to, but differing from, that commonly known as "head"—in which clayey loam is thickly interspersed with angular fragments of slate, which might, with great probability, be attributed to some such process as this. Be that as it may, I believe that in such a consolidated snow cap we have the true cause of the disputed phenomenon of terminal curvature.

May we not find in the same direction a sufficient explanation of the presumably transported blocks of South Devon, to which attention has been directed by Mr. Pengelly, at Waddeton, Englebourne,\* Druid, East Leigh,† Diptford, Morleigh, and Tamerton Folliott‡; of the boulders in the Dawlish and Ashcombe valleys noted by Mr. Pycroft§; and of similar blocks observable elsewhere?

That the granite boulder at Saunton, on the shore of of Barnstaple Bay, dealt with by Mr. Pengelly in our *Transactions*|| was carried by floating ice there is now no question; and Mr. T. M. Hall has shown the existence of other granite boulders, leading to a similar conclusion, at Bickington¶; but these I think belong to quite another division of the glacial epoch from that with which we have now to deal. Mr. Pengelly has proved\*\* that the Saunton block is older than the raised beach, which is itself older than our submerged forests, and the accumulation known as "head." The glacial epoch represented by the Saunton boulder is, therefore, separated from the present day by an enormous interval of time, characterised in part by interglacial conditions. The relations of terminal curvature to present surface contour, and more recent deposits, forbid our carrying back its origin to so remote a date. Are there then any indications of an Arctic climate in this county, apart

\* *Trans. Devon. Assoc.* vii. pp. 154-161.

† *Ibid.* ix. pp. 177-183.

‡ *Ibid.* xii. pp. 304-11. § *Ibid.* v. pp. 75-81.

|| *Ibid.* vi. pp. 211-222.

¶ *Ibid.* xi. pp. 428-9.

\*\* *Loc. cit.*



from the phenomenon under consideration, more recent than the North Devon boulders, to which also terminal curvature may be assigned? We shall find that there are.

The deposit known as "head," to which reference has already been made, and which has been the subject of lengthened investigation by Mr. Godwin-Austen, has long been recognized as indicating "a period of great subærial waste, a more rigid climate," which Mr. Ussher, in his *Cornish Post-Tertiary Geology*, correlates with the second glacial period, and characterises with "considerable snowfall and penetrating frosts,"\* the elevation of the land "perhaps culminating in continental conditions"—a state of affairs closely approximating to that which he suggests as the introduction of the glacial period proper, when there were "great quantities of snow accumulating on the highlands (possibly giving rise to a local glacier system)"; the two periods being separated by an epoch of subsidence. To me it seems clear that while the Saunton boulder dates from the older glacial era, probably from its close; terminal curvature with the "head" belongs to the later, possibly originating when the glacial conditions were beginning to lessen in severity.

The "head" of the Bovey Heathfield deposits has distinct Arctic if not precisely glacial characteristics. In association with it, there have been found remains of leaves "from which the dwarf birch (*Betula Nana*) and three species of willow (*Salix cinerea*, *S. repens*, and *S. amygdalina*) have been determined. These plants betoken a climate much colder than that which at present obtains in Devonshire. Indeed, the little birch is an Arctic plant, which has at present no British habitat south of Scotland," and takes us back "apparently quite to the modern verge of the glacial era."†

We have then absolute and not merely inferential proof, of the existence of an Arctic climate here during the formation of the "head." To the same period I assign the older "clitters" of the Dartmoor Tors—a true "head," peculiar indeed in form, but not in cause, nor essentially in character.

Mr. C. Spence Bate has expressed the opinion that the "clitter" "is formed of masses of granite that have been rent by the action of frost from the surface of the Tor;" and that the peculiar distribution of the blocks of the "clitter" "heaped one upon another, or lodged in the side of the valley at various distances from the Tor," is due to the action of ice "of a character somewhat peculiar to Dartmoor, and of a

\* p. 50.

† Mr. Pengelly's Presidential Address, *Trans. Devon. Assoc.* vol. ii. pp. 24-5.

sub-glacial character"—ice coating of the kind known as Hamel or Ammil, enabling the riven blocks to glide "more or less rapidly down the side of the hills until, meeting with an obstruction, many of them were gathered together."\*

The "snow-cap" to which reference has been made would, however, supply all the required conditions for the distribution of the "clitters"; and I have seen quite recent instances on the Moor of the rending asunder of granite blocks by the wedging influence of ice between the weathered joint faces. If modern winters can produce these results, those under which the "head" accumulated must have been far more potent; yet, if not in the "clitters," they have left little other trace behind.

There are still two further indices of Arctic conditions in Devon, both associated with our cavern phenomena. Dr. Geikie holds that "the cavern breccia and the numerous large limestone blocks, which overlie the Pleistocene fossiliferous strata in many caves, owe their origin in chief measure to the action of severe frost, and pertain for the most part to the close of the Pleistocene."† Beyond this we have the presence in our cave fauna of such undoubted northern forms as the reindeer, glutton, and cave pika, with the mammoth and woolly rhinoceros.

The evidence as to the condition of Devon during the first glacial period is not as yet very clear; we have proof of partial submergence in the Saunton boulder, but none of general submergence on the one hand, or of the existence of a glacier system on the other. With regard to the second glacial period, however, I think we have proof in the phenomena recited, and particularly in the terminal curvatures of our slate rocks, not indeed of glaciers, but of the existence of a "snow-cap" of great density spreading over the whole surface of the country, and presenting an appearance akin to that of the northern portions of the Hudson's Bay Territory bordering upon the Arctic Circle.

I have been induced to lay this stress upon facts which, to a certain extent, are not only familiar but accepted, because I think that the common incredulity concerning the glacial period in Devon has arisen from too exclusive regard being paid to the more pronounced phenomena, the existence of which in this district has never yet been proved. That the "snow-cap" may have developed in specially favourable localities into small local glaciers is indeed possible, but unlikely.

\* *Trans. Devon. Assoc.* iv. pp. 518-19.

† *Prehistoric Europe*, p. 543.