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ORIGINAL ARTICLES:

I.—ON THE DISPERSION OF SHAPPELL BOULDERS AND ORIGIN OF
BOULDER-CLAY.

By D. MACKINTOSH, F.G.S.

AS the attention of geologists has lately been re-directed to the above subjects by Mr. S. V. Wood¹ and Prof. Harkness,² I venture to hope that the following notes and observations, made during visits to Wasdale Crag and the neighbourhood, on the 7th and 15th of last June, will not prove uninteresting to the readers of the GEOLOGICAL MAGAZINE.

View of Wasdale Crag from the opposite side of Wasdale.

Boulders of granite from Wasdale Crag (or, as it may more conveniently be called, Wasdale Hill—the Crag being its southern escarpment) may be found down the valley of the Eden at a great distance from their parent rock; but it is not until one arrives at Shap village, on his journey southwards, that the boulders begin to obtrude themselves on his attention. A little beyond the Greyhound Inn, he will find that at least one-fourth of the stones which have been gathered off the fields are granite, many of the others being a kind of basaltic trap from the neighbourhood of Wasdale Hill. Further on he cannot fail to be struck with the number of huge granite boulders in the roadside walls, some of them angular, but many of them considerably rounded. I have been informed that there are few or no granite boulders much further west than Shap Abbey; and in this neighbourhood, therefore, the current which

¹ Quart. Journ. Geol. Soc., Vol. xxvi. p. 90, paper read Dec. 8, 1869.

² I was not present at the reading of Prof. Harkness's paper on the 25th of last May, but from the few lines of abstract in the fortnightly notices of the Geol. Soc., it would appear that, so far as the dispersing action of coast ice is concerned, his views agree with those advocated in this article.

transported the boulders in a northerly direction must have had its western boundary.

About a mile south of Shap, 5 or 6 feet in thickness of grey or greyish-brown "pinel," nearly as hard as rock, may be seen lying on Carboniferous limestone. It is rudely laminated, and contains many stones and boulders, including a large per-centage of Wasdale Hill granite. It is covered with a thin bed of red or foxy-coloured loam and loamy clay, with comparatively few stones. This was the first though not the most convincing indication I saw of what I expected, namely, that the Wasdale Hill boulders are "a part and parcel" of the pinel or mountain boulder-clay (for it is not to be found far away from the mountains) of the Lake District. Further on, I saw a block of granite on the roadside, about 12 feet in average diameter, and Mr. Hetherington, of the Shap Granite Company, informed me that he had seen a block high up on the side of a neighbouring hill, which measured $20 \times 15 \times 5$ feet. He likewise mentioned that he had seen a large block horizontally fractured, as if it had violently struck against another block or the rocky bottom of the sea. I afterwards saw several split blocks.

Near the Polishing Works, Shap Summit, a yellowish-brown pinel, so hard that it might appropriately be called Post-tertiary conglomerate, makes its appearance on the roadside. Here (as elsewhere) it is often covered with a facing of the overlying loose loam, and might easily escape the notice of one not in search of it, although it constitutes the main part of the drift of the district.

At the Polishing Works my attention was directed to the fact, that on some of the higher eminences to the north-east there are many granite boulders on the slopes facing Wasdale Hill, but none on their tops. Should it be found that on none of the eminences to the north and north-east of Wasdale Hill are there any boulders at a greater height than 900 or 1,000 feet above the sea, it would favour the supposition that at the time when the boulders were floated in these directions the land had not been so deeply submerged as when the transportation over Stainmore Pass occurred. At the latter period, the land must have been submerged to a greater depth than 1,400 feet, and during an intermediate submergence of about 1,300 feet the boulders may have found their way, nearly in the direction of the Shap and Kenda Road, into the valley of the Kent. The courses of the ice- and boulder-laden currents may have changed as the land became more deeply submerged. That the boulders did not find their way over lower gaps in the Pennine chain to the south of Stainmore can, I think, be easily explained, on the supposition that currents embracing Wasdale Hill or its neighbourhood, in their course, did not happen to flow through these gaps. There are many directions besides those in which these gaps are situated, which would appear to have never been traversed by currents laden with Shap granite boulders.¹

On walking along the tramway-cutting from Shap summit to the

¹ According to Mr. Green, of the Geol. Survey, there is a Shap granite boulder in the village of Royston, near Barnsley, and according to the Rev. J. Stanley Tute,

granite quarry, great boulders are found, not only on the surface, but completely buried in the pinel, which is here both grey and yellow, and rudely laminated—the laminæ being generally inclined or arched. It often graduates into a well-rounded conglomeratic gravel. The boulders here are chiefly whinstone (local basaltic trap) and granite. The nearer one gets to the quarry, the more one sees that the dispersion of the boulders and the accumulation of the pinel were contemporaneous.¹ On the slopes of Wasdale Hill, the pinel with granite boulders runs up to the bases of the rocky ledges, and fills up hollows. It differs but little from what one might regard as a beach deposit on a steep shore, where the stones would roll down or be washed down, and become imbedded in clay beneath the level of the assorting action of waves. At the same time, ground-ice and coast-ice must have had a share in giving rise to the peculiar character of this remarkable deposit.²

The south side of Wasdale Hill, down to a level of about 1,100 feet above the sea, is craggy, and the rocks are more or less moutonné. On the sloping face of the hard and compact rocky escarpment there are very few loose boulders, and still fewer on the summit. On the eastern side of the hill numbers may here and there be seen, but, excepting towards the base of the hill, surface-boulders are nowhere very plentiful. In cutting the tramway, however, thousands of them were dug out of the pinel.

At the quarry, near the western end of the Crag, blocks as large as $40 \times 30 \times 15$ feet are sometimes obtained by blasting. The granite is exceedingly hard, and little liable to be acted on by the weather. Here the pinel not only rises up to the base of the Crag, but runs up the sloping rock-surface until it terminates against the minor cliffs. In some places it adheres so tenaciously to the moutonné rock, that it is removed with great difficulty. The finer part of the deposit would appear to have come from the S.S.W.

Glaciated Granite.—I was fortunate in discovering a good-sized surface of granite which had been lately cleared of pinel, and it was nearly as exquisitely polished as at the Shap Summit Works. On throwing a bucketful of water on the surface, the grooves could be distinctly seen running nearly in the direction of E.N.E., or obliquely up the face of the sloping Crag. To the west of the quarry I afterwards found the glaciation running N.N.E. As the granite was not much planed down, but polished somewhat conformably to the undulating divisional planes, ice borne by a current from the direction of Wasdale Head may have glaciated the rock there are some Shap granite boulders in the brown clay west of Ripon. Is it certain that they all came over Stainmore Pass?

¹ The number of large granite boulders on the surface of or rather slightly imbedded in the pinel and overlying loam, may have resulted from the continual dropping down of boulders from the floating ice, as the land became more and more deeply submerged, and after the accumulation of the pinel had, in a great measure, ceased.

² Apart from the evidence the pinel presents of the action of ice, it somewhat resembles the brecciated part of the raised beach of Weston-super-Mare, which would appear to have been accumulated on a steep slope, as the land was sinking, and it is not very dissimilar to portions of the Old Red Conglomerate at the foot of Ullswater.

uphill on grounding. It could not have been caused by the valley-ignoring agency which glaciated a great part of the Lake District from N. to S., while the physical geography of the district forbids the idea of a local glacier, from the W.S.W. or W.S., acting at a sufficient height to smooth and score the southern face of Wasdale Crag up to the summit, for on the summit the rocks are moutonné. A valley-glacier, moreover, could not have carried granite boulders from Wasdale Crag transversely over the adjacent valley, and left them in great numbers on the opposite or southern side. Much less could a valley-glacier, or any movement of land-ice, have dispersed the boulders in the many different directions in which they are found. It is true the glaciation of the rock-surfaces and the distribution of the boulders may have been separate events, but the preponderance of evidence here seems to be in favour of the idea that all the superficial phenomena partially originated while the land was submerged.

Mode in which the Boulders were launched.—There would appear to be little difficulty in conceiving how the boulders in the neighbourhood, at comparatively low levels, on the N., E., and S.E., may have been floated by coast-ice; for though the cliffs and rocky projections of Wasdale Hill are too sloping and the granite too hard to furnish many blocks and fragments by the force of gravitation combined with the dilapidating action of frost, all must admit that the sea is pre-eminently a block-detaching agent.¹ The process of natural quarrying carried on by the waves at successive levels, as the land subsided or rose, would have supplied an immense number of blocks, and, at the same time, rounded those of them which present indications of having been subjected to attrition. The small number of boulders remaining on the surface of the hill, or not imbedded in the pinel or overlying loam, would seem to show that the transportation must nearly have kept pace with the process of natural quarrying and rounding. The breaking-up of coast-ice, and ground-ice converted into coast-ice, would appear sufficient to explain the launching of the boulders from what must have been a steeply-sloping sea-beach, progressively advancing down and up the sides of the hill as the land sunk or rose. But it is probable there were pauses in the oscillation of the land. Some of these may be represented by the great terrace of boulder-pinel and red loam at the base of the hill in the direction of Shap Wells, and by the terraces at higher levels on the N.N.E. side of the hill. The myriads of boulders transported over the 1,400-foot level of Stainmore Pass would seem to indicate another pause when (taking into account the depth of water required to float ice) very little, if any, of Wasdale Hill appeared above the sea, that is, supposing Stainmore Pass and Wasdale Hill to have been afterwards equally upheaved.

Derivation of the Great Eastern Dispersion.—How could a few feet of land, a few hundred yards in diameter, above low-water level, have supplied all the Wasdale Hill granite to be found to the east of

¹ See Mr. E. Hull's able article "On the Raised Beach of Cantyre," on block-detaching agency of the sea.—*GEOL. MAG.*, 1866, Vol. III. p. 7.

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BRITISH SPECIES OF THE GENUS DICRANOGRAPTUS.

the Pennine range of hills? The progressively upward action of ground-ice during storms may partly furnish an answer to this question, but I think the main explanation must be sought for in the deruding action of sea-waves encroaching on the top of the hill, which at one time may have been higher than at present. A previously-existing conical eminence may have been *truncated* by the sea, so as to leave the "plain of marine denudation," or table-land, now forming the summit of Wasdale Hill; and it is possible, if not probable, that the hill may have lost several hundred feet of its height during the process of natural quarrying which supplied the floating ice with all the boulders which found their way across Stainmore Pass. The preponderance of Wasdale Hill granite among the larger transported boulders (at least in many areas) may be accounted for by the fact that the compactness and distance between the joints or fractures of the granite would cause it to break up into blocks much larger than those resulting from the dilapidation of the neighbouring rocks, many of which indeed, would break up into mere chips or splinters.

Concluding Remarks.—The foregoing facts and considerations lead us to the conclusion that the cause which dispersed the boulders from Wasdale Hill radiated from the hill as from a centre. But the insignificant summit of the hill could not have supported a nearly sufficient quantity of land-ice to have furnished the floating ice on its breaking-up, while land-ice in such a position could not have detached the blocks from the solid rock. The blocks therefore must have been detached and rounded by sea-waves and sea-ice, and floated and transported by the latter. Winds may have partly or chiefly propelled the ice which floated the boulders found in the neighbourhood of Wasdale Hill, but currents must chiefly have carried the ice with the boulders which are found at great distances. Though the finer part of the pinel and loam must in a great measure have been derived from a source different from that which supplied the granite boulders, the accumulation of the pinel and loam and imbedding of the boulders must have taken place contemporaneously while the land was submerged.

The causes of the glaciation and mode of accumulation of the Drifts of other parts of the Lake District will form the subject of a future article.

II.—ON THE STRUCTURE AND AFFINITIES OF THE GENUS *DICRANOGRAPTUS*.

By JOHN HOPKINSON, F.G.S., F.R.M.S.

(PLATE XVI.)

THE name *Dicranograptus* was proposed by Hall, in his Memoir on the "Graptolites of the Quebec Group" (p. 112), for certain forms of Graptolites, some of which were then included in the genus *Didymograptus*, and others in *Diplograptus*. He, however, only considered these forms as constituting a sub-generic group of his genus *Climacograptus*, believing them to have a similar structure.