profiles agree quite well. In view of the various assumptions that have been made, the observed irregularities of the glacier, and the fact that the theoretical curve depends on only one disposable parameter τ, which takes a reasonable value, the agreement between theory and observation seems quite satisfactory.

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A NOTE ON THE USE OF MARGINAL DRAINAGE IN THE RECOGNITION OF UNGLACIATED ENCLAVES*

By S. E. HOLLINGWORTH

A RECENT interesting note by Professor D. L. Linton mentioning several bases for the delimitation of unglaciated enclaves would appear to invite some qualifying comment on one of the methods mentioned. The criterion of marginal drainage and overflow channels as marking the limit of extraneous ice against rising ice-free ground is legitimate, especially when their true marginal or subaerial character is supported by evidence of contemporaneous deposits in glacier-dammed lakes. They then mark the ice margin at their time of operation, but it is quite another matter to consider that in general the highest channels mark the maximum encroachment of the ice. The latter is certainly the view generally held for the Cleveland Hills area of north-east Yorkshire since Kendall's classic paper of 1902. In this example, cited by Professor Linton, the difference in the positions of the ice margin at the maximum and that during the initiation of the earliest marginal drainage may have been slight, but there seems some justification for envisaging a considerable change in climatic conditions in the interval.

It is generally accepted that marginal drainage channels will only operate below the snow line, for above that a level cross section of the land-ice contact will be concave upwards due to marginal snow accumulation and to a more rapid outflow of the thicker ice some distance from the ice margin. While assignment of a particular altitude to the snow line can only be a vague generalization at the best, it is perhaps not unreasonable to assume a severe climate with perhaps a snow line in the Cleveland area at the time of the newer drift glaciation of, say 1000 to 1200 ft. O.D. (305–366 m.) with little permanent snow on the exposed wind-swept plateau summits. Thick drifts of snow would survive the winter in the margins of the enveloping ice and the valleys within the hills might well be choked with permanent snow fields. If this were the case, an appreciable, possibly major, change of climatic conditions resulting in the raising of the snow line would be needed before marginal drainage in glacier lakes comes into being on the scale of the early stages of Kendall's sequence.

Independently of this speculation as to snow line, recent development of the additions to our

* Comment on Professor D. L. Linton's note on unglaciated enclaves in glaciated regions (*Journal of Glaciology*, Vol. 1, No. 8, 1951, p. 451–52.)

knowledge of the climatic conditions in the unglaciated areas in Britain during cold phases in the Pleistocene has demonstrated the extreme severity of the climate with very low mean temperatures, such as would produce perennially frozen ground to depths of possibly as much as 200 ft. (61 m.).* The absence of local ice in the regions of ice wedge formation suggests that the snow line was kept relatively high in southern England by low precipitation, possibly due to dry winds blowing outwards from the ice sheets to the north. The recent recognition of ice wedge features in the plateau area of the Cleveland Hills (G. W. Dimbleby, *Journal of Soil Science*, Vol. 3, 1951, p. 1–19) implies a severe climate and so in the absence of glaciation is possibly to be attributed to low precipitation of snow. Dimbleby's evidence suggests that the ice wedges described by him date from a cold phase earlier than the last glaciation of north-east England, but there is sufficient evidence of severe cold in the south of England contemporaneous with the Newer Drift glaciation of more northern areas to justify reasonable assumption of a severe climate for the Cleveland area at that time. It seems to me to be difficult to envisage the existence of large glacier lakes as coincident with low mean temperatures at the maximum of that glaciation in this area. Indeed it seems worth while considering whether the large body of water, which is considered to have occupied the Vale of Pickering (at the maximum) and was dammed by ice at both ends, was really contemporaneous with the maximum. It seems more likely that in this depression accumulating summer melt water would be frozen, and by the addition of possible winter snow would be built up to a mass of more or less stagnant ice which would melt out during the earlier stages of the glaciation.

Dimbleby's recognition of two suites of erratics, one preserved in the boulder clay of the infilling and one spread across and later than the infilling, is of major importance. The discussion of its significance would be out of place here but the existence of these erratics emphasizes the danger of relying upon the negative evidence of absence of foreign drift. Nevertheless, the highest channels are not really critical. The absence of "foreign" drift remains the criterion in such a case.

One interesting possible application of the morphological evidence for unglaciated enclaves such as the existence of "tors" arises in the case of the craggy outcrops of the Charnwood Forest.

Would it be reasonable to assume that they did not exist at the times of the older glaciations of the area and have been exposed by subsequent denudation (possibly largely by removal of Triassic sediments) or do they constitute an example of Professor Linton's unglaciated tor topography?

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9 *April* 1952

* S. E. Hollingworth and F. A. Bannister, *Mineral Mag.*, Vol. 29, 1950, p. 14–16; H. L. Hawkins and discussion, *Abs. Proc. Geol. Soc.*, No. 1481, p. 22–26; G. A. Kellaway and J. H. Taylor and discussion, *Abs. Proc. Geol. Soc.*, No. 1483, p. 40–50.

COMMENTS ON PROFESSOR S. E. HOLLINGWORTH'S NOTES

By D. L. Linton

Professor Hollingworth entirely expresses my own views when he states that melt water channels "mark the ice margin at their time of operation." The melt water channels of north-east Yorkshire that drained into and out of Lake Pickering were in operation when the ice of the Vale of York stood along the Escrick and York moraines in front of which the outflow channels (now marked by the courses of the Foss Beck and the Derwent) are situated. The Escrick moraine is the extreme limit hereabouts of the Newer Drift ice, and may be taken to represent the "maximum encroachment" of the Newer Drift glaciation. Its constitution was taken by Kendall and Wroot as implying deposition in and beneath water. Moreover within the hill country the terminal moraine at Nelly Hay Force marking the furthest penetration of ice in Wheeldale is clearly contemporary