FOUR TEMPORARY EXPOSURES OF SOLIFLUCTION DEPOSITS ON PENNINE HILLSLOPES IN NORTH-EAST CHESHIRE

by

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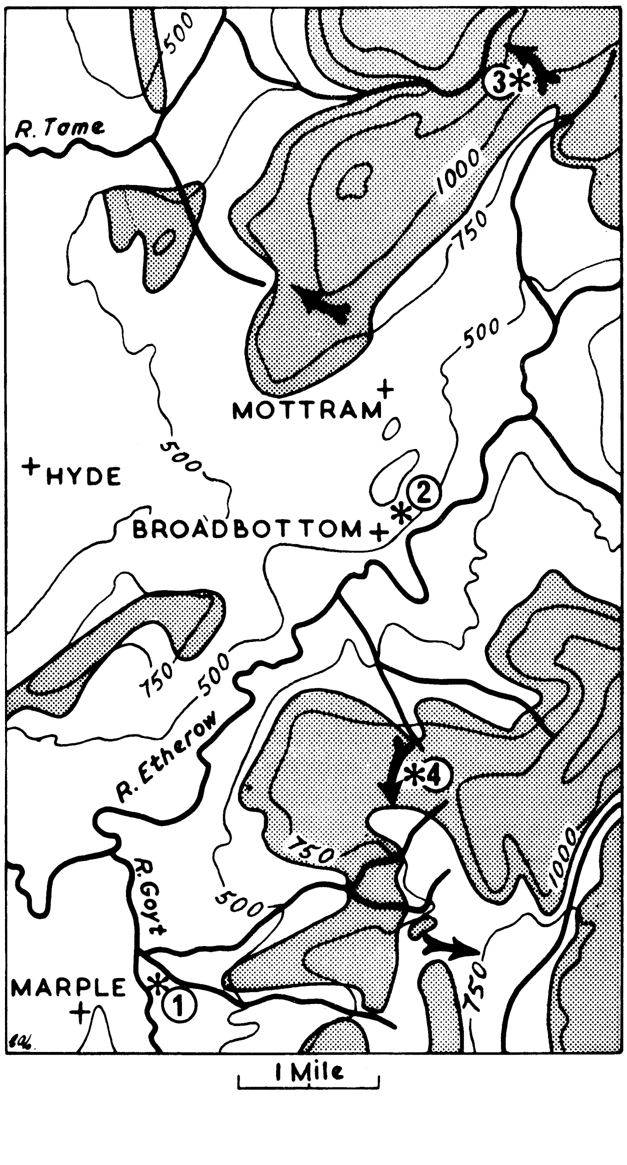
Summary

Four sections were temporarily exposed during September and October, 1966. Two revealed frost weathered debris in association with glacial deposits and the two others demonstrated the presence of solifluction materials on the valley slopes of meltwater channels. Each site thus provided valuable information for interpreting the glacial history and an assessment of their significance.

Introduction

Text-figure 1 is a general map of the area in which the sites are located. One section was observed in the bed of a tributary stream of the river Goyt and the others lie close to or on the watershed of the river Etherow. The area is varied in its relief and, during the Last or Weichsel Glaciation, ice covered much of the lower ground, mantling it with ground moraine and fluvio-glacial deposits. The upland relief hindered the free movement of meltwater within or at the ice margin and in some places streams eroded channels across the catchment divides. During the early and late stages of glaciation only the lower slopes were covered by ice, leaving the upper slopes susceptible to attack by frost and solifluction processes. * Such periglacial conditions caused the transference of much waste material downslope where it was incorporated within the basal load of the ice to form local ice-deposited sediments. In some localities however frost shattered debris mantles the hillslopes and during the late summer of 1966 four good exposures of such sediments were observed, and these are described here.

* Some writers have found it necessary to use a somewhat extended terminology to describe the geomorphological processes and associated deposits of cold climate regions. The terms used here are as defined in the American Geological Institute's 'Glossary of Geology and related Sciences' (1960). Thus for frost shattering and frost-shattered debris the terms used are congelifraction and congelifractate; and for frost heaving and frost-heaved debris - congeliturbation and congeliturbate. Solifluction is defined as the process which produces the slow flowage of weathered soil material downslope when saturated with water. It is useful too, to distinguish between the term periglacial which should be used when describing areas, conditions, processes and deposits adjacent to the ice margin, and cryergic which is used when reference is made to the same phenomena found in areas beyond the limits of glaciation.



Text-fig. 1. Location map of the North-east Cheshire area. Areas covered with glacial deposits are left unshaded; asterisks mark the position of periglacial deposits described in the text and arrows show the position of meltwater channels.

Marple Bridge (SJ 96898890)

This section was seen in the floor of the Mellor Brook some two hundred yards downstream of Cataract Bridge. The exposure was visible for a distance of thirty yards along the left bank of the stream. The succession was:-

Glacial	Boulder-clay	6 - 8 feet
Solifluction	Small sandstone fragments	4 - 8 inches
"	Sub-angular sandstone blocks in weathered sandy matrix	12 -36 inches
Bedrock	Woodhead Hill Sandstone (Carboniferous)	

At this site the brook has eroded a valley through the infill of a buried channel of the river Goyt (Rice 1957). The rock floor of this old valley is now partly exhumed and is exposed in the stream bed immediately upstream of the section. Overlying this bedrock surface is a layer of frost shattered rock debris derived from the sandstone beneath. Downstream this blocky waste material disappears into the stream bed but sufficient is exposed to show that it is poorly stratified and dips inwards towards the axial line of the old valley. Resting on top of the coarse congelifractate, there is a thin band of more comminuted debris with particles often reduced to between 0.5 and 1 inch in length. These are more sub-angular than the coarser debris beneath and were subjected to a more effective sorting process. The boulder-clay overlying the periglacial materials forms the main component of the buried valley infill but only the lower part of it is exposed. Its base is marked by a distinct unconformity separating it from the periglacial debris beneath.

Mottram Hill (SJ 99529418)

This section was noted in a road cutting on the east side of Mottram Hill at a height of 690 feet OD.

Soil	Soil	18 inches
Solifluction	Weathered shale and sandstone fragments	14 - 18 inches
Glacial	Stony till	4 inches
	Weathered clay till with stones	6 - 8 inches
Bedrock	Shales contorted but in situ	36 inches

The depositional succession shows that periglacial processes were active both before and after glaciation. At the base the top layers of the bedrock have been crushed and badly decomposed by freeze-thaw processes, and contorted through frost heaving. The till layers are thin and distinguished from each other by the absence of fines in the upper layer. It could be argued that this apparent stratification is a result of the reworking of the material by solifluction, but if this was so then the till must have been deposited only a short distance away because the present section is close to the hill summit. Some ninety rounded or sub-angular stones were taken from these layers of till and of these 12% were erratics and the rest local sandstones of varied textural composition. Since the exposure is only sixty feet below the hill summit, not all the sandstones could have been derived from the local cap rock and some must have been ice-transported together with the other erratics.

North Britain (SK 01139931)

In the summer of 1966 a new grid line was built across the Etherow valley. One of the pylons was constructed on the Tame-Etherow watershed at a place where a meltwater channel had been eroded. Incised from a height of 1100 feet O.D., the channel lies some two hundred feet above the altitudinal limit of the local boulder-clay (Bromehead 1933). The pylon legs straddle the valley wall and floor (Text-fig. 2) and excavations dug for the foundations had to penetrate some twenty feet below the valley floor before solid rock was encountered. Coarse angular sandstone fragments together with other head deposits were dug out (personal communications resident engineer C.E.G.B.) but the exposure was no longer available when the author visited the site. Sections still available on the valley slope showed beds of stratified solifluction materials consisting of layers of angular sandstone fragments alternating with layers of rotted, badly weathered shale and mudstone. The exposed beds were only five feet thick and formed part of a mantle extending over a terrace ranged along the lower portion of the channel wall (Text-fig. 2). The valley is about seventy feet deep with steep sides (26°) and a flat floor. At its outlet to the north, the infill, partly a result of peat accumulation, is 8 - 12 feet thick. The basal peat was dated as belonging to pollen Zone VIIa * (personal communication from J. Tallis) thus indicating that periglacial conditions ceased sometime before about 7500 BP.

Ludworth Intake (SJ 99439100)

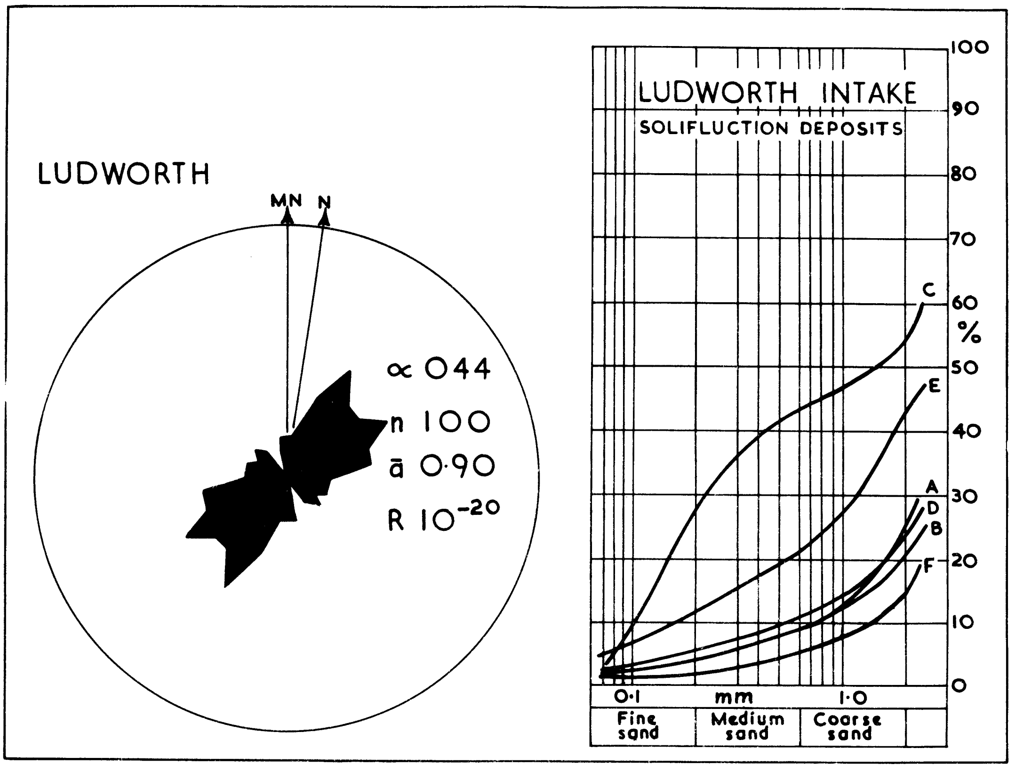
In order to improve the drainage of a small coal mine an adit has been cut into the side of another channel through which meltwaters escaped from the formerly ice-blocked Etherow valley. This channel was eroded through a watershed ridge and incised from a height of 920 feet O.D.. The adit was cut obliquely into the channel bank and extends for some thirty yards along it. Where the adit enters the bedrock a considerable thickness of solifluction material was exposed. This contained some erratics but consists almost entirely of Carboniferous shale and sandstone fragments.

A measured section showed the following succession:-

Soil	Layer	A	Soil and Subsoil	19 - 24 inches
Solifluction		B	Weathered shale	16 - 30 inches
"		C	Weathered shale and sandstone	3 - 6 inches
"		D	Weathered shale and sandstone	36 inches
"		E	Weathered shale	4 inches
"		F	Mudstone, sandstone and shale fragments	8 - 18 inches
Bedrock		G	Crushed, disturbed shales	13 inches
"		H	Shales	24 inches

* The pollen zones (see Godwin, 1956) cover the periods known as Late Glacial (zones I to III) and Post-Glacial (zones IV to VIII). Zones I and III of the Late Glacial were cold periods, separated by a milder phase (zone II) known as the Allerød interstadial. These zones have been dated by the Carbon-14 method (Godwin and Willis, 1959).

Text-fig. 2. The North Britain Channel as seen from the southern intake. (The excavations for the erection of the pylon are in the middle foreground: the drawing is based on photographs).



Text-fig. 3. 'Till-fabric' diagram for layer C of the solifluction deposit at Ludworth: Grain-size distribution of the several layers at Ludworth.

The individual layers were seen to vary in thickness when traced along the adit wall. Layer C which consisted of shale and sandstone, weathered to a coarse sandy-clay matrix, was found to be lenticular, but the other layers could be recognised in all parts of the exposure. Layers B, D and F were formed of broken rock fragments still easily identifiable as shale, mudstone and sandstone; in layer D sandstone blocks were embedded in the shales. Layer E contained the most decomposed rock material, being weathered to a fine clay matrix in which small shale particles were still identifiable. Layer G is probably shales in situ but badly weathered and distorted by frost action. Layer H represents the undisturbed shale of which only the top two feet was exposed.

In layer D a sample measurement was made to determine the stone orientation in the fabric. Text-figure 3A shows that the slope direction of the channel side exerted a major influence in determining the orientation of the elongated fragments measured. The channel side slopes in a direction N 42° E, and the mean direction of the fabric has been calculated as N 45° E. A second measure of the pattern form was calculated to indicate the degree of isotropic arrangement in the pattern. An equal division of the population into all sectors of the compass would give a percentage value of zero; the mean vector strength of this pattern is 66 per cent. A grain size analysis (Text-fig. 3B) for each layer was also completed. The two more finely comminuted layers (C and E) are quite distinct but the coarse layers, A, B, D, and F are remarkably alike.

Discussion

Stratification, a common but by no means universal feature of solifluction deposits, was observed at three of the localities described above. Solifluction takes place when the colloidal structure of silt and clay is destroyed and when there is a loss of cohesion due to the soil becoming water saturated. Permafrost is not necessary, for flow can occur where the upper layers of the soil are water saturated and the lower layers become seasonally frozen or are impermeable. In such conditions the solifluction deposits are unstratified and unsorted and, where the source rocks are resistant to chemical weathering, consist of quite angular debris. Stratification in the form of lenses of fine and coarse materials occurs when differential velocities, dependent upon the mass of the particles, are permitted within the flows. In early spring coarse debris can slide or roll over the still frozen subsoil, but later solifluction transports the fines downslope and redeposits them on top of the coarser talus. Such resorting however is somewhat localised within the solifluction sheets. An alternative mode of stratification occurs where conditions create an inversion of the original soil layers. In the initial stages of such a periglacial erosional 'cycle' solifluction removes any soil regolith developed on upper hillslopes and transfers it to the valley floors. This removal exposes bedrock which becomes subjected to intense mechanical weathering, particularly by frost, which penetrates the joints and pore-water spaces, thus breaking up the rock face. Clitter and small frost-shattered rubble form and are then removed by mass movement downslope, to be redistributed upon the old soil residual debris. The succession at Ludworth is interpreted as representing such conditions. Layers F – H are the legacy of a first periglacial cycle; layer E a derived soil layer; and layers A – D the fragments of bedrock transported by solifluction after the upland soil was removed.

The Mottram and Marple Bridge sections show that periglacial processes were active in the period immediately preceding ice invasion. Analysis of glacial sediments in the Manchester region shows invariably that the tills contain a high percentage of locally derived material; in stone counts involving a total of fifteen thousand stones seventy per cent have been shown to be of local derivation (Simpson 1962; Johnson unpublished work). It would appear that the ice moved over a surface, already disintegrated by frost and incorporated the debris into its basal layers. At the exposures at Marple Bridge and Mottram the cryoturbate material was largely undisturbed although covered by till. The contact face between the deposits is a sharp one and this suggests that glacial deposition was by a process of accretion from the basal layers of the ice sheet at a time when these had ceased to flow, and there is no suggestion that any plastering of the till on to the underlying rocks or periglacial debris occurred.

The congeliturbate accumulated on the channel walls and floors is of considerable thickness and thus the original form of the channels has been much modified. Thicknesses seen in the vertical sections exposed are of course misleading as to the actual depth. The true thickness at Ludworth is approximately six feet. The present valley sides at Ludworth and North Britain have slopes of twenty six degrees, but were obviously steeper when first eroded. The depth of infill at North Britain shows that such channels are not originally flat-floored troughs and, since the valleys have been streamless from the time when the ice melted, the infill can only have been brought by solifluction or soil creep from higher hill slopes in the vicinity.

The age of the channels and the periglacial deposits in them can now be considered. Three hypotheses are put forward for discussion.

(i) The channels were eroded during one of the earlier glacial periods and ice of the last glacial episode failed to reach the elevation at which they occur.

(ii) The channels were cut by meltwaters flowing sub-glacially or marginally to an ice sheet of the Main Weichselian period. After reaching its maximum limit the ice then downwasted leaving the upper slopes upon emergence to be attacked by frost, while ice stagnated in the valleys.

(iii) The channels were eroded during the Weichselian glaciation but due to unfavourable climate conditions solifluction was restricted during down-wasting. The head deposits did not accumulate in the channels until late Glacial (especially Zone III) times when solifluction was an extremely active process.

The first hypothesis seems untenable, since it would imply that the channels have remained essentially unaltered since their formation, in spite of a sequence of climatic changes from periglacial, through inter-glacial, periglacial, glacial and periglacial again, to post-glacial, extending over a period of time of the order of 100,000 years. If this was so then certainly the channels would have become very much altered by denudation and it is doubtful if much of their original form could have persisted. During the final glacial episode in this area the upper part of the Etherow valley (Longdendale) remained ice free (Bromehead 1933) and a reconnaissance survey has shown that the cryoturbate is much thicker in that area than that observed near to the channels. These are located on ridges which rise only a few tens of feet above the upper level of ground moraine deposition, and such a variation in thickness seems to support the conclusion that the channels were not eroded before the last glacial period.

The third alternative has much to commend it. The Zone III glaciers in England were limited to upland valleys in the Lake District and Northern England, where ice re-occupied corries formed in earlier times (Walker 1966), while at the same time in the Midlands and Southern England there were strong seasonal variations in temperature ranging from plus ten to minus ten degrees Centigrade (Manley 1964). Cryergic dunudation was thus very intense and these conditions extended southwards at least to the North Downs (Kerney, Brown and Chandler 1965), where considerable erosion at this time is known to have occurred. It could be argued that the solifluction mantle in northeast Cheshire must date from this period since deposits formed earlier would be greatly disturbed by the Zone III cold climate conditions. Slight disturbance of the lower layers of the solifluction mantle was seen at Ludworth and Mottram but the main objection to this third hypothesis is not the degree to which deposits were disturbed, but the failure to recognise the presence of cryergic deposits dating from the long cold climate period that lasted from the close of the Main Weichselian glaciation (c. 25000 - 18000 B.P.) until at least 12000 BP. During such a period a very extensive waste mantle must have been produced and it is very unlikely that its removal would have been accomplished during the Allerød interstadial (Zone II).

The evidence at Ludworth clearly favours the second hypothesis. The upper layers have been explained as an inversion of an upland soil regolith and subsoil due to mass movement in Zone III times and the lower layers as representing the base of the Zone 1 periglacial mantle. It is argued that the comminuted shale layer is the Alleröd soil but it has been greatly churned up and its material weathered by frost heaving. Pollen grains were found in this layer but were too crushed for a palynological investigation to be made.

If this interpretation is accepted then the relationship of the channels to the till found at lower altitudes requires further comment. The hypothesis implies that meltwaters eroded the channels at an early stage of glaciation and at a time when only the upper surface of the ice sheet was melting and the drift content of the ice surface was therefore small. Ground moraine deposition did not take place until later when the temperature of the basal ice had risen above its melting point and downwasting of the ice sheet was extremely rapid. The upper hillslopes must have emerged at an early stage in the ice retreat and were exposed to intense cryergic denudation, leading to the infilling of the abandoned meltwater courses at the same time as the boulder-clays and fluvio-glacial deposits were accreting beneath or at the edge of the ice sheet. In later times (Zone III) solifluction caused the cryoturbates formed upon the upper slopes to move down over the till surface - as at Mottram - and frost once more attacked the upper slopes to form a new waste mantle.

Such an interpretation demands a reconsideration of the criteria for determining the limits of a former ice sheet. Clearly it is not permissible to use the till margin, the upper altitudinal limit reached by erratics, or the position of meltwater channels to fix precise boundaries - they can only be used as marginal indicators for former ice sheets. Lastly a final comment can be made on the use of the term 'Local Drift'. Jowett (1914, p. 271) used it to describe what are quite unequivocably periglacially and not glacially formed deposits in the Rossendales. It has been used since in the Survey Memoirs (Wright et al., 1927; Tonks et al., 1931; Jones et al., 1938) but is misleading and should now be dropped from the literature of the Pleistocene period.

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