

A CONTRIBUTION TO GLACIAL STUDIES OF THE MALHAM TARN AREA

By R. CLARK

Northumberland College, Newcastle upon Tyne

INTRODUCTION

GLACIAL events in the Malham Tarn area cannot be considered wholly in isolation from those in adjoining Pennine districts. Much work on the regional glaciation has been published by Raistrick and current studies must take account of this. Much of the detail concerns the forms and events in the dale bottoms although Raistrick (1949) made some interpretation of features in the vicinity of the Tarn. He regarded the wider area as having been smothered by an ice-cap with the possible exception of the very highest crests, e.g. Ingleborough, 2,373 feet, and Pen-y-ghent, 2,273 feet (Fig. 1). King (1960) has redrawn attention to north-east directed striae at a comparable height on High Seat. Thus erosive and therefore quite thick and mobile ice is required over the upland round Mallerstang Common, although neighbouring hills were thought by Raistrick to have remained above the ice surface as well as lower hills near the eastern edge of the Pennines. These suggestions that there were many ice-free areas may result from the acceptance of inconclusive criteria. The absence of glacial drifts and erosional forms on the highest ground cannot demonstrate that no ice cover existed, as thin, little-travelled ice could be expected to be charged with a minimum of debris, and that locally derived, and to have little erosive effect. Similarly the presence of grotesque sculpturing of grit outcrops cannot itself indicate the occurrence of ice-free enclaves when similar features can be found in other regions which undoubtedly experienced "Newer Drift" glaciation. An approach to this type of problem might require the guidance of the "laws" controlling the surface profiles of ice-sheets. Manley (1964) has commented upon the evidence for a marked southward decline in severity of glaciation in the Pennines, and Raistrick discussed an eastward fall of the ice surface in the northern Pennines. Manley's data (1951, 1955, 1964) suggest a regional snowline at Würm maximum of the order of 1,500 feet.. The extent of land above this height is large and the growth of snow domes and cushions could progressively increase that area. Ultimately a large proportion of the accumulation necessary to create those ice depths for which there is abundant testimony, and to sustain that forward motion in the deeper ice channels to limits well beyond the present area, would take place on the surface of an ice-sheet concealing much of the topography. Thus the gathering ground would be greatly in excess of the area of upland higher than the regional snowline; it may be that the extent to which the ice spread can demonstrate the need for postulating such an expanded accumulation zone.

Much of the local work on deglaciation has been in terms of intermittent retreat of glaciers in the Pennine dales, and the anomalous glacial drainage

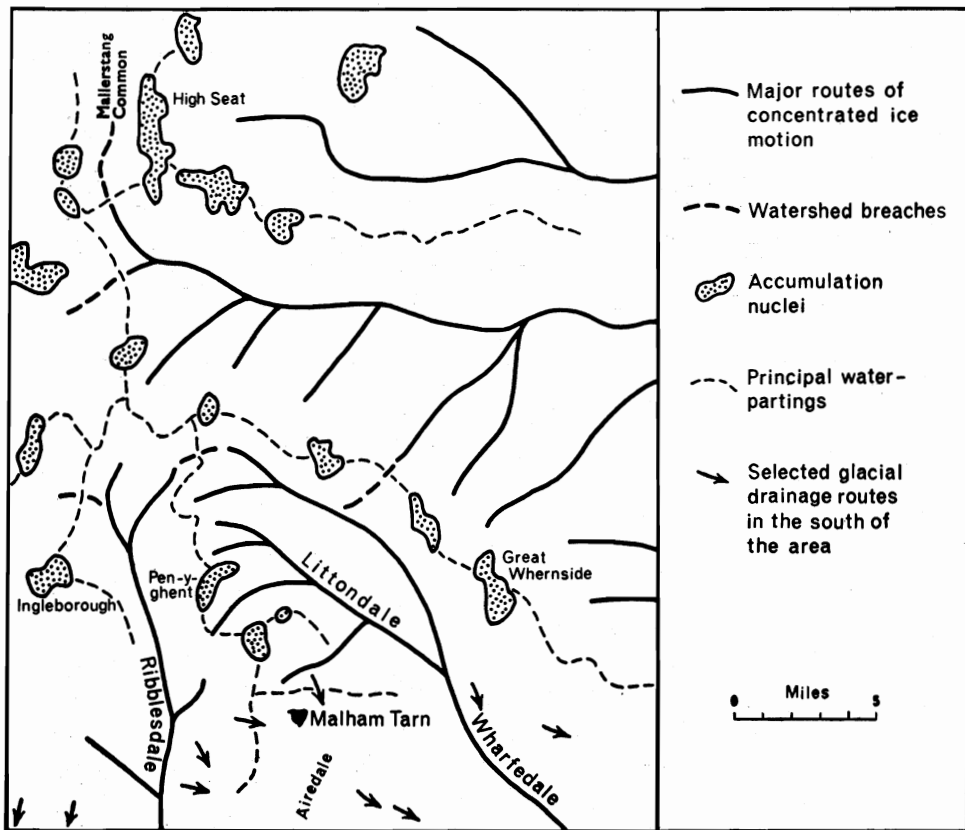


FIG. 1.
Elements of the "Glacial" landscape.

discharge routes have been regarded as marginal features or as spillways from glacial lakes. The dales form but a part of the area and the manner of ice-loss from the hillsides, benches and plateaus above has been somewhat neglected.

The area round the Tarn displays a number of features whose interpretation may help to clarify local events. Evidence will show that ice-loss did not involve the inward retreat of ice-margins so much as the downwasting of stagnant ice. There is little trace of truly marginal channels and of overflows from ice-impounded lakes. There is much evidence of the movement of water and of glacio-fluvial deposition beneath ice. Recent work in Britain (e.g. Sissons, 1960, 1961) has considered criteria for the recognition and explanation of such features, and shows that englacial water generally runs with the slope of the ice surface towards the ice margins.

In the belt of country between Ingleborough and Great Whernside and south to Skipton the high-level melt routes on the flanks of Ribblesdale, Airedale

and Wharfedale indicate the movement of water to south and east. No major watersheds intercepted this movement and as the dales open in those directions few anomalous routes were created though there are some which cross the minor spurs between valleys tributary to the dales. It will be shown that near the Tarn channels of this type were created under a complete ice cover and had no necessary relationship to the edges of shrinking valley glaciers. The phenomena of the Tarn area are influenced by its position between Ribble and Wharfe dales which have their heads in what was the heart of the ice-mass. Thus the area was flanked by two major ice outlets and further divided from the heart by Littondale. Evidence will suggest that, while the ice surface in the Tarn area had been high enough to be within the accumulation zone, and while the area had also received ice from the north and west, many features derive from the period of ice-loss. For part of this period the movement of melt water was determined by the slope of the ice surface and the distribution of various ice depths. The watersheds north and west of the Tarn where the Aire catchment meets the Ribble and Wharfe basins respectively were crossed by water so controlled, and though water leaving by the south and east moved more freely even there some courses were ice-controlled. As ice progressively wasted melt-water became unable to cross the higher crests and the Tarn area no longer received discharge from beyond. After this phase of deglaciation little further glacial modification of the landscape seems to have taken place.

GLACIAL LANDFORMS

In a treatment of particular features the area is divided into (1) the vicinity of the water-partings across which water entered the area, and (2) the "lower" ground nearer the Tarn from which water left the area.

(1) *North and West—Inflow Routes*

(a) *Highfolds*

Moisley (1954) has discussed the relationship of glacial forms to the "confusion" of closed depressions on the high limestone plateau north and north-east of the Tarn. Breaks in their rims he related to the escape of locally derived water over rock frozen into an impermeable state. High, dry, through valleys passing across some depressions were considered to be exits for water overflowing south from the valley glaciers of Wharfe and Litton dales. This proposition would require the existence of several hundreds of feet of ice in the dales while the Highfolds (Fig. 2) plateau was clear (as a nunatak or edge of a major ice-free area was not discussed). On Cowside in the vicinity of the intakes of the Highfolds channels no marginal channels or traces of free, sub-aerial flow are seen. The two channels follow parallel courses to the south-east becoming increasingly defined for much of their length. In the western one the irregularity of the long-profile though modified by drift has sufficient "uphill" sections to indicate the flow of water under some pressure which is suggestive of sub-glacial flow. A small arcuate "in-and-out" channel perched on the side of the main one is of the type indicating the short contact of a sinuous englacial channel upon underlying rock, a form of superimposition, in this case representing a stage in the integration of the main route, which at its southern end divides between

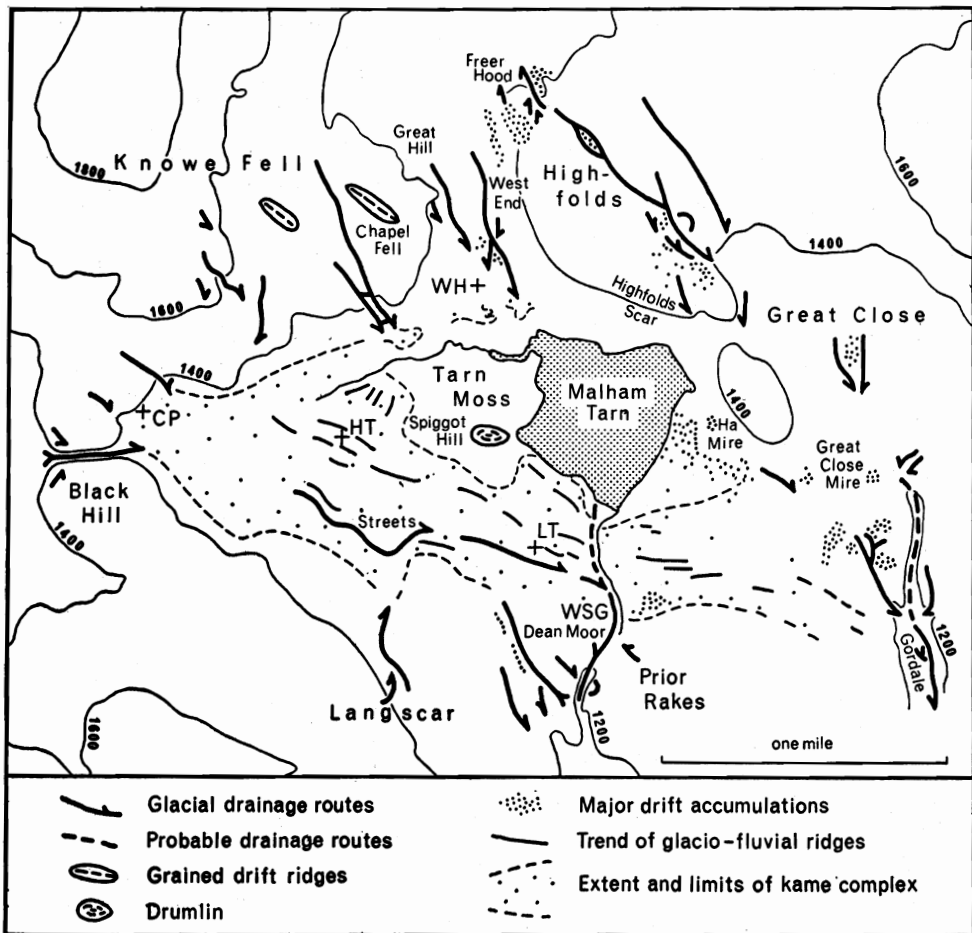


FIG. 2.

Glacial features in the vicinity of the Malham Tarn.

WH—Water Houses
LT—Low Trenhouse

CP—Capon Hall
HT—Higher Trenhouse

WSG—Water Sinks Gate

elongated, smoothed drift mounds. The scattering of large boulders on the mounds and elsewhere in the channels may tell of a final lowering of sparse englacial and ablation moraine to the channel floors. There is also a slight aggradation of channel slacks which could be related to the abandonment of this way for lower routes. The lowest level of marked incision in West Great Close is at about 1,400 feet. The lack of continued gullies across the Close would be difficult to explain in terms of free flow. A distributory ending at about 1,430 feet and one leading to a small chute south of Highfolds Scar

spur are also more easily explained in terms of sub-glacial drainage. The combination of evidence leads to the conclusion that the Highfolds channels carried water under some pressure across the plateau beneath an ice cover. The ice surface, which at a stage indicating substantial ablation must have been at least 1,600 feet above present sea level, would be expected to be in the accumulation zone at an earlier phase.

A series of chutes carrying water into the Cowside valley occurs north of Highfolds. One starting at 1,400 feet near Freer Hood is of interest in the implication of its abrupt start and finish. Clearly of small volume or duration the eroding water was in contact with rock for a short distance and the chute appears as a sub-glacial link in a mainly englacial system. A little further east a group of three chutes runs down the hillside. Two begin quite suddenly at a similar height, one forks and terminates abruptly just below, the third starts equally abruptly in a scoop suggestive of a moulin pit. Only one extends far towards the valley floor. With the chutes are patches of rubble-drift arranged either as rounded mounds or flat-topped benches. The shapes are more suggestive of accumulation than erosion and may be related to drift lodging in englacial cavities associated with the concentration of glacial drainage in the locality. North of West End up to Freer Hood are elongated drift mounds which extend to the intake height of the chutes.

(b) *Knowe Fell*

It is now convenient to turn west to Knowe Fell where the Ribble and Wharfe watersheds with the Aire meet in a landscape of sinks and pavements protruding through a thin drift cover crossed by shallow channels. Their smallness is interesting for the spur of Knowe Fell is well placed to intercept any drainage passing east. No important incisions cross the watershed but a chute descends the eastern slope to about fifteen hundred feet. The position of the channels shows that water did not flow freely from the north but was directed onto the rock from an ice cover as if by moulins. It might be that relatively thin ice over the ridge retained discontinuities developed during the stress of active motion across the ridge and that these, as in comparable localities, facilitated the growth of englacial water systems.

The undeveloped channels on the Knowe Fell spur contrast with larger ones on lower parts of the waterpartings to south and east. This variation can be related to the effect of progressive integration of water systems by which water was increasingly drawn to those systems able to discharge over lower points on a waterparting. Thus "col" channels tend to become major features at the expense of short-lived higher waterparting crossings.

Eastwards from Knowe Fell the waterparting runs by Chapel Fell to Highfolds. There are many large, smoothed sandstone boulders scattered over the bare limestone and there are also curious ridges mainly of coarse limestone cobbles. Some stand on elevated limestone platforms and rock projects through one or two. They are broadly parallel to each other and to a major NNW joint direction. One such ridge on Chapel Fell appears eroded on its east flank but in general they carry no signs of great recent modification. They may be described as coarse local drift grained in sympathy with the structure by ice

passing along the east side of Fountains Fell, the basal ice canalized by the shapes which its reaction with the rock caused it to form.

Among the ridges are glacial drainage channels at various altitudes. One near Limekiln Hill starts suddenly as if from a moulin, descends obliquely and ends at 1,410 feet. West of Chapel Fell a complicated cross-linked group of channels crosses the plateau. Four quite separate intakes feed the systems and show ice to have extended over the plateau at the time; the major member starts north of the waterparting which it reaches by a broad, open, shallow, sinuous and partly-aggraded gully; to the south it descends in a narrower and deeper cut through the rock. Flow became confined at about 1,430 feet, cut through the crest at about 1,480 feet and ceased to be erosive at about 1,310 feet. Its depositional counterpart is found below this level banked against the hillside north of Tarn Moss. The debris face is steep as though an "ice-contact" slope and the feature tails away east. The material had little chance to develop sorting and structure under the postulated conditions of deposition, rather being dumped chaotically down the steep hillside.

Further east the Great Hill channels continue the sequence. A tiny channel occurs west of the main channel which descends some forty feet towards Water Houses (WH) in a well-defined, winding gully some six hundred yards long. An abrupt start and similar end point to it having been that part of a glacial drainage system where water had erosive contact with underlying rock; it ceases at about 1,330 feet.

Concluding this sequence is the West End channel which is important for the relationship between erosion and deposition. This channel forks at its southern end and the western branch was disused first as its perched position many feet above the eastern limb implies. North of the fork the main gully winds down from a rock-cut, "up-and-down" section on the watershed, beyond which a short, rising reach leads to the crest and cut-banks with moulded drift show how water was funnelled into the routeway.

A most important deposit lies at the foot of the eastern branch of the West End channel, the bench which projects into Tarn Moss, its flat top at about 1,245 feet. Its age and local significance have been discussed by Pigott and Pigott (1959) who suggest that from its relationship to the basal Late Glacial clays under the Moss it is an earlier feature than late Zone I. The possibility of it being a delta-fan of the West End channel, its top representing an early Tarn water level, was noted. The present suggestion is that the bench is indeed a depositional feature built up by water from that channel but that it was sub-glacial and of a period when water was still derived from ice covering the Tarn-Cowside watershed. This is in agreement with the evidence that it pre-dates the Late Glacial basal lake clays of course, but it is not regarded as being related to a free-water surface and so would not have any bearing on levels in a subsequent Tarn.

(c) *Black Hill*

The Knowe Fell spur drops south to a col between Capon Hall (CP) and Black Hill. Two small gullies descend east from the crest of this part of the spur. Their size right at the crest shows that they were not formed by local

“normal” water movement. They could have been fed from an ice margin running along the crest but there is no other evidence of such a margin; as other features in the neighbourhood are seen to be sub-glacial, and as there appear to be no morphological reasons to suggest that these two gullies could not be sub-glacial it is suggested that they are small chutes. In many cases well-formed chutes commence on crest lines. No traces of uphill flow were seen west of the crest line and it is clear that the channels did not operate long or effectively enough for a true superimposition across the ridge to occur. This failure is almost certainly due to the more favourable location of the lower col near Black Hill. This is the main route by which water entered the Tarn area from the west; it is markedly incised and at the western entrance the water-trimmed bluffs and the minor feeder channels show how water was funnelled over the col.

Further south two gullies at Langscar have both chute sections and reaches parallel with the contours. They fed water north towards the depositional counterpart of the Black Hill channel and the termination of the longer one at about 1,280 feet suggests a broad contemporaneity with the Black Hill route. At this time ice over the Ribblesdale catchment and ice over the Tarn area was continuous and drainage from former to latter became progressively drawn to the Black Hill col through which it passed under some pressure.

Summary

The manner in which glacial drainage from the north and west converged on the lower ground round the Tarn and Great Close has been noted. The arc from Highfolds by Knowe Fell and Black Hill to Langscar presents evidence of a number of routes many of which cross the waterparting. The disuse of such routes implies the availability of lower alternatives with a fall of englacial water-levels as the ice surface declined. The change was one from “ice-controlled” movement capable of overcoming relief barriers to flow in sympathy with the shape of the ground. The northern routes ceased to operate as water was abstracted to Littondale, the chutes descending towards Cowside Beck belonging to this phase. In the west the Black Hill route succumbed to lower channels in Ribblesdale though it may be that this involved stages of integration represented by col routes east of Settle. It should be noted that the various parts of an area would not experience the change in nature of drainage in unison because of the local circumstance of relief and ice thickness.

It remains to consider the testimony of the lower ground to see the effect of the inflow of water, and trace the way in which it left the area.

(2) *Tarn Basin—Constructional Features and Outflow Routes*

(a) *Constructional features*

Malham Tarn and the peat of Tarn Moss hide a substantial part of the lower ground. Pigott and Pigott (1959) have described the irregular surface of boulder-clay beneath the peat and intervening deposits. Mounds among depressions some thirty feet lower than the lake level have been discovered. It was suggested that these mounds, together with Spiggot Hill and the group of rather similarly-aligned hillocks to the south comprise a family of small drumlins moulded by ice moving from the north-west. Of the buried mounds

little more can be written. Spiggot Hill on the evidence currently available appears to be a drumlin, but the hillocks to the south are in a different category. The drumlin belonged to a period of mobile ice to which the grained rubble ridges of Chapel Fell also belong. The hillocks are of fragile glacio-fluvial material which can only indicate that the ice amongst which they were formed was erosively incompetent. O'Connor (1964) has commented upon the incoherent nature of much of this deposit and suggested that great erosion of the drift cover has taken place. But the glacio-fluvial landforms retain a freshness of shape apparently little modified even by surface wash and creep. They carry negligible signs of having been eroded. Such surface water as there is has had little effect where it flows in the paths of earlier melt water and generally shows misfit relationships. The catchment for surface drainage is very small and no significant streams follow routes newer than the glacial episode. There seem to have been no other effective agencies of erosion and it is concluded that the drift topography is little modified.

Glacio-fluvial deposits at the ends of channels on Chapel Fell and at West End have been noted. East from the Black Hill col there spreads an extensive kame complex characteristically accompanied by sub-parallel water routes. It is traceable as far as Gordale. Various degrees of sorting and structure are displayed in the sands and gravels—in places the material is highly-sorted, bedded and ripple-marked. However, these are not essential features of glacio-fluvial deposition for, as with open streams, deposition can occur tumultuously. An interesting feature is the presence of unusually large boulders on but not in the kames. These may represent the coarser part of englacial debris let down onto pre-formed mounds. They are also to be found on till not concealed by kame deposits.

The form of the kames includes smooth fan-like spreads near to Capon Hall, and many elongated, rounded ridges somewhat resembling drumlins; it is these near Low Trenhouse (LT) that have been taken for drumlins, and by Raistrick (1949) for a terminal moraine. But they are characterized by crooked crests, embayments, and "ice-contact" slopes. Moreover, taking the tract as a whole the alignments are far from corresponding. There are also esker-like forms perhaps overlooked because of their small size, only a few feet high and wide east of Malham Water. They are up to two hundred yards long and form an overlapping echelon.

The greatest development of the tract is in the Streets-Higher Tren House (HT) area. Extensions from the main axis occur towards Langscar, northwards towards Water Houses, southwards to Dean Moor and there is some slight spread east of Malham Water. The northward extension ends at the Moss but beyond, near Water Houses, is a bench quite close in distance and height to that at the foot of the West End channel. Its origin cannot be clearly related to any feature on the high ground to the north and, indeed, in places it slopes down towards the north. It may be that it was built by water moving at the foot of the hillslope from the south-west.

(b) *Malham Water*

At Water Sinks Gate (WSG) the outflow from the Tarn passes along a depression crossing the kames. In this locality the depression joins a channel

from Streets, an integral part of the kame tract. In its passage south the united route is joined by a gully from the east and by others from Prior Rakes and Dean Moor. The Locks Scar feeder west of Dean Moor has a humped profile and ends with a bifurcation. There is also in the main valley a small "in-and-out" channel. East and west of Dean Scar further channels belong to this group. It is clear that the group formed a major discharge route and, from the evidence of Locks Scar, that some movement was "ice-controlled". The location of this exit may be considered in association with a characteristic of the kame tract, its reduced development east of Water Sinks Gate. The lack of a development matching that to the west can be seen as the consequence of the increasing abstraction by the Water Sinks route and the decreasing opportunity, as ice thinned, for water to move east against the slope of the underlying land.

(c) *Great Close and Gordale*

In Great Close there are small gullies in the lower slope towards the Mire. These appear to be caused by the concentration of locally derived water after the Highfolds channels operated. The most significant feature of the area is the short but prominent passage cut into rock by water moving from Ha Mire to Great Close Mire. The Pigotts (1959) regarded this incision as initiated at a level of about 1,240 feet and indicating an early outflow of the Tarn basin, further suggesting that the hillocks round Water Sinks Gate appeared not to have formed a higher barrier. The exit there and that at Great Close Mire are the two possible exits not just for the Tarn but for the last glacial drainage of the Tarn and Moss basin. The former outlet is through drift, the latter through rock; it has been seen that there are reasons for believing that the former existed beneath an ice cover and it is difficult to believe that the latter could remain in use for long after the former became well-established, or be formed subsequently. The level of incision of the Great Close Mire channel is very similar to the 1,245 feet bench level of the West End sub-glacial delta-kame and it might be speculated that sub-glacial water from the West End and adjacent channels moved by Great Close Mire towards Gordale.

That Gordale carried meltwater can be seen from several items of evidence besides its location near other meltwater features and the termination of the kame tract adjacent to it. Small gullies lead into Gordale near Great Close Mire and Mastiles Lane. South of the Mire a small melt-water channel begins with the union of separate but well-formed feeders and follows an incised, winding course with irregular long-profile to join Gordale at Mastiles Lane. Clearly it discharged its water into Gordale, though its exit is a little above the floor of the main valley. Further south in the more deeply-cut part of the valley there is a strongly defined "in-and-out" channel of the sort noted from Highfolds and Water Sinks.

It thus becomes evident that both Gordale and the Malham Water valley discharged meltwater, and that the latter became the major exit for water involved in the building of kame tract and fed in through the Black Hill col. It is also possible for the Great Close Mire incision and therefore upper Gordale to have received water from the channels north of Tarn Moss, though the linking evidence is less firm in this case. It also appears that the last melting

of local ice made no major change or addition to the glacial landforms produced while the watershed crossings north and west of the Tarn were still able to operate, though the patchy coating of ablation moraine would be lowered into place during this phase.

CONCLUSION

The landforms which have been used as a basis for the present interpretation belong to the periods of active ice-motion and subsequent stagnation and dissipation. Most of the glacial drainage channels are now dry though the routes of the principal streams have been shown to be as old as the deglaciation. Dry valleys are characteristic of limestone terrain and some particular features of individual valleys have been noted above to show why they are considered to be of glacial origin. It may be appropriate to list these points which are in association diagnostic.

- Abrupt start and/or conclusion above foot of slope
- Fully-formed start on ridge crest
- Origin in scoops or hollows—? eroded by water descending shafts in ice (moulines)
- Crossing a waterparting
- Humps in long-profile (up-and-down)
- Cross-links between channels
- Oblique downhill paths
- Change from cross-slope to down-slope paths
- In-and-out sections.

Nevertheless the absence of all these features is not conclusive evidence that a valley did not carry melt water. In a late phase of ice wastage when the necessary conditions for high englacial water levels in thick ice and the build-up of "head" against relief barriers were lost, water moved under the ice to the low ground. Thus where ice wasted *in situ* the last phase was one in which all valleys carried glacial drainage though the efficacy of the flow varied greatly from place to place. In the present locality Cowside and Darnbrook valleys would pass through that phase after the cessation of cross-watershed flow to the Aire basin and the fall of water levels within Littondale ice. It has been seen from near the Tarn that this last phase failed to modify the Water Sinks and Gordale routes.

Clayton (1966) has considered the problems posed by dry valleys in the limestone. Relevant to the present study is the consideration of valleys which open from high ground onto little-dissected erosion surfaces. Instances east of the Tarn were noted with a suggestion that valleys developing on a particular surface lost their water as rejuvenation advancing into that older surface led to a fall in the water-table. This suggestion involves a substantially pre-glacial origin for the valleys which were perhaps reoccupied during periods of frozen ground. In such a case relatively small valleys would be required to survive the whole repeated range of interglacial, periglacial and glacial conditions. It has been seen in the present study that some valleys which have a sudden end can be explained in terms of the behaviour of englacial water systems; the Highfolds channels are of this type.

Clayton showed that the wider Malham area was an ice-dispersal area centred on Langstrothdale; in the present account the more limited area round the Tarn is also seen as being within the zone of accumulation at the time of maximum glaciation. Clayton rightly stresses that Millstone Grit erratics in the limestone area do not in themselves indicate direction of ice movement. But the direction of water motion which produced the highest watershed gullies indicates a general fall of ice surface to south and east while the few ice-moulded features which indicate a direction of movement generally confirm the inference that ice moved in conformity with its surface slope. The watershed gullies leading south from Cowside show ice surfaces to have been higher to the north and those leading east near Black Hill tell the same about ice over Ribblesdale. Thus it is feasible to postulate spill of some Ribblesdale ice east towards the Tarn while the accumulation of ice between Highfolds and Fountains Fell, impounded by Littondale ice, might gain some relief by spill south. Such paths were effective discharge routes within an ice-sheet though far less-developed than the major ice streams near Ribblehead and in the larger dales. Such conditions in the Tarn area would make Fountains Fell a likely source of the grit erratics.

Evidence has been given that the kames south of the Tarn were built beneath an ice cover. Within the kames are small ice-wedge pseudomorphs and traces of frost disturbance. The sub-glacial environment during down-wasting is unlikely to have been characterized by deep freezing of the sands and gravels while the location of the casts within the kames suggests that they are not contemporary with sedimentation. It is thus possible that they were produced in a period of severe cold subsequent to deglaciation. The survival of superficial frost phenomena and of the thin cover of ablation moraine is further evidence that the kames have undergone little post-glacial erosion.

The Pigotts (1959) showed that the Tarn area was free of ice at the latest by the end of the Older Dryas time (Pollen Zone IC) about 10,000 years B.C. This appears to be a key date in any attempt to produce a local glacial chronology. Three Late Glacial phases (IA, IC, III) of severe cold which could produce frost features have been determined between 14,000 and 8,300 B.C. No evidence is yet available as to whether the Malham upland was ice-free in the earliest of these phases but it may be unlikely, as evidence of early Zone I has mainly been found in peripheral areas of the Würm glaciation. Frost structures have been widely reported from within the territory of the Newer Drift glaciation and much of this area was ice-free by the end of Zone I. Abundant evidence of the morphological effects of severe cold in Britain has been dated to Zone III ending 8,300 B.C. and it may be that the Malham features belong to this time. The evidence of the Tarn stratigraphy is of the local occurrence of cold periods in Pollen Zones IC and III but at present only one phase of frost activity has been recognized in the gravel pits; continued examination is to be encouraged.

The accumulation and loss of the ice responsible for the landforms discussed above belong to the Newer Drift glaciation equivalent to the Würm (Weichsel) glacial stages of the Continent. Both British and Continental glaciations appear to have been complex and no full agreement has been reached upon the stratigraphy and chronology of these episodes. A recent discussion by Penny (1964)

considers an equivalence of our Newer Drift maximum with the Main Würm which began about 23,000 B.C. The local landforms do not permit more than a general relative chronology to be discussed and fitted into a period of about 13,000 years reaching Zone IC. Essentially the landforms tell of a period of ice erosion and transport followed by a period of decreasing ice thickness and stagnation characterized by glacio-fluvial activity. In this latter period two stages may be detected, of ice-controlled water movement succeeded by less effective land-controlled flow. Change from the first style of flow to the second, being dependent upon local conditions, was dischronous. Clearly there is not yet sufficient data upon which to erect more than a skeletal local chronology.

REFERENCES

- CLAYTON, K. M. (1966). The Origin of the Landforms of the Malham Area. *Field Studies*, 2 (3), 359-384.
- KING, C. A. M. (1960). *The Yorkshire Dales*. Geographical Association, Sheffield.
- MANLEY, G. (1951). The Range of Variation of the British Climate. *Geogr. J.*, 117 (1), 43-65.
- MANLEY, G. (1955). On the occurrence of Ice Domes and permanently Snow-covered Summits. *J. Glaciol.*, 2 (17), 453-456.
- MANLEY, G. (1964). The Evolution of the Climatic Environment. In: Watson, J. W. and Sissons, J. B. (Eds.), *The British Isles* (pp. 152-176). Nelson.
- MOISLEY, H. A. (1954). Some Karstic features in the Malham Tarn District. *Ann. Rep., Council for the Promotion of Field Studies*, 1953-54, 33-42.
- O'CONNOR, J. (1964). The Geology of the Area around Malham Tarn, Yorkshire. *Field Studies*, 2 (1), 53-82.
- PENNY, L. F. (1964). A Review of the Last Glaciation in Great Britain. *Proc. Yorks. geol. Soc.*, 34 (4), 387-411.
- PIGOTT, M. E. and PIGOTT, C. D. (1959). Stratigraphy and Pollen Analysis of Malham Tarn and Tarn Moss. *Field Studies*, 1 (1), 84-101.
- RAISTRICK, A. (1949). In: Raistrick, A. and Illingworth, J. L. *The Face of North-west Yorkshire*. Dalesman, Clapham.
- SISSONS, J. B. (1960). Some aspects of Glacial Drainage Channels in Britain. Part I. *Scot. geogr. Mag.*, 76 (3), 131-146.
- SISSONS, J. B. (1961). Some aspects of Glacial Drainage Channels in Britain. Part II. *Scot. geogr. Mag.*, 77 (1), 15-36.

NOTES ON TERMINOLOGY AND USAGE

Ablation moraine

Material held in the ice above the more concentrated debris at its base gradually became gathered together as the ice ablated or thinned; it is thus let down onto any underlying material. Its occurrence is subject to controls such as the quantity of material held in the ice and the degree of lateral movement which took place at surface and basal melting-fronts of the ice.

Kame

A constructional form of water-transported material produced in or adjacent to ice. The degree of sorting is very variable. Because of the great variety of environments possible for the accumulation of glacio-fluvial material kames show considerable range of character which can lead to further classification.

Esker

A form of kame. Often the depositional evidence of concentrated flow of water in or under an ice-sheet. Usually marked by great length relative to breadth and often accompanied by flanking depressions; they occur singly or in complex groupings. Eskers may be classified according to location and morphology; "the engorged esker" is the depositional counterpart of the sub-glacial chute.

Chute

A glacial drainage route excavated directly or obliquely down a slope. Sometimes simple, single features; sometimes components of major complexes. Now often dry or carrying underfit streams.

Moulin and Moulin Pit

Moulin—a shaft within ice carrying water to the bottom where its swirl may produce erosional forms such as the scoop-like moulin pit, or constructional forms—a type of kame.

“Up-and-down” or humped profile

Term used to describe the long profile of some glacial drainage channels. Generally but not always associated with channels crossing ridges. Such profiles may indicate that flow was in confined passages under hydrostatic “head”.

“In-and-out” channel

Usually a short, curved channel open at each end and found on a hill or valley side. Such a feature appears to indicate that part of a swinging englacial channel has impinged onto and cut into the underlying ground. Incision rather than slip-off down the land surface suggests great vigour in the moving water. “In-and-out” channels are widespread in glaciated uplands.

Ice-controlled flow

Movement of concentrated water within or under ice may follow courses quite unrelated to the underlying land surface. Ice thickness, ice surface topography, hydrostatic pressure and englacial water levels influence such routes. Cols on ridges frequently become the sites at which ice-controlled water crosses waterpartings either eroding, depositing or both.