LANDFORM STUDIES IN MOSEDALE, NORTHEASTERN LAKE DISTRICT: OPPORTUNITIES FOR FIELD INVESTIGATIONS

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ABSTRACT

Mosedale is part of the valley of the River Caldew in the Skiddaw upland of the northeastern Lake District. It possesses a diverse, interesting and problematic assemblage of landforms and is convenient to Blencathra Field Centre. The landforms result from glacial, periglacial, fluvial and hillslopes processes and, although some of them have been described previously, others have not. Landforms of one time and environment occur adjacent to those of another. The area is a valuable locality for the field teaching and evaluation of upland geomorphology. In this paper, something of the variety of landforms, materials and processes is outlined for each district in turn. That is followed by suggestions for further enquiry about landform development in time and place. Some questions are posed. These should not be thought of as being the only relevant ones that might be asked about the area: they are intended to help set enquiry off. Mosedale offers a challenge to students at all levels and its landforms demonstrate a complexity that is rarely presented in the textbooks.

INTRODUCTION

Upland areas attract research and teaching in both earth and life sciences. In part, that is for the pleasure in being there and, substantially, for relative freedom of access to such features as landforms, outcrops and habitats, especially in comparison with intensively occupied lowland areas. But, importantly, it is for the broad exemplification of characteristic upland environments and processes and their demonstrable spatial and temporal variance.

The study of upland landforms in the British Isles, over the last twenty or so years, has been characterised by a tendency to focus on specific features, sediments and/or processes. In so doing, a large volume of valuable data has been assembled concerning, for example, cirques (*e.g.* Gordon, 1977), Loch Lomond Stadial glaciers and their moraines (*e.g.* Cornish, 1981; Gray, 1982), protalus ramparts and fossil rock glaciers (*e.g.* Ballantyne & Kirkbride, 1986; Wilson, 1993a), alluvial fans (*e.g.* Harvey & Renwick, 1987; Tipping & Halliday, 1994), debris cones (*e.g.* Brazier *et al.*, 1988), slope failures (*e.g.* Johnson & Walthall, 1979; Skempton *et al.*, 1989), avalanche-related landforms (*e.g.* Ward, 1985; Ballantyne, 1989), aeolian deposits (Pye & Paine, 1984; Ballantyne & Whittington, 1987; Wilson, 1989; Ballantyne, 1998), and talus (*e.g.* Statham, 1976; Wilson, 1990; Hinchliffe *et al.*, 1998). The detailed information now available has, in some cases, enabled estimation of rates of landform development and sediment accumulation. With few notable exceptions (*e.g.* Rose, 1980; Ballantyne, 1984, 1991) assemblages of upland landforms and their inter-relationships have rarely been explored, this is unfortunate because landforms are

components of the landscape continuum within which the spatial and temporal context of landform assemblages must be viewed for patterns of regional physiographic development to be revealed.

The Lake District upland is one that endures a particular concentration of field study - teaching, personal projects, and research. It has shared in the general tendency for recent landform studies to have focussed on particular types of feature (*e.g.* Sissons, 1980; Wilson, 1993b; Evans & Cox, 1995; Whalley, 1997). There have been no recent 'assemblage-continuum' landscape studies for any part of the Lake District.

Though it lacks the spectacular scenery of the central Lake District, the Mosedale-Carrock Fell region (Fig. 1) on the northeast side of the Skiddaw upland is an appropriate place to essay such a study. Part of the area lies, in direct line, within 6 km of Blencathra Field Centre. It is easily reached by road: nowhere in the area is far from a road. Paths and tracks traverse it. Also, it is largely open ground. A great variety of landforms lie within quite a small compass, enhancing its value as a teaching locality. The range of features, large and small, reflects influences of lithology, structure and aspect. Imposed on the major features, developed in earlier times, is a record of glacial, periglacial, temperate and anthropic processes in the suites of smaller features. How these, interrelating in time and place, constitute a complex landscape forms a field for fruitful enquiry. Furthermore, the proportion of recent Lake District landform studies made in the Skiddaw area (Boardman, 1985; Warburton, 1985, 1997; Evans, 1994; Oxford, 1994; Clark & Wilson, 1997; Wilson & Clark, 1999) provides some foundation for work in and around Mosedale.

The description and discussion of the local landscape units attempts to strike a balance between being informative and sustaining the opportunity for open-ended examination of the localities.

PHYSICAL SETTING

The River Caldew rises on the eastern slopes of Skiddaw and follows a generally northerly course to join the River Eden at Carlisle. Before leaving the uplands, the Caldew flows east through Mosedale where it is flanked to the north by Carrock Fell (663 m OD) and, on the south, by Bowscale Fell (702 m OD) (Fig. 1). Along the 3 km length of Mosedale the river falls from 280 m to 220 m: an average gradient of 1°. The valley floor is narrowest (ca 50 m) just east of the Caldew's confluence with Grainsgill Beck and widest (ca 350 m) in the vicinity of Swineside. At the hamlet of Mosedale, the valley opens into a north-south vale along the east side of the Skiddaw upland.

Between the crest of the Carrock Fell - Miton Hill ridge and the axis of Mosedale, almost parallel with them and running close to the boundary between lower steeper and upper slopes of the fell, is the boundary between Skiddaw Group rocks and the intruded rocks of the Carrock Fell Complex (Fig. 1). Though the intrusive rocks form the spine of Carrock Fell, and are well exposed, they are not seen east of Carrock End Fault. The various rocks of the Complex are particularly well exposed on the cliffs along Carrock Fell End, the steep almost straight east end of Carrock Fell. In the present study area, that hillside is in gabbros of the Mosedale Series. Skiddaw Group rocks consist mainly of cleaved mudstones and siltstones with some coarse-grained arenaceous strata (Eastwood *et al.*, 1968; Roberts, 1990). Axes of fold structures in the Skiddaw Group trend parallel with Mosedale and the strike of the Carrock Fell Complex outcrop. The Skiddaw Granite is exposed on the west margin of the area near where Grainsgill Beck joins the River Caldew
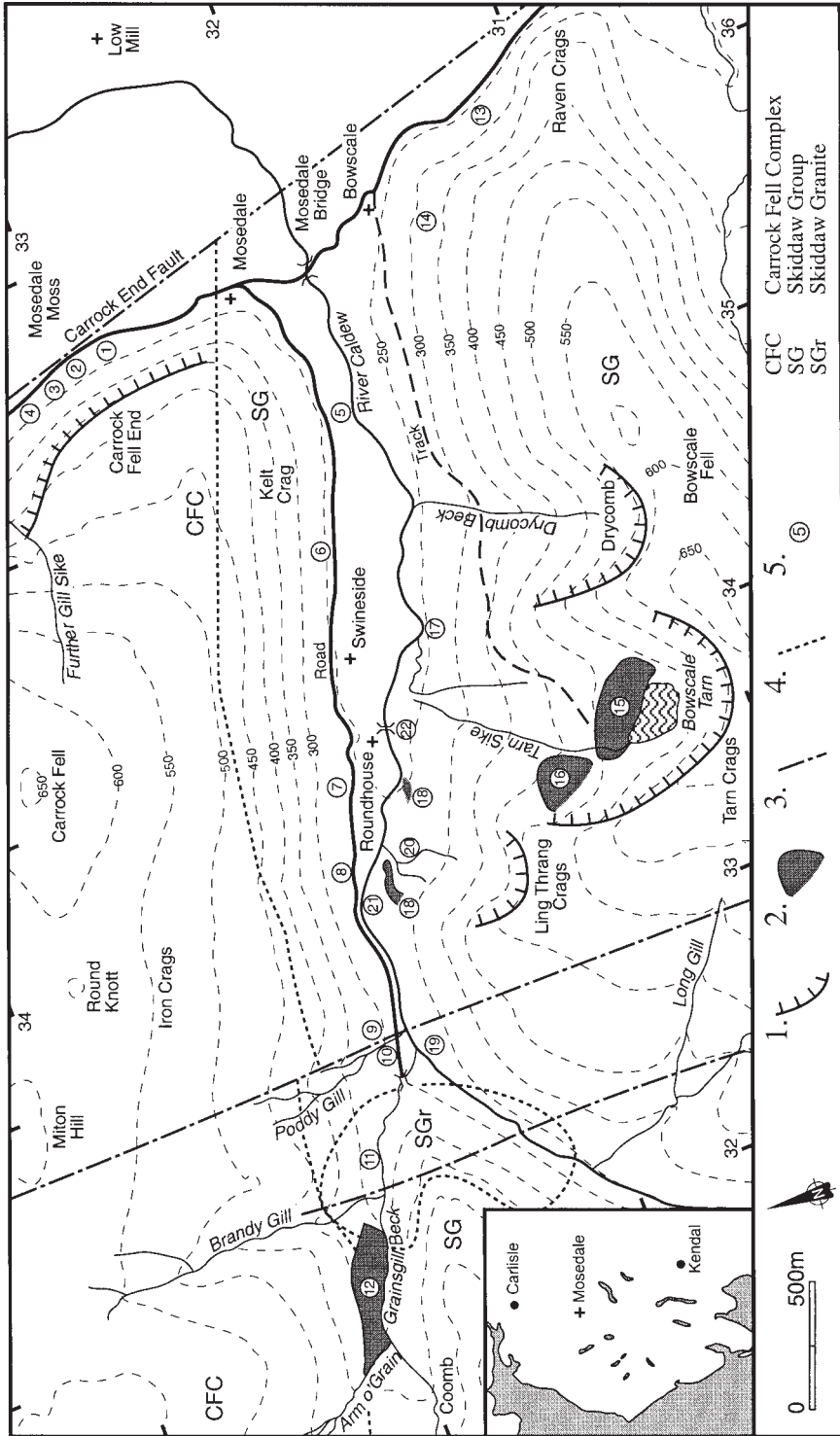
Fig. 1 Topography and geology of Mosedale, northeastern Lake District.
Explanation of symbols: 1, crest of very steep slopes. 2, prominent debris accumulations. 3, faults. 4, geological boundaries.
5, nameless sites described in text.

(Fig. 1). Thermal metamorphism of Skiddaw Group rocks, associated with emplacement of both Carrock Fell Complex rocks and Skiddaw Granite, has been recorded across much of the outcrop in the study area (Eastwood *et al.*, 1968), but seems to have had little effect on landform development.

Mosedale is included by Evans (1994) as one of three glacial troughs within the Skiddaw upland, though all three probably owe their locations to structural influences (Clark, 1994). Evans (1994) considered that the Skiddaw upland and its accumulation of local ice served to exclude and divert the ice generated in the more extensive Lake District uplands further south but that the ice generated in the Skiddaw upland lacked vigour to produce 'a strong erosional imprint.' On the other hand, the Geological Survey (Eastwood *et al.*, 1968) recorded the distribution of various rocks from further south in glacial tills within the Skiddaw upland as well as the movement of Mosedale Series gabbros northwards uphill and across the summit ridge of Carrock Fell, a direction normal to the trend of Mosedale.

There are large-scale landscape problems in this area that are shared with the rest of the Skiddaw upland and these may be mentioned as part of the background to work in Mosedale. Seen from a high or distant viewpoint, the dale seems to consist of a steeper-sided inner valley between higher, broader, less-steep slopes. It is as though renewed deepening conjoined with limited widening has taken place. Whether that deepening was produced by the work of ice or whether the deepening was earlier and the trough form of the inner valley represents a subsequent modification by ice is not clear. However, this aspect of landscape development relates to the comment, below, on the line of the Carrock End Fault.

Past glaciation of the area is taken to be the case. The following text considers local features that might be ascribed to glaciation but it should also be noted that within just a few, say five, kilometres from the valley there is an abundance of evidence, both in the upland and across low ground, regarding the extent of ice and of events during the most recent general glaciation. In this part of the northern Lake District, the change from a thick cover of moving ice to the last fragmentary remnants of stagnant ice took place from approximately 15,000 to 13,000 radiocarbon years ago (rya). There followed a period called the Windermere Interstadial, 13,000 to 11,000 rya, of significantly warmer conditions in which herbaceous vegetation, juniper scrub and birch woodland became established. This was succeeded by the Loch Lomond Stadial, 11,000 to 10,000 rya, characterised by a climate of arctic severity and the development of small glaciers in many cirques and valley heads (Pennington, 1978; Sissons, 1980).

Since about 10,000 years ago, but increasingly within the last millennium, human activity (*e.g.* cutting peat, clearing woodland, pasturing stock, controlling rivers, and mining) has had an impact on run-off and stream discharges, vegetation and slope stability, and sediment availability. That should be kept in mind along with the series of other environmental changes in assessing the landscape.

Investigating the Landforms

It will become obvious that the Mosedale area presents a wide variety of landforms and materials and has experienced many geomorphological processes. This concentration, together with its accessibility, makes it a very suitable locality for field studies over a range of levels and with purposes extending from demonstration by tutor to independent enquiry.

The following account limits the amount of analysis and synthesis accompanying description so as not to pre-empt or over-determine the conclusions that might be reached by others, both in the matters of detail and of broader understanding. Nor do we presume that the interpretations we have included or excluded are definitive; scrutiny and appraisal are integral parts of enquiry and our text is not immune to that.

The following notes are neither comprehensive nor intended to prescribe field studies but rather to suggest some ways in which various places up and down the dale might be looked at further. It is not possible to take account here of differences in the experience of students but the following questions and leads to enquiry are intended to help in the planning of work in the field. There are limits to what field investigation of landscape questions can achieve but field facts and relationships are crucial to interpretation. They must be interpreted in the light of experience of other places and, of course, theory - the body of concepts and understanding about the making of landscape by which observation is both directed and appraised.

Some characteristics of the Mosedale area and its landscape history are taken as given, the large-scale units of hillside, ridge-top, valley, marginal lowland, though how this landscape of big landforms came about is itself a worthwhile and proper subject of study. And, though questions will be asked about glaciation, that the area had earlier been largely or even completely covered by local and invading ice is accepted.

The various parts into which the Mosedale area has been divided give an order to the text. That order can be changed to suit circumstance. Landscape parts are related to their neighbours, giving or receiving materials including water, which, liquid or solid, often serves as an agent of transport. If the processes, their sequence and consequences, can be sorted out for one area, it may be possible to hypothesise about what went on in adjoining areas and, thus, build up an account of some or of all the parts that make up the whole area.

It will be particularly useful to be able to recognise the main local rocks; finer and coarser sorts of the Skiddaw Group, the dark and pale gabbroic rocks and pinkish microgranites of the Carrock Fell Complex, the local Skiddaw Granite and its altered forms. As well, it would be valuable, in some studies, to be able to recognise certain of the Borrowdale Volcanic Group rocks, lavas and pyroclastics, that may have been brought into the area by ice.

THE LINE OF CARROCK END FAULT

There is a sharp, almost north-south, break between the uplands flanking Mosedale and the low ground to the east that follows the line of a presumed fault (Fig. 1). The division is quite straight north from Mungrisdale (NY 364 306) as far as the northeast flank of Carrock Fell. At Mungrisdale, there is a small offset in the line of the hillfoot and, possibly, a small eastward offset on the north side of valley mouth, at Mosedale. Otherwise, straightness is barely affected by the base of the recess in the hillside south of Bowscale nor, to the north, at the bases of Further Gill Sike and Scurth (NY 353 336). Though all three recesses are more pronounced further upslope than at slopefoot, they are confined to the lower hillsides. Straightness extends indifferently across a succession of rock types. The gross morphology and the altitudes sustained by the hills west of the fault also seem independent of rock type.

The lower, mainly below ca 400 m OD, parts of the hillsides that fall to the eastern low ground are notably steeper than the upper. One, or a combination of, circumstance(s) may

account for this. Erosion by north-moving ice in the most recent of, or during several of, Quaternary glaciations may have effected steepening. Late removal, by ice or otherwise, of rock east of the fault plane during lowering of the land may have occurred. Or, basal steepening may tell of late movement along the fault; that is, after the upper hillsides had attained much of their present character.

CARROCK FELL

The east side of Carrock Fell (Carrock Fell End)

The shoulder of Carrock Fell, where it turns from Mosedale to face east along Carrock Fell End, is in mudstones and siltstones of the Skiddaw Group. Only the extreme southern low part of the east face is in Skiddaw Group rocks. There are some rock outcrops and patches of scree but not the continuous cover and protalus features found on the north side of Mosedale (see below). Gabbroic rocks then form the east-facing Carrock Fell End for ca 1 km north to the Further Gill Sike area (Fig. 1). A line of cliffs in these rocks, mainly between 300-350 m OD, separates the lower and upper hillsides. The hillslope above the cliffs is an area of intermingled bare rock and generally coarse rock debris. The slope below the cliffs, down to ca 220 m OD, is heavily scree encumbered, with some rock protrusions, but with little development of any basal concavity or talus-foot features (unless concealed by flanking peat of Mosedale Moss). The scree is generally angular and coarse with many boulders exceeding 1 m in maximum dimension. All the blocks comprising the scree are of local (gabbroic) material. However, the scree does not form a simple undifferentiated slope but possesses a wide variety of features. Access to sites described below may be gained from the road running north from the hamlet of Mosedale.

At NY 356 328 (1 on Fig. 1), the scree base has a steep convexity that rises 12 m above road level at gradients of 10-28°. At the crest of this convexity is an unusually large block of 8x5x4 m (possibly the 'Chapel Stone' of the 1:10,000 OS map). The origin of the convexity is unknown; it may be built entirely of gabbro blocks derived from the cliffs or may be a pre-scree feature that has become covered in blocks. Evidence for the presence of pre-scree material along this hillside is available at NY 357 329 (2 on Fig. 1) where peat rests on rounded gravels and angular scree blocks also overlie glacial (?) pebbles. In general there is very limited spread of scree material away from the base of the slopes. East of the road, at the western edge of Mosedale Moss, molehills contain some sand; roadside molehills further north include Skiddaw Group and Borrowdale Volcanic Group lithologies.

At NY 355 331 (3 on Fig. 1), the scree surface comprises large open-work self-supporting blocks, many of which have maximum dimensions in the range 2-4 m. At the scree foot, blocks form a steep-sided bench-like feature 10 m in width. There is little evidence for fine material either amongst the scree or washed out from scree base onto adjacent glacial sediments.

At NY 356 332 (4 on Fig. 1), the scree base rises onto a bench of glacial material. Here again, the scree is very open and coarse. One section of cliff has lost, among other debris, 9 large blocks up to 10x8x6 m in size that are now arranged in a downslope line as if from some considerable rockfall, but this does not appear to have resulted in a significant recess in the line of cliffs above.

The cliff base rises into the Further Gill Sike recess and the scree on the south side of the gill is very coarse with little evident fine material. Blocks up to 4.5x3.5x1.5 m occur

here. The scree ends in a steep front ca 6 m high, possibly the outer face of a major rockfall, with a lower platform of boulders extending for ca 18 m at a more gentle gradient than characteristic scree angles. This may represent run-out of scree material onto a gentler scree-foot slope or be derived from the base of a rock fall or from the base of scree accumulation. There are no surface forms indicative of creep or flow here. The hillside below the platform slopes less steeply than scree but is boulder covered and its base is exposed in a road cutting (NY 354 335) that reveals glacial drift below. The bouldery cover is thin, generally less than 0.5 m, with boulders embedded or enclosed in a fine matrix. Neither surface form nor section tells whether this is a flow, slide, or roll deposit.

Several questions - concerning the scree and pre-scree materials, the processes by which these materials accumulated, their chronology, and the origin of the cliff dividing upper and lower hillslopes - may be posed subsequent to field examination. Suggestions are given following description of the screes on the north side of Mosedale (see below).

The Carrock Fell ridge

The break between the steep, largely scree-clad, north side of Mosedale and the upper, less steep, hillside runs at about 450 m OD and close to the junction between Skiddaw Group and Carrock Fell Complex rocks (Fig. 1). Access to the sites described is by footpath from near Mosedale hamlet or a pathless ascent alongside Poddy Gill. West of ca easting 331 the lower northern flanks of the dale are less steep, scree is discontinuous and the inflexion to the upper hillside more transitional. Characteristic southward falls of the upper slope are 150-200 m in ca 1 km. West of Iron Crags and Round Knott, the ground is less rough than to the east, with fewer outcrops and with extensive spreads of blanket peat. There are few surface streams. The headstreams of Poddy Gill are shallowly incised (520-450 m OD), hardly at all further upslope but deeply as they enter the gill itself.

Many, but scattered, large boulders project through the thinner peat and its vegetation and there are few exposures of substrate beneath the peat. Most of what there are reveal superficial covers, stones and gravel dispersed in sand-silt matrix or close-packed angular gabbro clasts from gravel to ca 10 cm in main dimension but with some to ca 30 cm. The few exposures may not reveal the range of cover types. The new edition of the *Cockermouth geology map* (British Geological Survey, 1997) shows much of this area to be covered by glacial till but our traverses located no convincing exposures of till.

In the vicinity of the shallow heads of Poddy Gill, are two boulder spreads, both aligned downslope, the larger ca 40 m wide. The evident overlap of peat along parts of their margins points to a greater extent than presently revealed. Boulders reach ca 2 m in length and many are about 1 m long. Surfaces of the spreads show locally dominant fabrics, principally upslope imbrication and flat-lying. Upslope of some particularly large boulders, smaller clasts have imbricated fabric and some of the largest clasts have several smaller clasts resting on their upper surfaces. There is an absence of fine material among the surface boulders.

The Iron Crags area is one of cross-slope rock exposures that have shed angular boulders to about 3 m in largest dimension. Some outcrops have been degraded into lines of loose blocks with boulder lobes and benches along some lower margins. At Iron Crags, rock faces are up to ca 5 m high with widened near-vertical and horizontal joints, dislodged blocks and accumulated fallen blocks (Fig. 2). This sort of terrain extends more broadly east of Iron Crags.

Round Knott (603 m OD; Fig. 3) is the largest of the crestline crags west of Carrock
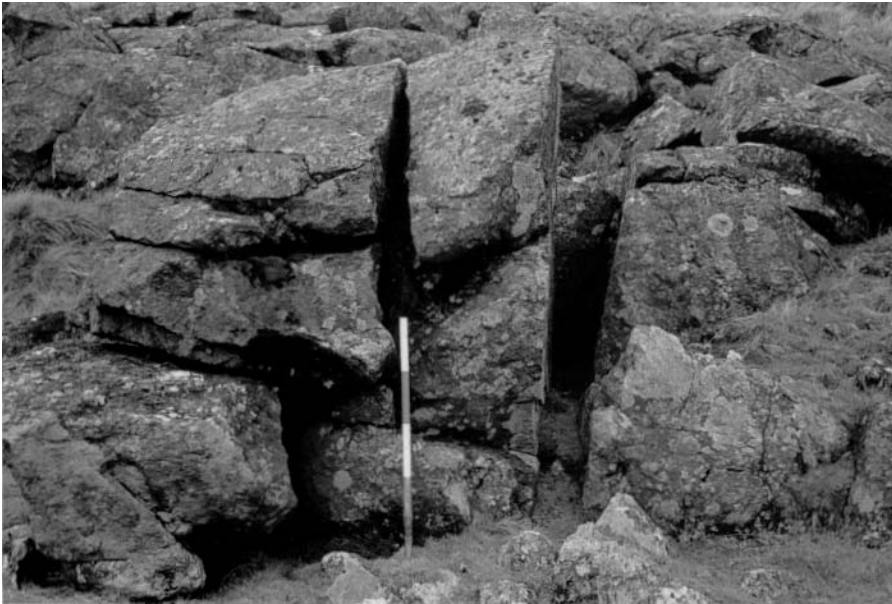
FIG. 2 Widened joints and dislodged blocks of gabbro outcrop at Iron Crags.
The survey pole is 1 m long.

Fell. Its cliffed edges are surrounded by a zone of clitter. It stands highest on south and east sides where there are sloping smooth rock-faces, near-vertical cliffs and narrow rock steps across the margins of the crag. A small isolated ca 1 m high rock pinnacle close to the northeast periphery of Round Knott is rather smaller than, but otherwise similar to, the plinth-like outcrops along the crestline west to Miton Hill.

The view of Carrock Fell from Round Knott is significant. The profile consists of a succession of near-horizontal and sloping facets like successively smaller upturned dishes each placed on the next lower. Joints in the *in situ* surface microgranite of Carrock Fell are widened and parts of the outcrops much broken.

Blanket peat covers the gentler slopes east of Round Knott but the steeper parts are a mosaic of degraded outcrops and spreads of moved blocks. Again, there are places where a preferred fabric, including blocks standing on edge and aligned downslope, is evident in the block spreads. Not everywhere is it immediately obvious whether a cross-slope zone of blocks is the front of a boulder sheet or the line of a shattered outcrop. The middle and lower slopes of this part of the hillside are similarly rough with debris sheets and lobe fronts, some standing several metres high. This terrain continues east to the southeast spur of the ridge where, on a prominent bench at 440-460 m OD, there are smooth rock knolls, steep cliffs and clitter, and patches of blanket peat, thick and wet in the hollows - a small area of quite distinct topography.

Many questions are raised by the landforms on the ridge of Carrock Fell. There is first the question of glaciation. Is there glacial till on that smooth western part where the Geological Survey mapped it? To be reasonably sure of transport by ice, and deposition from ice, it would need rocks other than the local igneous rocks to be found, especially Borrowdale Volcanic Group rocks. In that western part there are the boulder spreads above Poddy Gill to consider. Can the boulders be matched to any outcrop? How could they have

FIG. 3 The crestline crags of Round Knott rise above a gently sloping cover of blanket peat.

moved there: did they move as a set of boulders or collect there and get their present character where they now are? What processes may have been involved in packing and arranging the boulders? These may not be easy questions but the landscape poses them.

Further east is the rough rockier ground. Many outcrops are shattered: do any of them, Round Knott, Carrock Fell and others, retain any surfaces that could reasonably be ascribed to passage of ice? What was happening on these upper slopes when the screes were forming below, on the north side of Mosedale? What processes worked on the bedrock and moved its debris? How in general does the size of blocks there compare with those on various parts of the scree below? What sorts of landforms did the debris produce - can any of its paths of movement be traced to the top of the scree? It is perhaps easier for water and finer debris to move onto the slopes below than for the largest blocks. But some big blocks have done so.

The near-horizontal benches notched into rock outcrops along the crest of the Carrock Fell ridge have been little studied. They are most prominent on Carrock Fell summit, but occur on Round Knott and west to Miton Hill. They are evidently erosional features: by what agencies can rock be detached and then removed across almost level surfaces? Is there evidence that the processes are active or now inactive? What landforms would the processes produce if continued over a long period?

THE NORTH SIDE OF MOSEDALE

From the hamlet of Mosedale to the confluence of the River Caldew and Grainsgill Beck, the north side of Mosedale is formed by the south-facing flank of the Carrock Fell - Miton Hill ridge (Fig. 1). The hillside rises steeply from the valley floor to 450-500 m OD, the boundary between Skiddaw Group rocks to the south and the Carrock Fell Complex to the north, and thereafter less steeply to the ridge crest, which is everywhere above 590 m OD. Although this side of Mosedale is less accidented than the south side it nevertheless carries a variety of landforms. The relationships between these landforms are well seen from positions along the track from the hamlet of Bowscale to Bowscale Tarn, on the south side of Mosedale. Access to sites described may be gained from the road running west from the hamlet of Mosedale.

FIG. 4. The bench of 'glacial' sediments (5 on Figure 1) on the north side of Mosedale.

Glacial sediments

West of the hamlet of Mosedale at NY 352 321 (5 on Fig. 1) a bench of glacial material, possibly with constructional steep outer face but partly trimmed by either meltwater or later river action, or both, occupies the area between road and river (Fig. 4). This feature lies within enclosed pasture and permission to visit should be sought from the landowner. Eastwood *et al.* (1968) report the material as 'gravels' containing many clasts of Borrowdale Volcanic Group lavas and other rocks from the central Lake District and considered them to be 'frontal deposits' associated with an ice lobe that extended west into Mosedale from the ice that occupied the Mungrisdale-Mosedale valley. Shallow exposures on the river side of the bench show interbedded sands and gravels. Sand beds fine upwards and are capped in places by thin laminae of silt and/or clay. Gravels are well-rounded and contain clasts of Carrock Fell gabbro, Skiddaw Group rocks and Skiddaw Granite, in addition to those identified by Eastwood *et al.* (1968). Sand rip-up clasts also occur within the gravels. No clear clast imbrication or sand ripples were observed in the exposures inspected.

The Geological Survey's rather tentative conclusions about this bench give it an interest but also imply a difficulty in determining its origin. It exemplifies the point that contribution to a conclusion can come from deciding some of the proposed explanations to be the least likely. It might also be pointed out, again with potential application elsewhere, that while material above the level of the river can be observed, though presently in rather small separated exposures, it should not be presumed that the base of the deposit is at river level. Similarly, the riverside flanks of the bench need some consideration: are any points shaped by more recent erosion - if so the deposit may have been more extensive. Are there parts which might be much as deposited? Not all surfaces of accumulations laid down under or at the margins of ice masses decline in a down-ice direction. If the explanation for this accumulation offered by the Geological Survey (Eastwood *et al.*, 1968) is accepted then there are implications regarding the extent and frontal position of ice in the upper Caldew

Fig. 5. Mosaic of scree and vegetation patches on the north side of Mosedale.
Scree-foot pits (6 on Fig. 1) can be seen in the middle of the photograph. The courses
of old stream channels are evident in the enclosed fields of the valley-floor alluvium.

valley at that time. There is also the question of how meltwater discharging into Mosedale
from both the ice lobe, from which the sands and gravels may have derived, and ice in the
catchment of the upper Caldew escaped from the valley. Are there any shoreline remnants
or other evidence that might indicate the former existence of an ice-dammed lake? As to
the possibility that the bench may be built of material from the valley sides, the north side
is the more obvious candidate. Comparison between hillside deposits, for example as
exposed in the roadside pits further west (6 on Fig. 1), and material making the bench
would prove instructive. Present exposures on the bench are small and confined to the
southern flank. As much information as possible has to be drawn from them about manner
and direction of debris transport and origin of the material and care must be taken over
extending conclusions to the rest of the bench.

Screes

The hillside above and west of the glacial sediments is a mosaic of scree and vegetation
patches (Fig. 5) with scree becoming more extensive to the west. In the vicinities of Kelt
Crag and Roundhouse, upper scree slopes are broken by projections of bedrock which serve
to separate paths of scree movement. Locally scree cover may be thin. At NY 346 323 (6
on Fig. 1), two roadside pits at scree base expose sections in debris of up to 7 m thickness.
In the east pit, below a surface layer of openwork clasts, the upper 2-3 m of debris contains
a higher proportion of clasts to fines than below. The base of the upper stony layer is
irregular indicating a shallowly-gullied surface concealed by later accumulation - or some
other process capable of producing that distinction. The finer-grained sub-surface material
consists of matrix-supported coarse gravel clasts with occasional clusters of clast-supported
gravel, but no significant or laterally persistent internal discontinuities were observed (cf.

Hinchliffe *et al.*, 1998). In the west pit the upper 1.5 m of debris is also more stony than material below. In both pits coarse (>2 mm) debris is predominantly of angular Skiddaw Group rocks; Borrowdale Volcanic Group lavas and Carrock Fell gabbro form a minor proportion of the debris but some gabbro boulders exceed 1 m in maximum dimension. A sample of fine (<2 mm) sub-surface debris from the west pit consisted of 68% sand, 26% silt and 6% clay. Hillslope gradient alongside and immediately above the pits is 24.5-28°. There is an absence of marked hillside basal concavity, debris extensions away from the hillfoot, and evidence of river trimming. These characteristics of the scree foot persist as far west as easting 340 and the scree face is relatively smooth and debris size is generally of smaller grade than further west.

These hillside screes, and those along Carrock Fell End, are more complex than at first they appear. There are many points to investigate: some of these require examination of rock exposures higher on the scree and localities along the transition from the gentler upper slopes of Carrock Fell to the steeper scree slopes. Screes can be quite unstable: it can be easy to start slides of rock and to lose balance. Care and judgement must be exercised during work in this area. Scree may be thought of as material temporarily held in store between providing places and ultimate destinations; questions can be framed in that context. Most of the scree along Carrock Fell End north to Further Gill is made of Mosedale Series gabbros, that in Mosedale lies over Skiddaw Group rocks so the presence there of Carrock Fell igneous, mainly, and other rocks in the scree could be looked for. 'Other rocks' may have come in during glaciation and have got into the scree with Carrock Fell rocks from the slope above the Mosedale scree. Similarly, rocks from beyond the immediate area may be present amongst scree blocks along Carrock Fell End. How Carrock Fell blocks were liberated from bedrock and moved downslope, some to reach the top of the Mosedale scree, was considered above but if the upper slopes of Carrock Fell are not to be visited then their junction with the scree might well be looked at.

There is a significant difference between scree formation and scree mobility. The first implies active supply of rock fragments from outcrops of bedrock, that is, the processes that detach the pieces are at work. Mobility, the movement of fragments across the surface of the scree, is expectable while scree is forming but can persist after significant release of new debris has ceased. Indeed a scree surface can be stabilised and vegetated: where for whatever reason vegetation is disrupted mobility may be resumed even though little or no new material is being added.

How do shapes and sizes of scree pieces match shapes and recess sizes on bedrock surfaces? Do bedrock surfaces show any/many places that are fresh, newly-broken - no weathering, no lichens, no mosses. Are there places on the scree where the fragment surfaces look fresh - paler coloured perhaps? If so, do they join or lead to places of recent bedrock detachment; are all surfaces of the blocks 'fresh' - may they have been recently moved, perhaps after loss of vegetation cover? Are there any fragments of disrupted vegetation or other signs of recent disturbance in the neighbourhood?

In some places it is the finer scree that remobilises more readily when vegetation is disrupted, including below gullies and gaps between rock outcrops. Water input to the scree top is more concentrated at such places.

Accumulation of scree goes along with back-wearing of outcrops and if scree is only slowly, or hardly at all removed from slope base it builds up higher and higher up the slope so covering the lower parts of outcrops. The top edge of a scree might then be the newest

to accumulate and be thin while the basal scree which continued to receive some debris tends to be thicker. What characteristics would give blocks the best chances to get to the bottom of a long scree? On any line down the scree is there any evidence for sorting by size of biggest blocks - *i.e.* differences in size between the biggest blocks at various positions on a line down the scree. Is there any evidence that there has been division and diminution of area of rock outcrop?

The sizes of blocks released from outcrop depend on spacing between lines of weakness in the bedrock and that spacing is rarely constant through an extensive mass of rock. As well, some big blocks could break on falling from the outcrop or by being affected as they lie on or in a scree by the same process as attacked the outcrop. Also, the character of a scree can be affected by whether blocks were released piecemeal or in great masses, as rockfalls. Careful examination of the scree along Carrock Fell End and the north side of Mosedale will show variations of these sorts. In particular the size of scree blocks along Carrock Fell End is generally much greater than those in Mosedale, a contrast that highlights the influence of rock type and structure.

The pre-scree material along Carrock Fell End (2 and 4 on Fig. 1), roadside pits at scree base in Mosedale (6 on Fig. 1) and another further west reveal what is below the surface layer at those sites. The shapes and types of rock fragments within these materials may provide clues to the process(es) that led to accumulation of these sub-surface deposits. Is there evidence for deposition by glacial ice or hillslope debris flows? If debris flows are thought to have supplied the material, what implications are there, if any, for the relative ages of scree and sub-surface material, and hillslope processes at the times of debris production?

As well as at the Roundhouse bench (see below), the base of the Mosedale scree west as far as where the scree base, road and river come close together, is succeeded towards the valley floor by more gentle slopes covered by boulders apparently from the hillfoot. Thus the question arises how and when such block spreads up to almost 200 m wide could have been made: how could such big blocks have moved over such slopes? Along Carrock Fell End, the scree base benches raise a similar question of how and when they were constructed; are they all glacial accumulations now covered by scree blocks or are some composed entirely of scree?

It should be possible to build up some picture of how the local screes developed. It requires a particular environment and a fit between different previous and, in this area, later environments. And, at the time and in the environment of scree formation, what was happening on the higher slopes of Carrock Fell, on valley floor, and elsewhere in Mosedale?

Roundhouse hillfoot bench and debris fan
Between NY 336 326 and 340 325, near Roundhouse (7 on Fig. 1), a hillfoot bench at ca 255-280 m OD, extending ca 150 m towards the river and comprising ice-abraded rock bosses and material mapped as boulder clay by the Geological Survey (Eastwood *et al.*, 1968), separates scree base from valley floor alluvial tract. Upslope from the bench, the scree is diversified by discrete paths of fine and very coarse debris. Locally, paths of active scree spread on to a lobe of debris that extends from the base of inactive older scree. Bulges, tongues or lobes of debris extend beyond the present scree base, across the hillfoot bench, between rock bosses, and in places to the valley floor. Though mainly of coarse open-textured material, a sand-silt matrix occurs at the bed of these hillfoot features. Clearly, the hillfoot bedrock bench predates them.

At NY 335 326 (8 on Fig. 1), a large debris fan, with apex at ca 300 m OD, occupies the lower hillside; above the apex a major gully breaks the upper scree slope. The fan lacks an obvious main channel and it seems likely that most water from the gully infiltrates. However, routes of former surface water flow are indicated by dry channels with levées of coarse debris. Fan long profile is not smooth or evenly concave; there is some suggestion of debris build-up above the base, possibly by debris flows, following initial extension of the fan to its present downslope limit. On the western margin of the fan, a linear concentration of coarse debris may result from washout of fines by water escaping from the fan.

Slope-foot morphology is markedly different immediately east and west of the fan. To the east, a long (150 m) concavity, within which a slight convexity is present, extends from the scree base and terminates at a 1 m high bluff close to the River Caldew. West of the fan, the slopefoot zone rises in two broad convex steps to the scree base. The lower step is 50 m wide, its riser gradient 21° and its tread gradients 8-13°. The upslope margin of the step terminates at a 3 m high 'wall' of boulders forming the 34° riser of the upper step; tread gradients are in the range 16-25° and step width is 40 m. Scree base lies along the upper edge of the step.

Below the road, on the side of the track leading down to the buildings at Roundhouse, there have been cobbles and gravel taken out of drains. Are they wholly local or have some been brought into the area, presumably by ice? The surfaces of the Skiddaw Group rock bosses near the road merit examination. Are they shaped by passage of ice or by frost riving? Surfaces plucked by moving ice and those weathered by frost can be quite similar; ice-abraded surfaces are more distinctive. Relative positions of abraded and plucked surfaces could suggest direction of ice movement that need not be the same as perhaps inferred from the bench of glacial sediments nearer Mosedale. Fine scratches on the rock surfaces may not have survived later weathering but larger grooves and sculpting features may be present. The loose blocks on the bench round the rock exposures raise one or two questions. Are they all the same sort of rock as the bedrock? Do their edges and corners match in character with edges and corners on the bedrock? If they have come from the hillside to the north, how might they have moved across a surface much less steep than the hillside?

The blocks comprising the debris fan may be compared with those of the adjacent screes. Given that fan and scree are products of contrasting processes, differences between their constituent materials might be anticipated. Are fan and scree blocks of similar size, shape and composition? Any conclusion will require explanation. What process(es) produced the boulder levées on the fan and why does it have several (dry) channels?

Poddy Gill area
The River Caldew, at its confluence with Grainsgill Beck, cascades from its upper basin into the west end of Mosedale. There the screes along the north side of Mosedale give way to other landforms, a lower hillside debris 'bulge' between the screes and the foot of Poddy Gill and, from the foot of the gill west into the bottom of the Grainsgill valley, a debris fan.

The surface of the debris 'bulge,' (9 on Fig. 1), ca 200 m wide, falls from ca 330 m OD to the Caldew at 270 m OD. Its central downslope profile is convex, the steep distal slope diversified by subsidiary steep-fronted debris lobes or tongues possibly derived from failures in the main front of the 'bulge'. Alongside the road, where it crosses the bottom of the bulge, small exposures reveal both large boulders and fine matrix.

A broad, ca 600 m wide, part of the upper hillside converges into Poddy Gill above 340 m OD in contrast with the rather even hillside further east. The related debris fan (10 on Fig. 1) is ca 200 m wide along the valley floor. The western edge of the fan has been modified by mining works and the main feeder stream diverted to the east side of the fan to keep water and debris from mine facilities, now removed. The base of the fan, steepened by Grainsgill Beck, has two fairly clear exposures. West of the bridge over the beck, the top 3 m show many large clasts most closely concentrated in the top 1 m but generally matrix-supported. The bottom ca 3 m is fines-dominated with fewer clasts. In the steep stream bank east of the bridge, clasts are to about 1 m in maximum dimension but fines dominate throughout the 5-6 m thickness exposed. Near the apex of the fan, a shallow exposure shows a surface layer of irregular depth with mostly openwork concentration of clasts including gabbro boulders to ca 0.5 m in maximum dimension, with fewer large clasts and a dominance of fines beneath the surface layer.

In the incised gill above the fan, are further small accumulations of debris on both narrow gill floor and steep sides including material of fine grades. It is again evident that, despite the more obvious and widespread presence of large clasts at the land surface, there is also an abundance of fine material.

The Poddy Gill debris 'bulge' and the adjacent fan also pose questions about their origin(s). How were the two debris accumulations supplied and built up? How, if at all, do the materials in the 'bulge' and fan differ where seen on the stream bank and in other exposures? How, in each case, might manner of supply and nature of material have affected the shape of the accumulation? Sizes of largest clasts in exposures at the base of the fan raise questions of what modes of transport were involved. How might the westward change on the hillside from scree slopes to debris 'bulge' be explained? How do the two features fit into an account of the Mosedale landforms? Consider processes and time: formation of the two features may not have been completely contemporary. This isn't an easy one.

The Valley of Grainsgill Beck

The valley of Grainsgill Beck extends northwest from confluence with the River Caldew for 2.5 km to its headwaters on Miller Moss (NY 305 335). The Miller Moss reach falls from 590 m OD to 550 m OD in a distance of 0.75 km: an average gradient of ca 3°. The longer reach to confluence with the Caldew at 280 m OD is substantially steeper: an average gradient of ca 9°. Two north bank tributaries (Brandy Gill and Arm o'Grain) join Grainsgill 0.5 km and 1 km respectively above the confluence. Only that part of the valley shown in Figure 1 is considered here. A track branching from the road, just east of the bridge over Grainsgill Beck, provides access to the valley.

Various workings at the Carrock wolfram mine in Grainsgill (NY 325 329, 11 on Fig. 1) have produced relevant exposures. A downslope cut through scree well above its base shows thin scree, 30-40 cm and, depending on clast sizes, 1-3 clasts thick. No fines were seen on clasts or rock base: preferential wash of fines to scree base may have taken place with consequence for scree-foot processes. A cross-slope exposure nearer scree base, west of Poddy Gill, reveals a matrix-supported but clast-rich material, varying in thickness from less than 1 m to about 2 m. It overlies a quite smooth surface of well-jointed, open-jointed Skiddaw Group rock.

As with the roadside pits at scree base in Mosedale, exposures through scree in the valley of Grainsgill Beck reveal thickness of scree and characteristics of subjacent materials.

The exposures demonstrate that scree forms a relatively thin surface cover and rests on bedrock or some thickness of matrix-supported debris. Does the scree represent an accumulation that is distinct from the underlying debris or is it merely a surface lag deposit, having lost finer material by surface and near-surface flow of water? If it is decided that the scree is a distinct facies then there are implications for the age and origin of the underlying debris. Scree blocks are often assumed to have been released from hillside outcrops by freeze-thaw processes following the loss of local ice cover. If that is so, when and how did the underlying debris accumulate? Can it be demonstrated that this debris relates to ice wastage or is it a product of hillslope processes following ice loss? If the latter, what was the nature of those processes and when did they occur? There is also a possibility that the matrix-supported debris is not all of the same origin and/or age. The chronology of climate change between 15,000 and 10,000 radiocarbon years ago needs to be remembered here. Because screes mantle many steep hillsides in upland Britain, the questions raised by the scree and sub-scree debris in both Mosedale and the valley of Grainsgill Beck are of wider significance for understanding hillslope development in formerly glaciated uplands.

The lower part of Brandy Gill, from base of gill incision to confluence with Grainsgill Beck, is a debris fan (disturbed by mining activities). Above the fan, on the east side of the gill incision, is a perched convex debris accumulation that looks like a lodged residual from an upslope slope failure or debris flow, but might be a residual of a previously more extensive valley-side debris cover.

A broad hillside terrace, now predominantly vegetated, occurs on the north side of Grainsgill Beck immediately downstream of its confluence with Arm o'Grain and extends down valley for ca 600 m (NY 319 331, 12 on Fig. 1). The terrace is an interesting but enigmatic feature seemingly not matched elsewhere in the Mosedale area. There are no previous reports or interpretations of its nature and origin that might help focus or prejudice thinking. Detailed understanding of its internal composition is hindered by the lack of exposures. Close to the confluence, the terrace frontal slope rises 25 m above Grainsgill Beck at a maximum gradient of 28°; from stream side to foot of backing slope terrace width is 105 m. Further east, frontal-slope height, gradient and terrace width are generally smaller although, locally, frontal-slope gradients of 38-39° occur. The terrace surface is divided into ridges and hummocks by shallow (<1.5 m deep) linear depressions some of which carry drainage, have exposed boulders along their axes, and extend down the frontal slope; other depressions are apparently dry and completely vegetated. At its western end, the terrace is separated from the backing slope by a prominent depression. The backing slope has an extensive boulder cover but is not of simple smooth form; lobes, steps and benches, some of which extend into the depression, are prominent features. The east end of the terrace gives way to a steeper (10-15°) boulder-strewn slope down to the lower part of the Brandy Gill fan.

The western end of the debris terrace drops steeply into the Arm o'Grain valley. The upper of the two westernmost of the gullies that cross the terrace starts close to the top of the east-side bluff of Arm o'Grain valley. The gully head is close to a mound of large boulders. Both gully and mound give the impression they could have been formed by water moving from the northwest well above the present level of the Arm o'Grain stream.

Initially, the visible boulders on the surface of the terrace could be examined with a view to establishing whether they derive from the south or north side of the valley. The boundary between Skiddaw Group and Carrock Fell Complex rocks runs along the valley at the base of the boulder-strewn hillside rising above the terrace. Although the terrace is

'attached' to the south-facing hillside it does not necessarily follow that all the debris was supplied from that hillside. The question of whether the debris was supplied from either or both of the valley sides is compounded by the possibility that some or all debris may have been supplied from an up-valley source - the southeastern slopes of Great Lingy Hill, between Grainsgill Beck and Arm o'Grain. Other investigation may concentrate on the surface morphology of the terrace. Are the ridges and depressions, found on the surface, erosional, constructional or both? Is there other evidence, in addition to that earlier suggested, for water from the Arm o'Grain valley having passed across the surface of the terrace? And of what significance, if any, is the boulder-strewn hillside rising above the terrace - do the various features provide indication of mode(s) of boulder transport? Can the terrace and boulder slope be linked as a continuum of hillslope features? Time and processes need to be considered in assessment of such a continuum, and the involvement of hillslopes above the boulder-strewn hillside should not be overlooked if such assessment is made.

In the Arm o'Grain valley, upstream of the debris terrace, is a debris accumulation, its surface rising upstream in three steps as if accumulated or denuded in stages. At its lower end it is ca 5 m thick. At the junction with a gully entering from Great Lingy Hill, the debris is ca 2 m thick on rock, its base somewhat above the main stream. The gully floor is at the level of the infill surface. The infill does not extend further up the main valley and, immediately upstream, the gill narrows to become a steep-sided rock-cut gorge.

The west side of Arm o'Grain valley, below the gully junction, is a steep ca 12 m high fall to the valley floor, mainly, apparently, the front of a debris accumulation. There are prominent recesses on the frontal slope, of various lengths and, perhaps, of more than one origin. Towards the confluence with Grainsgill, this slope is less steep but of similar character. Its present form may, in part, have been determined after removal of an infill that had allowed water to pass across the present course of Arm o'Grain east and, later, cutting gullies on the surface of the debris terrace. The ramp-like slope down to the west edge of the Brandy Gill fan may thus have been the distal slope of the combined hillside and Arm o'Grain accumulation.

On the south side of Grainsgill Beck, up valley from confluence with Arm o'Grain, is the recess of Coomb (NY 313 329, Fig. 1). Hollingworth (1931) depicted a cirque in this vicinity but later workers (*i.e.* Clough, 1977; Evans, 1994; Evans & Cox, 1995) did not. The recess has smooth vegetated slopes without outcrops, scree or prominent slope-foot debris accumulations. However, snow and/or ice have probably been important in recess development and their role is considered later in conjunction with those recesses on the south side of Mosedale. The absence of exposed scree and the lack of prominent slope-foot debris accumulations at the base of Coomb may relate to the relatively steep gradient and/or presence at slope-foot of Grainsgill Beck that served to evacuate debris as, or after, it built up. Down valley from Coomb, the steep upper slopes of the hillside carry several unvegetated boulder spreads, less steep than characteristic scree angles. The lower slopes, where undercut by the beck, show up to 4 m of dominantly-fine material containing dispersed large boulders, some of which are rounded.

THE SOUTH SIDE OF MOSEDALE

From the hamlet of Bowscale to the confluence of River Caldew and Grainsgill Beck, the northern slopes of Bowscale Fell form the south side of Mosedale (Fig. 1). The valley side rises from ca 250 m OD in the vicinity of Roundhouse and Swineside to 650 m OD at the

head of Tarn Crags and is entirely within the outcrop of Skiddaw Group rocks. In contrast to the north side of the valley, the south side is generally of lower gradient, particularly within the altitudinal range 250-500 m OD, has less coarse scree, is predominantly vegetated, and carries three prominent recesses (Fig. 6): Drycomb, the recess holding Bowscale Tarn, and, further west but lower on the hillside, that backed by Ling Thrang Crags. Landform relationships are well seen from positions along the break of slope at ca 450 m OD on the north side of Mosedale. Access to the areas and features described below may be gained from the road south of Bowscale, by the track leading to Bowscale Tarn, or by footbridge across the Caldew at Roundhouse.

South of Bowscale, the eastern end of the Bowscale Fell ridge, along the line of Carrock End Fault, has a shallow recess (NY 359 312, 13 on Fig. 1) flanked on the south by Raven Crags. The recess, unnamed on maps, ranges from 240 m to 450 m OD and extends across slope for ca 400 m. Its backslope is vegetated with a few low crags protruding: there is little scree present and a basal debris slope, extending for ca 100 m east of the road, has low amplitude hummocks and bench-like features but no major constructional accumulations. On the upslope side of the road, shallow exposures of slope debris show matrix-supported angular clasts of Skiddaw Group rocks. Between Bowscale and Drycomb, the hillside is essentially smooth though with one small recess above Bowscale hamlet (NY 357 316, 14 on Fig. 1) that is floored by debris with dominant water-retentive matrix, probably largely derived from the local Skiddaw Group rocks. A steep bank across the base of the recess resembles the front of a solifluction sheet. Elsewhere on the hillside, the only significant features are small-scale (<1 m high) solifluction terraces and terracettes containing clasts of the local rocks.

Drycomb

Drycomb (NY 345 313, Figs. 1 & 6) is the easternmost prominent recess on the south side of Mosedale. Although Hollingworth's (1931) map indicates it as a cirque, it was not accorded such status by either Clough (1977) or Evans & Cox (1995). Evans (1994) regarded Drycomb as "too shallow and steep-floored to be considered a glacial cirque" but thought it may have been shaped in part by nivation. The headwall of Drycomb rises to 600 m OD and carries low crags and some scree; the recess extends 500 m across slope and has an axis aspect of 17°. There are no benches, banks or ridges of debris evident but shallow exposures where the Bowscale Tarn track crosses Drycomb Beck (Fig. 1) show platy clasts of Skiddaw Group rocks, aligned parallel with surface slope, in a matrix comprising 69% sand, 24% silt and 7% clay. In this vicinity, and also immediately east of the confluence of Drycomb Beck and River Caldew, there is 7-8 m thickness of debris.

Bowscale Tarn

The central recess on the south side of Mosedale is the Bowscale Tarn cirque (NY 337 314, Figs. 1 & 6). Clough (1977) categorised it as a class 1 cirque, being very distinct with all cirque elements clearly represented. Evans (1994) and Evans & Cox (1995) listed it as a grade 1 cirque, being classic with all textbook attributes, and reported the following parameters: elevation range 390-645 m OD, width 800 m, headwall maximum height 140 m, and axis aspect 13°. Crags occur all round the headwall and extend further down the western than the eastern sidewall.

The northern shore of Bowscale Tarn is formed by the proximal slope of a massive

FIG. 6. The south side of Mosedale, showing from left to right the recesses of Drycomb, Bowscale Tarn cirque and Ling Thrang Crags.

moraine ridge (15 on Fig. 1) some 400 m long and rising 20 m above the waterline and 40 m above the hillside below; moraine maximum thickness is estimated as 30 m and its volume as 680,000 m^3 (Evans, 1994). Angular boulders, up to 3 m in length, of Skiddaw Group rocks occur on the crest and slopes of the moraine. Moraine volume corresponds to the removal of either a 5.9 m thickness of rock across the entire 116,000 m^2 headwall map area or a lowering of the cirque floor by 11 m (Evans, 1994), but it seems likely the debris came from a combination of these sources. On account of moraine 'freshness' and pollen types identified in samples from the basal muds of the tarn, Manley (1959) and Pennington (1978) ascribe the glacier that created the moraine to the final episode of glaciation: the Loch Lomond Stadial (LLS). Subsequent researchers (Sissons, 1980; Evans, 1994), assuming the moraine crest delimited downslope glacier extent and inferring the upslope glacier limits, established some ice-mass and palaeoclimatic parameters. Glacier surface gradient was reported as 17°, area 0.13 km^2, volume 0.005 km^3, maximum thickness 95 m, and maximum surface velocity 35 metres/year; the equilibrium line altitude on the glacier was estimated to have been within the range 523-549 m OD. The size of the Bowscale Tarn moraine implies that the LLS glacier, although active, had approximately stable margins for a considerable time when at its maximum extent. Snow blown from the plateau area above the cirque is thought to have made a significant contribution to glacier mass (Manley, 1959; Sissons, 1980). It has also been suggested that the total volume of moraine debris is unlikely to result from erosion during the short LLS but may, in part, be a product of the preceding glacial phase (the Dimlington Stadial ca 26,000-13,000 radiocarbon years ago) reworked by the LLS glacier. Excavation of the cirque basin probably occurred during repeated episodes of cirque glaciation (cf. Boardman, 1992).

No detailed description of moraine surface morphology has been published; our field observations have identified a complex morphology. At two locations on the moraine (west of the Tarn Sike channel and near the eastern end of the ridge, east of a col on the moraine crest) a series of breaks of slope indicate that in those areas the moraine comprises three closely-spaced ridges. West of the col, on the south (proximal) side of the moraine, a low platform exists and extends west along the proximal slope before merging with the ridge crest. Below the col on the north (distal) side of the moraine is a dry and vegetated gully. Debris ridges are absent from the lower part of the cirque backwall and submerged ridges are not indicated by bathymetric survey (Evans, 1994); there is very little scree on the backwall.

A prominent arcuate accumulation of debris, extending downslope from ca 440 m to 400 m OD, occurs on the hillside immediately below the northwestern end of the moraine (16 on Fig. 1). The plan form of the debris indicates that it derives from the sidewall of the cirque rather than from the moraine. The debris is currently vegetated and no exposures were seen. On the surface of the accumulation a series of low amplitude steps or benches run discontinuously across slope. Evans (1994) noted the presence of this debris accumulation and suggested the possibility of deposition in association with another small glacier or snowbed.

As Evans (1994) recorded, the moraine does not extend across the full width of the cirque. The LLS glacier headed in the centre of the backwall and faced north leaving much of the east and west sidewalls ice free. Debris flows and gullies occur downslope of the

Bowscale Tarn moraine ridge and there are many surface boulders. These were released from the eastern flanking hillside as well as from glacier front and moraine. The lower valley-side debris sheet has since been cut back at its base by the river.

The principal exposure of hillfoot debris is at an active river cliff between Tarn Sike and Drycomb Beck (17 on Fig. 1). Some 13-14 m of debris are exposed with Skiddaw Group bedrock at the base. The material is matrix-rich, contains clasts of only Skiddaw rocks, some of which exceed 1m in length, and its saturated base displays manganese/iron horizons. From the basal part of the section, a matrix sample was 46% sand, 43% silt and 11% clay. The only obvious division is a stone line running horizontally across the face less than half way up the section. In the upper part of the section there is a rather massive platiness resembling descriptions of fragipan soil layers, little development of voids but silt coatings round but mainly under small clasts. Nearer to the top of section no silt coats were observed in the inspected part of the exposure. No involutions or similar structures, possibly indicative of frost-related processes, were observed. The deposit may be built up as a stack of debris flows at the foot of a slope rising from 240 m to 660 m but the upper part is largely a divergent slope and it is unlikely the river cuts here into the thickest hillfoot accumulation along the south side of Mosedale.

Ling Thrang Crags

The Ling Thrang Crags recess (NY 333 322, Figs. 1 & 6) is smaller than its two eastern neighbours. Although figured as a cirque on diagrams in Hollingworth (1931) and Eastwood *et al.* (1968), it was Clough (1977) who first assessed its morphometric attributes. Referring to the site as Swineside Combe, he categorised it as a class 2 cirque, being distinct but with one or more cirque elements rather poorly developed. It was also regarded as a cirque by Evans (1994) and Evans & Cox (1995), although listed as a grade 5 cirque: one that is marginal, its cirque status and origin doubtful. They reported the cirque as having an elevation range from 315 m to 460 m OD, a width of 390 m, a headwall maximum height of 85 m, and an axis aspect of 36°. Its marginal status results primarily from its floor minimum gradient of 18-19°. Crags occur around the headwall of the cirque and extend down both eastern and western bounding spurs; on the latter spur crags reach almost to the base of slope. In the centre of the cirque, below the highest crags, is a smooth vegetated slope that becomes markedly concave in its lower reaches.

The existence of debris ridges downslope of the lower limit of the Ling Thrang Crags cirque does not appear to have been previously recorded but there is clear field evidence for two ridges (18 on Fig. 1). The western ridge is 135m long and curved in plan, turning sharply at its western end to join the steep footslope of the western bounding spur (Fig. 7). On the profile surveyed across the highest part of the ridge the distal slope is 18 m in length, 5 m in height and has a maximum gradient of 19°. The proximal slope is 22.5 m long, 4 m high and has a maximum gradient of 13°. Ridge basal width is 39 m. Large boulders of Skiddaw Group rocks occur on the ridge crest and distal slope. A low-gradient peat-covered area, across which drainage passes from the cirque to the Caldew, separates the eastern end of the ridge from a scarp 1-3.5 m high and 300 m in length cut into a hillfoot debris apron. At its higher eastern end, debris-apron morphology includes remnants of a short ridge the proximal slope of which has a maximum gradient of 4° and rises ca 2 m above the backing depression. An exposure in the scarp shows ridge material is

FIG. 7. The slope-foot ridge at the western end of the Ling Thrang Crags recess.
In front of the ridge and right of centre a low river-cut bluff separates a terrace
from the floodplain of the River Caldew.

poorly-sorted and matrix-supported; most clasts are either angular or subangular with edge-rounding, some clasts are striated, and all are of Skiddaw Group rocks.

Between the River Caldew and the ridges, a low river-cut bluff divides floodplain from river terrace (Fig. 7). The terrace is ca 2 m above river level, although in some areas it rises slightly higher. Exposed boulders are of Skiddaw Group rocks, Skiddaw Granite and Carrock Fell gabbro.

West and south of the Ling Thrang Crags cirque, the western flank of Bowscale Fell drops over 400 m in ca 2 km to the River Caldew. The slope is uneven but with marked basal steepening and, in its lower reaches, is diversified by solifluction sheets with sinuous fronts, some collapsed, outcrops with scree patches or clitter on less steep slopes, and considerable accumulations of debris at the foot of the hillside. There is a complex of primary debris tongues and lobes locally with convex fronts rising 5-7 m, with secondary tongues, lobes and bulges from the main accumulations.

A gully, cut into these slopes, increasing in size down from ca 390 m OD has built up a considerable boulder fan at slope foot (19 on Fig. 1) and subsequent incision of slope-foot material suggests occasions of considerable discharge. Extent of surface cover of large boulders may give a misleading impression of debris character for the rather few exposures at slope failure sites reveal much fine material. Although the hillfoot west from ca easting 330 is dominantly one of debris accumulation, some relationship with river activity may be appreciated east of the Long Gill confluence where, at eastings 322-324, an alluvial flat replaces the eroded base of the slope-foot deposits.

The location of the lowest hillside features shows the valley floor level to have been established at or before time of accumulation. In the vicinity of confluence with Grainsgill Beck, the channel of the River Caldew may have been pushed to the north side of the valley floor by the accumulation of hillfoot debris.

Opportunities for enquiry

The prominent recesses of Drycomb, Bowscale Tarn cirque and Ling Thrang Crags that dominate the southern slopes of Mosedale present several opportunities for enquiry. The Bowscale Tarn cirque and its LLS glacier and moraine are well-documented (Manley, 1959; Pennington, 1978; Sissons, 1980; Evans, 1994; Evans & Cox, 1995) and the available information provides a useful base for similar or complementary studies. One aspect of the moraine that has not been investigated previously concerns the significance of the breaks of slope that show the moraine to comprise, in part, of several closely-spaced ridges; similarly the low platform below the moraine crest on the proximal slope. Detailed morphological mapping or simple surveying with tape, poles and clinometer would reveal the extent and amplitude of the features. Do they relate to former ice-margins or are they the result of post-depositional modification (slumping/channelling)? It may not be easy to establish their origin but they have implications for moraines beyond the immediate location. The origin(s) of both crest-line col and distal-slope gully near the eastern end of the moraine can also be considered. Are they the result of post-depositional mass movement(s) or do they relate to fluvial incision? If the former origin is favoured, is the moved debris present as an accumulation at the gully foot? If the latter, what was the source of the water - a previously-higher tarn level or meltwater from the glacier while it was building the moraine? The present outflow from the tarn need not have functioned for all the time since loss of ice. Is there any depositional evidence downslope of the present outflow that might indicate moraine breaching by mass movement(s) or the removal of substantial quantities of debris by the stream cutting through the moraine, or both? Discussion may also focus on the absence of scree on the backwall of the cirque in comparison with slopes on the north side of Mosedale.

The arcuate accumulation of debris below the northwestern end of the moraine could also be investigated with a view to determining its likely origin. Its position, below the crags of the western sidewall of the cirque, and plan form indicate the debris has moved away from that hillside. Does it represent the moraine of another small LLS ice mass or could it have been emplaced by solifluction or more rapid mass movement processes? Because exposures in the debris are absent, assessment of likely processes will have to be based on morphology and local setting; again morphological mapping and/or surveying may provide useful data to aid decision-making.

The debris ridges at the slope-foot below the Ling Thrang Crags cirque could form the basis for an exercise similar to that suggested above. However, there are important differences between the sites, including aspect and altitude, and in the morphology and location of the debris accumulations in relation to the backwall of their respective recesses. If a glacial origin for the ridges below Ling Thrang Crags is preferred to other explanations, reconstruction of the glacier dimensions could be undertaken both for its own sake and for comparison with the glaciers that occupied the Bowscale Tarn cirque and other sites in the Skiddaw upland (cf. Sissons, 1980; Evans, 1994; Wilson & Clark, 1999).

The hillslope debris accumulations west of the Ling Thrang Crags cirque provide further scope for investigation of valley-side landforms through measurement and mapping, and the marked contrasts in debris cover between those slopes and those of the cirque require explanation.

Linked to these studies of recess and adjacent debris accumulations is the broader issue of the recesses themselves (including Coomb in the valley of Grainsgill Beck and the recesses at the eastern end of the Bowscale Fell ridge - 13 and 14 on Fig.1) - how did they

form, why do they occupy different altitudinal ranges, why are some larger than others? Although snow and ice are generally regarded as important erosive agents contributing to development of hillside recesses it is also recognised that such recesses represent the cumulative effect of erosion during several glacial cycles in which ice-sheet glaciation and more restricted (valley and cirque) glaciation (cf. Boardman, 1992) and/or snowpatches contribute. Glacier development in the Lake District during the LLS may or may not serve as an appropriate analogy for explaining recess development throughout the Quaternary but it may provide some understanding of the factors involved. The analysis by Sissons (1980), of LLS glaciation in the Lake District, argued for glacier nourishment by both direct snowfall and snow transfer from high ground adjacent to glacier sites by winds from slightly west of south. In that context, it is instructive to assess the Mosedale recesses in relation to the extents of high ground located slightly west of south above their headwalls. Such an exercise would show clearly the advantageous position of the Bowscale Tarn cirque and the inferior location of Drycomb for snow gather. The Ling Thrang Crags cirque would also have been well placed to collect snow blown along the broad western flank of Bowscale Fell. This may strengthen the case for occurrence of a LLS glacier in that cirque and interpretation of the debris ridges as moraines. Given the view propounded by Boardman (1992) (see above), it could be argued that snow transfer to the Mosedale recesses from the same direction as during the LLS was important in earlier Pleistocene cold stages.

MOSEDALE: THE VALLEY FLOOR

The lower part of the cascades of the River Caldew into Mosedale sees a transition from hillside debris accumulations alongside the river to riverside alluvial deposits. The alluvial reach to the vicinity of Swineside, 270-240 m OD, is relatively steep; that downstream to Mosedale Bridge and beyond notably less so. Depth of infill above bedrock is unknown from the cascades downstream to beyond the Mosedale area.

On the north side of the river, coarse alluvium extends to the eastern base of the Poddy Gill debris 'bulge' and to the adjacent scree foot. There are traces there of an old stream channel across the alluvium which forms a terrace ca 1.5 m above the present channel. On the south side, a cobble terrace stands a little higher with traces of braid channels, patches of sandy alluvium, intervening boulder ridges and fragments of a slightly higher level. There are patches of peat up to ca 1 m in thickness. Narrow lower alluvial flats border the river.

At the west end of the southern alluvial area, hillside boulder lobes and tongues reach the terrace. They appear to lap on to it but the relationship, relevant to determining order in time, between soliflual and fluvial deposits merits further examination.

The outer slopes of the two valley floor ridges below the Ling Thrang Crags cirque have been attacked by stream erosion and terrace alluvium lies against their steepened cut-banks. Thus, the previous extents of the ridges and the depths to their bases are not known. The low gradient hillslope, between and south of these ridges (20 on Fig. 1), and the high terrace surface appear to merge. The location here of the contact between alluvium and hillside material is important in respect of any constraint, for example by residual ice, that may have affected the spread of alluvium toward the hillfoot. Clasts of Skiddaw Granite have been noted from fluvial sediments but, so far, not from the flats and slopes south of the alluvium.

A northward bend of the river (21 on Fig. 1) has cut out terraces, impinged on and

exposed north-bank scree-foot material. Immediately to the east, the river turns away from the northern edge of the valley giving more room to scree-foot run-out features: locally their fronts appear river-trimmed and their bases may be below the present alluvium surface. Material exposed in drains, at the southern base of the ice-smoothed rock bosses at Roundhouse (see above), contains a variety of rock types; this may be glacial and possibly analogous with deposits exposed in the bench of glacial material (5 on Fig. 1) near Mosedale hamlet.

In the river at Roundhouse, is a small ait (eyot) perhaps a survival from a time when the Caldew had braided channels. The high terrace south of the river, there, has been cut out locally and the course of the bluff confining the alluvial flats has been determined by protective bedrock protruding from the base of the valley side (21 on Fig. 1). If that rock and one in the river bed are *in situ* they, together with the rock bench north of Roundhouse (7 on Fig. 1), might mark the site of a cross-valley rock bar. Otherwise, below the cascades, the appearance of bedrock at valley-floor level is limited to the base of the active southside river cliff (17 on Fig. 1).

East of Roundhouse, alluvium is finer and the river profile less steep. The broadest spreads of alluvium, north of the river, are enclosed, improved and protected from flooding by embankments but old stream channels through the fields can be seen from some viewpoints (Fig. 5). As well, drains intercepting hill-foot drainage run roughly parallel to the river for ca 1 km before discharging into it, a feature also seen in the larger alluvial area further east. The base of the slopes of rather finer scree material east of Swineside meet the alluvium with little decline in steepness and not significantly steepened by the river in its earlier wanderings, at least in relation to the latest river levels.

The south side hill-foot below Bowscale Tarn has been steepened by the river and the high river terrace abuts the bluff. Tarn Sike has incised the lower hillside through the bluff and built a small fan in the incision above the valley floor features. Though the high terrace is absent further east, the hill-foot bluff continues as far as easting 354. Where Drycomb Beck joins the Caldew, bluff steepening has been very recent and there are several gullies and slump fissures of various degrees of freshness in the thick hillfoot superficial material.

There are other nearby indications of recent river work. The river has been cutting laterally into an older long-stable gravel strath that retains a peat cover about 0.5 m thick, very wet from hill-foot drainage. The underlying gravels, exposed to a similar thickness, show prominent colouring from mineral deposition, probably of manganese and iron compounds. It is quite likely that the alluvial flats across the river carried a peat cover before the land was improved for farming.

As well as looking at valley floor features as examples of fluvial landforms, there are opportunities to consider relationships between adjacent valley floor and hillside landforms and materials from the point of view of their relative ages, the succession of formative processes over time and the conjunction of localities with different but contemporaneous processes.

It might well be held in mind that, as well as examining the river and valley floor at close quarters, further perspective can be added from higher viewpoints. The easiest are from the slopes of Bowscale Fell but, from there, the junction of valley floor and foot of hillside is rather hidden; not so from the road up Mosedale.

The transition, near the cascades, from hillside to fluvial landforms was noticed earlier. There may be exposures or other evidence that throws light on the relationship. Do the

frontal slopes of any hillfoot debris accumulations show any signs of having been cut into by the river in the way the ridges below Ling Thrang Crags have been? Do they seem to overlap alluvium at all?

In the vicinity of those ridges, there are clear traces of the older higher spread of alluvium having been cut into, and of the river having changed from flowing in braided channels to a single channel. Is this change accompanied by differences in coarseness of alluvium? (sizes of largest cobbles incorporated in the deposits?) Are the down-valley profiles of the successive alluvium surfaces the same or may lowering of the river bed have been accompanied by changes in grade of alluvium and in stream profile steepness?

On the north side of the valley, where boulder flats have extended from scree foot onto the valley floor, is there evidence of their outer limits having been trimmed by the river? If they are still (at any site) exposed in section, do they appear to extend below present river level, or not, and with what significance?

In the vicinity of Roundhouse, Swineside and the uppermost fields on the valley floor, are there changes in the character of the riverside alluvium? When the highest alluvial terrace, presumably an older accumulation than the present floodplain, is followed down the valley, does it maintain a constant height above the river? Is there any evidence of changes in its position relative to the present floodplain? For example, does it pass beneath the floodplain? Whatever you conclude about the relationship will be relevant to deciphering the development of the valley floor.

There is no very clear evidence on this next point but you may be able to form an opinion on whether the alluvium of the fields near Swineside laps onto the base of screes. It would be interesting to know just where the base of the scree is in that place; it seems possible that the floor of the valley could have been lower when the screes were accumulating: what do you conclude?

At the least, it will be clear that the valley floor has been subject to change since the last glaciers disappeared, that it has been and is a collecting and transporting path for water and debris from surrounding hillsides.

The Eastern Lowland

The adjacent hillsides, where accessible, give an overall view of this area while footpaths and lanes give adequate access to this quite different part of the Caldew valley. In the 3 km from Mosedale Bridge to the bridge (NY 361 342) near Norman Crag, the River Caldew falls about 10 m, a slope nearer to horizontal than to 1°. The rock encountered by the river near the lower bridge is the first met below the cascades at the head of Mosedale or, if *in situ*, the rock in the bed at Roundhouse. The north-south corridor between the Mosedale hills and the upland to the east is floored by superficial deposits of unknown depths on rockhead of unknown form. The course of the Caldew, whether it, prior to the most recent glaciation, turned north or south on leaving the hills, is also unknown.

The fields immediately northeast of Bowscale hamlet stand well above the riverside alluvium. Their area was mapped by the British Geological Survey (1997) as glacial till, a continuation of the deposit along the foot of the slopes north from Bowscale Fell. Exposures in the fields are few, small, obscured and inconclusive.

East of the Bowscale-Mosedale road, the alluvial flats spread in the form of a fan with courses of former distributaries and contributaries still traceable. Alluvium is very fine and its accumulation in thin layers by flooding is evident in some river bank exposures. There

are riverbed stretches of coarser material; the degree to which this is currently added to or is wholly an older deposit has not been investigated.

The large fan (NY 365 305), similarly built out east from Mungrisdale into the lowlands, extends north towards the Mosedale fan. Incision of the River Glenderamackin, in its southward course, has left the Mungrisdale fan somewhat perched but water from its northern side moves to a south-north alluvial channel at the foot of the glacial till slope, east of the lowland, and thence to the Caldew. That route was possibly used by the last glacial meltwater to pass north into the Caldew catchment at the end of the most recent glaciation. Along poorly-drained parts of the east margin of the Mungrisdale fan, and between the two fans, peat mires have accumulated and appear to have extended onto the lower parts of the fans. Each local community had an area of peat which contributed to the local economy and was difficult to convert to farmland. The south-north drumlin-like features on the lower part of the eastern hillside between Low Mill (NY 368 324) and Moss Dyke (NY 369 314), though less prominent than those about 2 km further north and south, do extend the range of forms and processes exhibited in the Mosedale area.

Only by fixing the river course, and reducing spread of floodwaters by embanking, could the alluvial lowlands be permanently improved for farming. The Caldew and its sediment now follow a single constant course. Embanking and the presence of back swamps have made it difficult for surface water and drainage from flanking hills to enter the river. Consequently there are long drains alongside the river and residual ill-drained areas of mire and carr vegetation. Various characteristics of the alluvium can be observed on the banks of the Caldew and of Further Gill Sike in the vicinity of Carrhead Bridge (NY 364 334). Relationships between fluvial landforms and the glacial till cover at the foot of the eastern hillside are observable at several places.

Although it is easy to cross the eastern lowland, and view its features, it is less easy than elsewhere to leave lanes and paths. In consequence, the discussion of field study possibilities there is not taken beyond those already noted - with one exception and that is of a general sort. Now that the throughput of most water and sediment is confined to one route rather than spread among shifting routes as previously, the one channel may not always or everywhere have been cleared out to its previous bed when such clearing has been attempted. In consequence there may be places where the stream bed now stands higher relative to surrounding lands than once it did; that would join with the flood banks to inhibit drainage of adjacent lands. The course of the river could be looked at with this further point in mind.

CONCLUSIONS

However diverse, interesting, and problematic Mosedale's landforms may be, for most students it will be learning about the study of landforms rather than knowing the area that most matters. Mosedale can add to the repertoire of forms and materials encountered in the field and to the range of field problems to be, if not solved, then wrestled with.

It should become obvious that deciding what category a landform falls into, and what name to give it, is not an end to enquiry, even though a lot can be learned in the course of deciding on a classification. It will also become clear that not all forms and materials are readily classified. It is both salutary and essential to realise that landforms, individual features and assemblages, are rarely present in the field quite as the photographs and idealised diagrams of textbooks lead us to anticipate. Few forms are 'classic', few landscapes

so ordered as in the diagrams. Many features are modest and enigmatic, many landscapes seemingly untidy and disordered. In such circumstances, the challenge to understand is often both greater and more rewarding than in the case of those sites that virtually flaunt their stories. Mosedale lies somewhere between the obvious and the enigmatic. It presents some fairly obvious features alongside the more obscure, features of one time and environment next to those of another. Its story has to be coaxed out and put into order: that is one of the reasons why it is a valuable learning resource.

GLOSSARY OF SELECTED TERMS

Ait (**eyot**): an islet of alluvium in a river.
Clasts: coarse sediment particles.
Clast-supported: sediment in which adjacent **clasts** are touching one another.
Clitter: an accumulation of frost-weathered boulders (blockfield) around a rock outcrop, such as the boulders around tors on Dartmoor.
Debris flow: the rapid downslope movement of rock debris mixed with water.
Equilibrium line: the altitudinal line on a glacier where ablation balances accumulation.
Facies: a distinct sedimentary body distinguished from others by composition and/or appearance.
Fabric: the three-dimensional arrangement of particles in a deposit.
Fragipan: a dense, closely-packed but uncemented soil horizon. In the British Isles, fragipans are frequently attributed to the former occurrence of permafrost.
Imbrication: overlapping **clasts** that generally dip up-current. Frequently seen in river gravels.
Involutions: convolute layers in a soil or sediment resulting from frost-related processes.
Matrix: fine sediment particles in which **clasts** may be embedded.
Matrix-supported: sediment in which **clasts** are dispersed within the matrix.
Nivation: the erosive and depositional processes associated with snowbeds.
Protalus: a talus/scree-foot position.
Rip-up clasts: lumps of cohesive sediment that have been ripped up from a sedimentary unit by subaqueous strong currents, transported and re-deposited downstream, and preserved within younger sediments from which they are distinguishable by their shape, colour and/or grain size properties.

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