GEOMORPHOLOGY IN THE NORTHERN LAKE DISTRICT, UK: SOME POSSIBILITIES FOR FIELD WORK AND DATA ANALYSIS

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ABSTRACT

The Lake District, northern England, offers many opportunities for geomorphological field work and analysis of data collected in the field. An array of landforms and sediments resulting from glacial, periglacial, mass movement and fluvial processes are readily available for exploration. Many are relict forms resulting from past processes but may be undergoing transformation as a result of current processes; fluvial erosion of valley-bottom glacial moraines being an example. The challenge of dating landforms, in particular those of glacial origin, is discussed. Concepts of the landscape as a 'palimpsest' and slopes as 'sediment cascades' are of value in understanding the complexity of the Lake District. The adjustment of form to process is illustrated with reference to river discharge and meander wavength. Published research studies form the basis of our knowledge but these are often incomplete or limited in their generality. This short article shows that opportunity exists for researchers and students to contribute to our knowledge of the region.

INTRODUCTION

The landscape of the northern Lake District is a subtle mixture of an inherited landscape – particularly from past glacial and periglacial processes – and currently active processes. The concept of landscape as a palimpsest (an old manuscript on which writing is overprinted on older script), is particularly useful here. In essence, we have to distinguish the record of long-term glacial or pre-glacial processes, modified by ~12,000 years of temperate climate (the Holocene), with latterly the human influences of farming, industry, and tourism in what has been called (controversially) the Anthropocene.

Human influences may be indirect. For example, changes in land use or land cover will influence runoff and therefore the fluvial system and, pertinent to the Lake District, flood risk. The most profound change affecting the Lake District landscape in the last ~12,000 years has been the widespread deforestation starting around 5000 BP. We do not know what impact it had on fluvial hydrology but comparisons in other areas between forested and grassland catchments suggest it could have been significant e.g. Kirby et al., 1991.

Three notable contributions have been made in the last decade to the geomorphological literature on the Lake District: the book by Peter Wilson (2010) *Lake District Mountain Landforms,* the *Quaternary of the Lake District Field Guide* (McDougall and Evans, 2015) and the chapter by David Evans (2020) in *Landscapes and Landforms of England and Wales*.

The aim of this short article is to review recent work and point to areas and themes where opportunities for field work and data analysis are to be encouraged. These forms of investigation complement one another: field work providing the data for analysis. But the data, may of course raise questions about the field observations, an example of this being the dates of glacial moraines, referred to below. The focus is on three themes: dating landscape change; relict and active landforms; and, the role of process in influencing form. Finally, research areas where further studies would be especially rewarding are suggested.

GEOMORPHOLOGICAL ANALYSIS OF THE LANDSCAPE OF THE NORTHERN LAKE DISTRICT

Dating landscape change: absolute and relative ages

The challenge of dating landscape change goes back to nineteenth-century attempts to calculate the age of the Earth. Not until 1950 did we have what are now called 'absolute dating methods' beginning with the development of ^{14}C dating by Willard F. Libby in Chicago but expanding into many other approaches based on known decay rates of radioactive isotopes: importantly for the Lake District the dating of glacial moraines with ^{36}Cl and ^{10}Be (Wilson et al., 2013).

Moraines

Manley (1959), Pennington (1978) and Sissons (1980) broadly agreed that the prominent moraines in many Lake District valleys were the result of a readvance of glaciers during the Younger Dryas (12,900 – 11,700 BP). This interpretation is challenged by McDougall (2013) and later by others (see sections of McDougall and Evans, 2015). The latter authors suggest a different style of glaciation with plateau icefields and outlet glaciers descending into valleys more extensively than previously acknowledged but broadly within the same period. The problem has been to distinguish moraines of possible different ages. Sissons (1980) had used 'freshness' of form – the sharpness of slopes - which he compared with the more subdued forms of older moraines. Radiometric dating has been applied to boulders on the surface of moraines (Wilson et al., 2013), but the results are not conclusive. As we can see from the dates for the Rosthwaite moraine (Figure 1), at the limit of McDougall's suggested glacier, the dates are much older than expected. Even the dating of the mid-Langstrath moraine, within Sissons' Younger Dryas limit, produces older than expected ages. The most likely explanation for anomalous dates, is that boulders have been exposed to weathering for long periods and have been re-cycled onto the surface of Younger Dryas glaciers.

The dated moraines at Rosthwaite and mid-Langstrath can be inspected and compared to their up-valley or down-valley counterparts. The impressive (fresh?) moraine at Steel End (NY 354337) is adjacent to the main A591 road at the southern end of Thirlmere and is regarded as of Younger Dryas age by McDougall in contrast to Sissons' views. These contrasting interpretations are very clear regarding several valleys on Figure 1.

The lack of dates for alleged Younger Dryas age moraines (*à la* Sissons, 1980) is notable. However, recent dating using ^{10}Be on boulders of the Keskadale corrie moraines (NY 200173), produced estimated ages of 12.3+/- 1.1 ka and 12.5+/-1.0 ka BP dates within the accepted Younger Dryas time frame (Hughes et al., 2019).

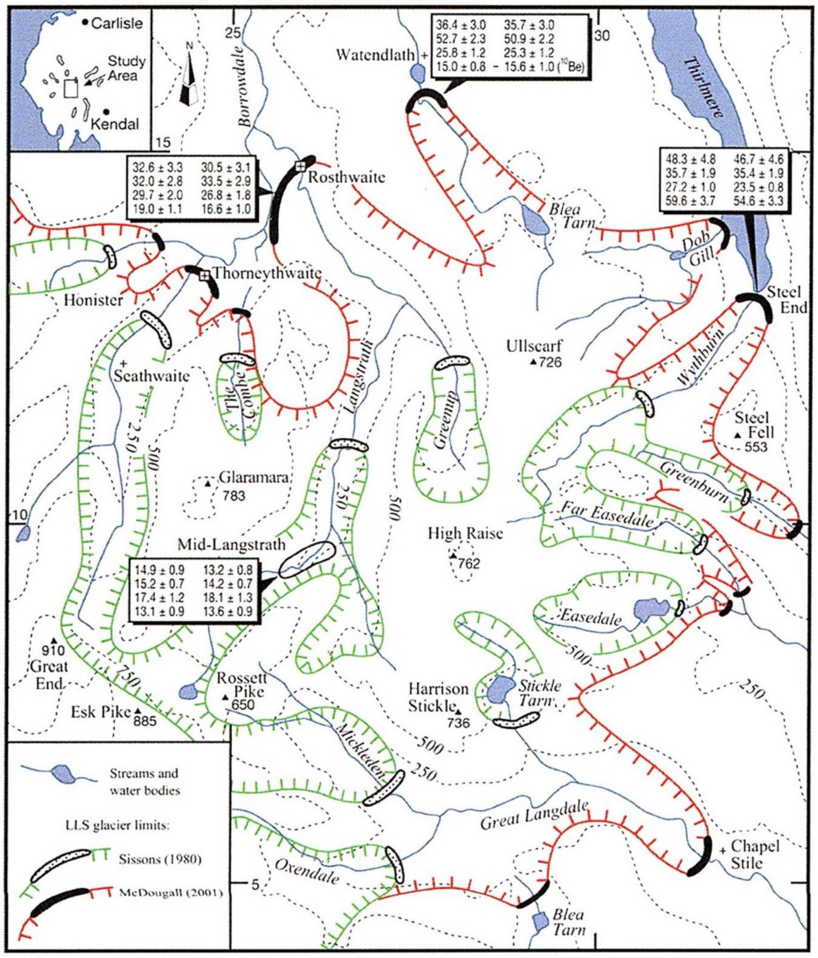

Figure 1. Younger Dryas glacier limits based on Sissons (1980) and McDougall (2001). ^{36}Cl age-based estimates are given in the boxes. Dates on left- and right-hand side are for same boulders using different assumptions (from Wilson et al., 2013; reproduced by permission of John Wiley & Sons).

Soils

Soils develop certain characteristics with time. For example, soils become deeper as the weathering of underlying materials progress. The A horizon thickens as organic material accumulates. The B horizon may acquire clay due to translocation from above. Soils vary greatly because they are influenced by their environment e.g. climate, parent material and site vegetation.Time is just one factor in the development of a soil. These complex relationships are fully explored in *Soils and Geomorphology* (Birkeland, 1999).

Soils on landforms of different ages should display different characteristics. They can, therefore, be used as a tool for assessing the age of landforms. This is illustrated with reference to the Mosedale Beck valley near Threlkeld, northern Lake District. The valley is unique in northern England for displaying the evidence for three glacial events (Boardman, 1980, 1996). The most recent of these, during the Younger Dryas, was responsible for a moraine in Wolf Crags corrie (NY 355225) at the southern end of the valley. Meltwater from the corrie glacier was initially thought to have formed an impressive series of terraces and boulder bars in the Mosedale valley (Rose and Boardman, 1983). This was a reasonable assumption of the basis of the size of boulders moved, the lack of dating evidence and the former presence of the corrie glacier (Figure 2).

Figure 2. Boulder-strewn terrace in Mosedale Beck valley Flow is away from the camera and the beck is ~3m wide.

However, documentary evidence was later found for an exceptional ‘cloudburst’ causing extensive localised flooding in the valley and in the nearby Vale of St. John’s (Lock, 1749). The flooding had occurred on 22 August 1749. This raised the possibility that the landform sequence in Mosedale was more recent than had previously been assumed. Hudleston (1935) remarks that the 1749 cloudburst in Mosedale and St. John’s is ‘still the most imposing modern example of a cloudbursts’s effect that we have in the whole of the Lake District’ (p. 27).

The development of soils on the terraces of Mosedale Beck is shown in Figure 3a (from Smith and Boardman, 1989). In Figure 3b representative soil profiles are shown. M10 is from a terrace 6m above the present stream and is a well-developed profile (A/E/Bg horizons) with podsol characteristics, of almost 1m depth. M2, at 4m above the stream, is a truncated brown earth having lost part of its B horizon. The depth of the silty B horizon at M4 appears to be the result of the addition of older soil material during flooding, in which developed subsequently a thin A horizon (Figure 3c). Such A horizons are characteristic of young soils. Thus, the soil sequence suggests major erosion up to the 4m level above the current stream, followed by deposition and development of young soils with thin A horizons. The likely explanation being that the 1749 flood caused erosion and deposition up to this level. There are many sites in the Mosedale valley where soils on terraces can easily be exposed with a spade and their history explored.

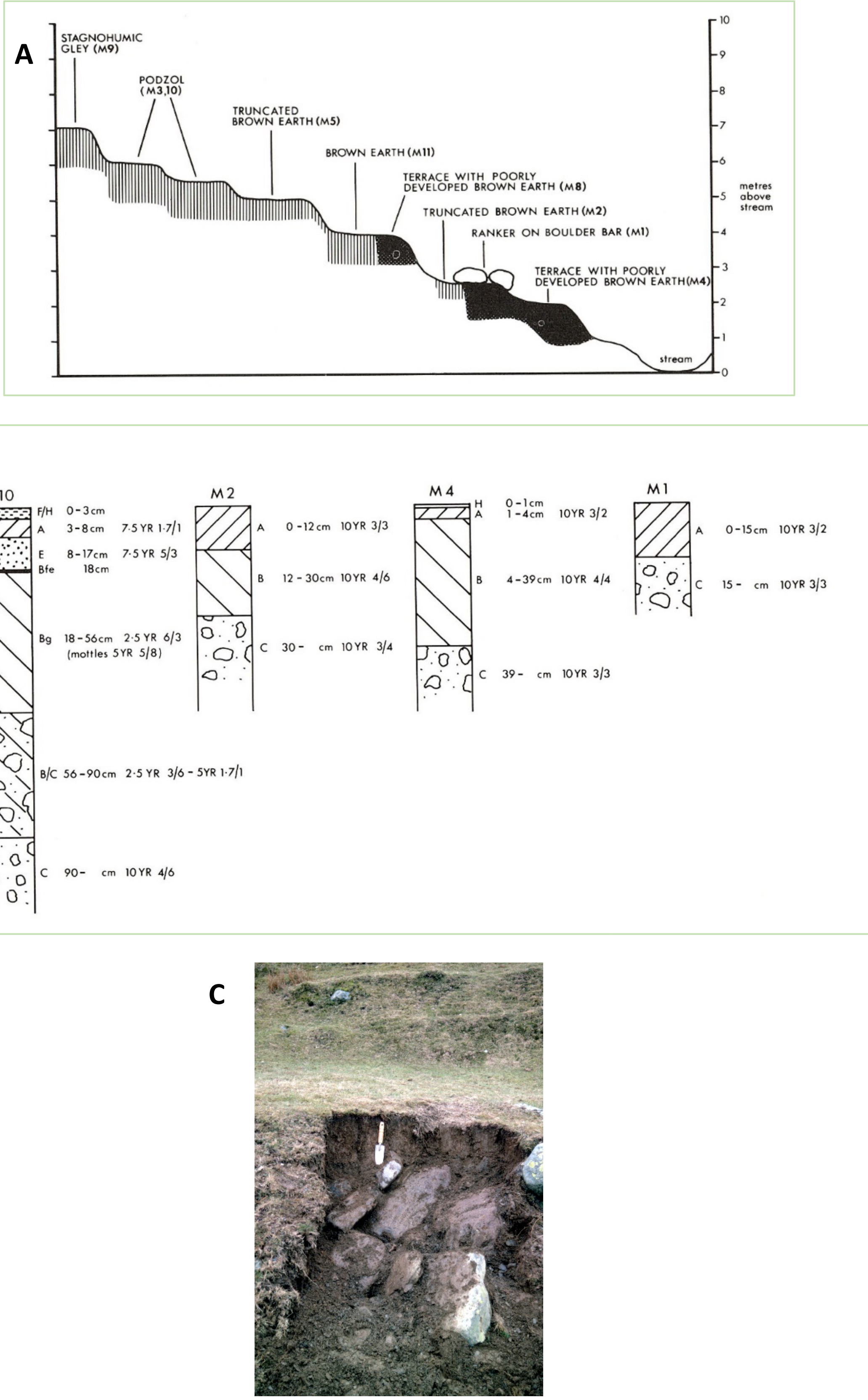

Figure 3. Mosedale Beck. (A) sequence and associated soils; (B) soil profiles;
(C) Mosedale soil: silty flood deposits overlying imbricate boulders, profile M4.

Lichens

Lichenometry has been widely used for the dating of recent landforms based on the assumption of a constant growth rate to a maximum size. The approach was developed by Roland Beschel in the 1950s e.g. Beschel (1957). The most commonly-used lichen is the yellow-green *Rhizocarpon geographicum* (Figure 4a). Maximum diameters of series of lichens in a limited area e.g. a river bar, can be measured. Comparison is then made to a growth-rate curve, most often obtained from nearby datable structures such as bridges or gravestones. An example of a curve, made in the 1980s, in the Keswick-Threlkeld area is given in Figure 4b. Growth rates are likely influenced by rainfall, aspect and lithology of the subsurface. In the case of Figure 4b, all measured lichens were on Borrowdale Volcanic rocks. In the Lake District, the efficacy of such a curve is limited by the fast growth of lichens in a warm, wet climate and the curves are not likely to be of value for dating surfaces older than ~150 years.

A

B

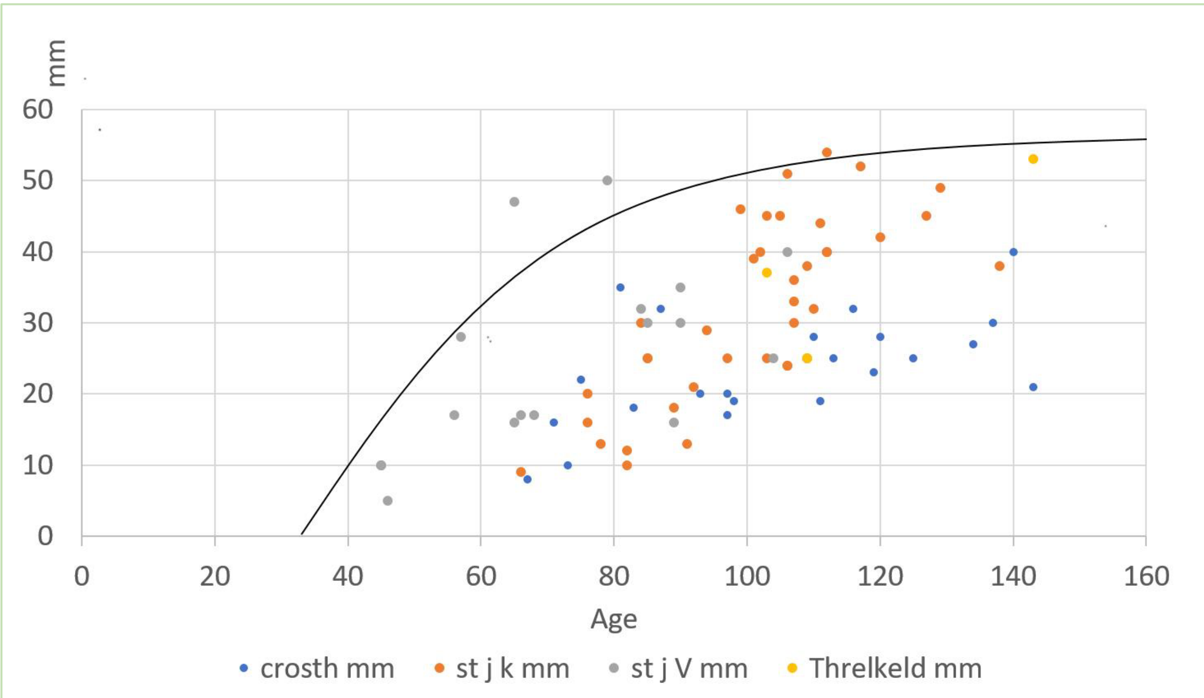

Figure 4. (A) Lichens on Borrowdale Volcanic boulder: *Rhizocarpon geographicum*. (B). Growth-rate curve for Keswick-Threlkeld area using yellow-green lichen (*Rhizocarpon geographicum*) for west-facing Borrowdale Volcanic lithologies on gravestones in four graveyards with envelope curve drawn by eye. (Continued overleaf).

C

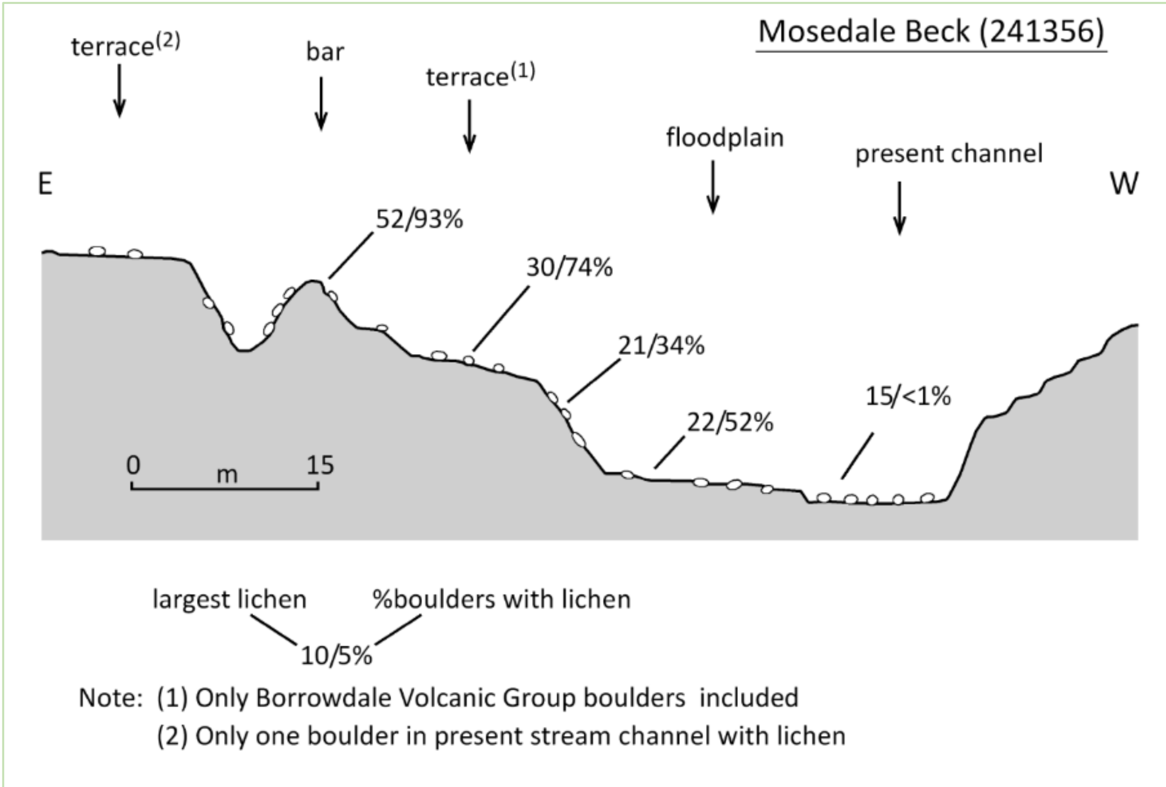

Figure 4 continued: (C) Lichen size and distribution, Mosedale Beck (at NY 241356).

Soils in Mosedale Beck valley suggest relatively recent development on lower terraces and bars. Based on a very limited survey (Figure 4c), the size and distribution of lichens suggests that the floodplain and low terraces have all been disturbed by floods more recent than 1749. The example quoted here demonstrates the potential for soil and lichen studies in the dating of landforms. Lichen growth rate curves have been used in the northern Lake District for dating recent fan deposits (Johnson and Warburton, 2002), for recent disturbance of the stones at Castlerigg Stone Circle (NY 291237) (Winchester, 1988) and for the de-roofing of houses at Haweswter (Mitchell, 2004 pp 124-131).

Relict and active landforms: alluvial fans and scree slopes

Alluvial fans

Alluvial fans occur in all Lakeland valleys and are especially frequent where steep valleysides are gullied. The fans mark the point where the gully gradient decreases as they encounter the valley bottom and sediment deposition occurs. In the northern Lake District, the fans cannot be older than ~16,000 years and within the former limits of Younger Dryas glaciers they cannot be older than ~11,700 years. Fans vary in appearance, some appear to be totally inactive and well vegetated, whereas others are receiving sediment and actively expanding at the present time. Retrenched, well vegetated fans, as in the case of that in Figure 5, suggest a very active phase of fan building, most likely in immediate post-glacial time, followed by a reduction in sediment supply but with sufficient water energy to re-entrench under Holocene temperate conditions. The fan, at the point where Short Gill debouches into the Caldew valley (NY 321321), is notable for its large size relating to a small catchment area (1.3 km^2). The retrenched stream grades to the floodplain of the Caldew (Figure 5).

Alluvial fans in the Seathwaite valley have been mapped and most appear to be active at the present time (Boardman and Smith, 1994). By far the most interesting is at Stockley Bridge (NY 235111) where an intermittently active fan crosses the track to Seathwaite (Figure 6). At river level, the fan material overlies organic peat, humic sand and fibrous organic woody debris of birch and alder (Parker et al., 1994; Wild et al., 2001). The fan is composed of poorly-sorted material, most likely from debris flows incorporating glacial sediments from the slopes above. The fan also overlies the continuation of a valley-side stone wall and cut wooden stakes presumably the remains of a stock fence across the former flood plain. Radiocarbon dates on the peat and on stakes of between 1301 and 1660 AD suggest Medieval woodland clearance, farming activities and destabilisation of the hillside, leading to aggradation of the fan. Clearance coincides with the deteriorating climate of the Little

Ice Age. Sheep were first introduced into the Lake District by Viking settlers and extensive sheep farming by tenants of monastic owners was taking place in the Borrowdale valleys in Medieval times. Unravelling this story required a combination of geomorphological mapping, archaeological excavation, radiocarbon dating, pollen analysis and documentary evidence (Wild et al., 2001). Unfortunately, the peat bed at the site has now largely been eroded away by the river but remnants of the peat layer are visible beneath flood plain deposits downstream of the fan.

Figure 5. Dissected alluvial fan in the upper Caldew valley valley, Cumbria.

Figure 6. Stockley Bridge fan: unsorted colluvial deposits (debris flows?) overlying a bed of peat (photo 1993).

Twenty-three alluvial fans in the Buttermere-Crummock Water valley were mapped and measured by Smith (1996). He also gives details of stream basin area, stream gradient and basin lithology. None are 'particularly active at present'. As would be expected, there is a good relationship between basin area and fan size (Figure 7), despite problems emphasised by Smith in measuring fan area. Present day inactivity on the fans suggest that they are largely Late Glacial in origin. Two fans in the Wast Water valley are also added to the data in Figure 7 (Boardman, 1996). Both had small glaciers in their catchment in the Younger Dryas (Sissons, 1980) as had several of the fans in the Buttermere-Crummock Water valley. The presence or absence of glaciers seems to make little difference to the general relationships in Figure 7. In comparison with data for alluvial fans in other regions, those in Figure 7, appear to be small in fan area compared to their basin size (cf Harvey, 1989 Figure 7.5). This probably relates to the relative inactivity of Lake District alluvial fans and the short period of geological time for their development.

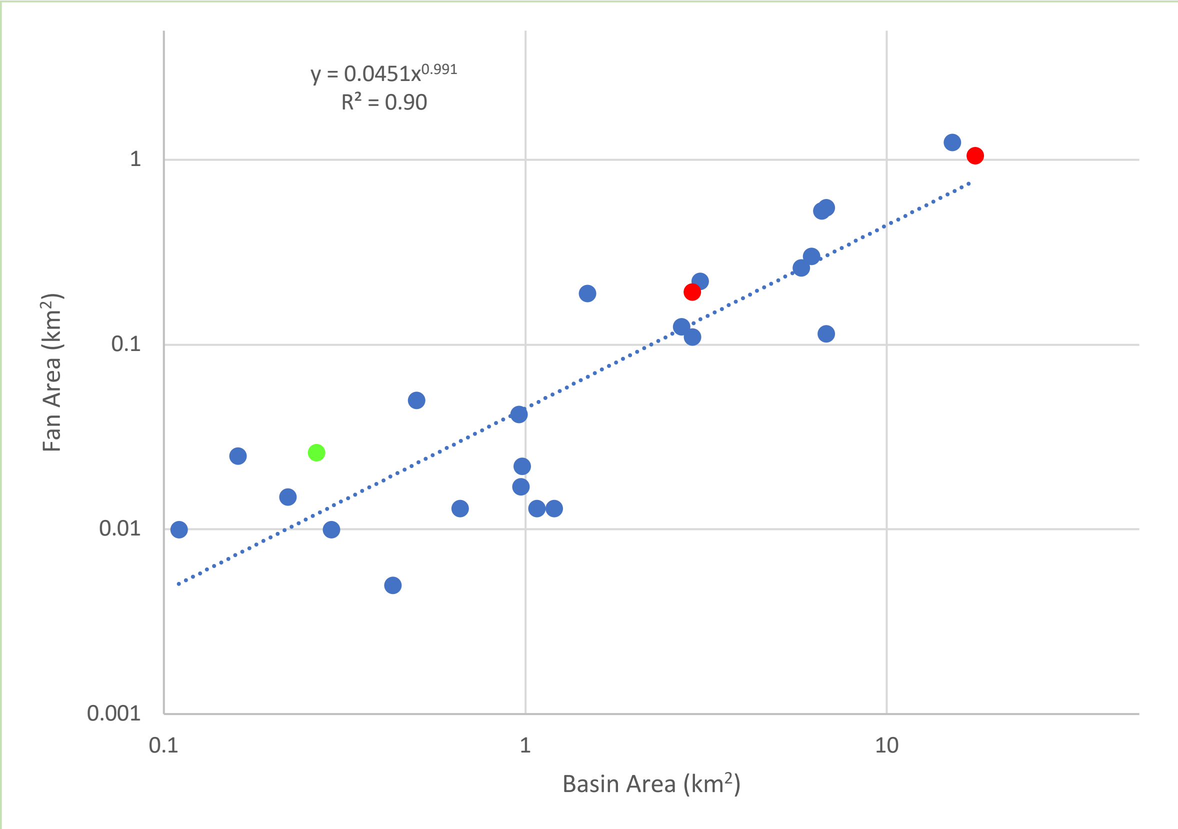

Figure 7. Alluvial fans in the Buttermere – Crummock Water valley (data from Smith, 1996). Fans in the Wast Water valley (**red**) and at Sandbed (**green**) s are also plotted.

The alluvial fan at Sandbeds (NY 234291), on the western flanks of the Skiddaw massif, is described in some detail by Boardman (1985). A small quarry in the fan material showed edge-rounded slate gravels partly infilling a channel. An iron-stained involuted horizon suggested active layer disturbance under periglacial conditions during fan formation. The fan area to basin area (25,500: 265,000 m²) places it close to the best fit line in Figure 7. The estimated volume of material in the fan of 153,000 m³ suggests a high denudation rate in the small catchment. Boardman (1985) argued for a period of 1000 years of Younger Dryas time for fan formation with severe frost weathering of the Skiddaw Slate slopes and snow meltwater transport probably over frozen ground. The estimated mean surface lowering in the catchment was 0.58 m or 0.58 mm/yr. However, it seems more reasonable to allow for 4000+ years since Late Devensian ice vacated the site for fan formation under both relatively mild and periglacial conditions, thus reducing the denudation rate considerably. The quarry in the Sandbeds fan is not now accessible due to afforestation.

Screes and slopes

Screes (or talus slopes) frequently occur in the northern Lake District below cliffs on steep valley sides. They are part of a set of processes, including large rockfalls, by which slopes are adjusting to the removal of glacial ice. These processes include frost shattering. The balance of these processes is much in dispute as is the issue of the timing of the episodes of landscape transformation. It is clear, however, that scree slopes in the Lake District are active to some extent today but that major phases of development occurred in the past, most likely, as with alluvial fans, in the period after deglaciation at the end of the Late Devensian glacial episode, the Younger Dryas, and the Little Ice Age e.g. ~1400 – 1800 AD.

Most comment on screes in the Lake District has focused on the Wast Water screes (Figure 8). Little significant progress has been made since the early work of Andrews (1961), except for the observations of Wilson (2013) regarding the likelihood of major mass movements contributing to the material on the screes. He points to the evidence for large cracks denoting tensional spreading along the scarp above the screes which would precede major rock falls (see also Wilson, 2010 pp 114-117 for discussion of rockfall talus in the Lake District).

Screes are an important component of slope systems in the Lake District. The concept of 'sediment cascades' has been promoted, for example through the book of Burt and Allison (2010) and applied specifically to the Lake District by Joyce et al. (2018). Sediment movement on slopes is suggested to proceed by a series of supply, transfer and storage sites with lakes in glaciated terrain being important stores. The concept can be illustrated by reference to the Seathwaite valley and the Stockley Bridge fan. Material is supplied to the higher slopes by weathering processes and transferred downslope by intermittent fluvial action (torrents) and mass movements (debris flows) and stored in the fan. Erosion of the toe of the fan by Seathwaite Beck transfers sediment eventually to the Derwent Water delta (NY 263191) and lake basin. A major source of sediment is provided by eroding hummocky moraine in the Seathwaite valley (see Boardman (2016). Students should be encouraged to sketch and label key elements of the slope system and consider the residence times of sediment in storage sites. The sites include river channels where transport is not continuous and is strongly related to sediment size and frequency of major flood events. It is worth noting that Seathwaite Farm (NY 235122) was damaged by flooding in 1966 and the beck is routed away from the farm by a protective wall.

Figure 8. Wast Water screes (Elizabeth Burt).

In the northern Lake District, a significant feature is large areas of slopes which are now well vegetated but which are in fact vegetated screes. Much of the lower slopes of the Skiddaw massif and of Whinlatter Forest (NY 212248) fall into this category. The depth of scree deposits at Whinlatter has allowed a major forestry enterprise to flourish. Vegetated screes on the lower slopes of Latrigg (NY 275244) were explored with trenches, trial pits and boreholes prior to the construction of the Keswick bypass in 1975: thicknesses of up to 12.5 m were recorded (Boardman, 1985). Many footslopes in the northern Lake District are composed of vegetated scree and, as they are eroded and re-cycled by streams, they come to constitute a component of flood plains and alluvial fans. The screes themselves are relict features from periglacial times with the vegetation cover established during the Holocene.

The role of geomorphological processes in influencing landform development

It is a basic tenet of geomorphology that there is a close relationship between process and form. This means that the landforms we see around us have been formed by a particular process or set of processes. But this relationship can be difficult to unravel. The obvious problem that has already been discussed is that many landforms are the product of processes that no longer shape our environment, glacial landforms being a clear example in the Lake District. We then have to take into account the modification of the glacial form by subsequent processes such as mass movements and erosion by rivers. We return to the concept of the landscape as a palimpsest. However, the relationship can be demonstrated by taking simpler examples where landforms are being currently influenced by processes.

In the northern Lake District rivers are actively changing the landscape of the valleys and influencing slope forming processes by undercutting. Nowhere is this more clearly demonstrated than in the recent flooding and property damage in Keswick, Cockermouth and Workington as a result of Storm Desmond in December 2015 (Rodgers, 2018). But this was not a unique event: extensive flooding and damage to towns occurred in 2009 when 377 mm of rainfall recorded at Seathwaite in 36 hours (Sibley, 2010; Schillereff and Macdonald, 2020) and also in January 2005 with over 150 mm at several gauges on the 7th (Warburton et al., 2008). Recurring storm damage to the road (A591) through the Thirlmere valley and over Dunmail Raise (NY 327188) is recorded in Johnson and Warburton (2002).

Date analysis example

The discharge of a river is the result of rainfall and runoff within the catchment. Discharge varies through the year and often through the day. It can be measured at gauging stations or estimated using simple equations. Data from the National River Flow Archive (http://nrfa.ceh.ac.uk/data) is readily available. From this archive, the most useful data for a particular station is the Maximum Mean Daily Flow (MMF) in m^3/sec (cumecs). So how might this influence the form of the river channel? Classic work in the 1950s showed the close relation between river discharge, channel width and meander wavelength (Leopold and Wolman, 1957). Actually, it is bankfull discharge that is important, but that value is not so easily obtained, so we can use instead MMF.

In Table 1, data from the National Archive and meander wavelengths from the Derwent catchment, northern Lake District, are listed. The wavelengths are measured from 1:25,000 topographic maps. Measurements were made near to the gauging station but avoiding channel reaches where straightening appeared to have occurred, as in the St. John's Beck section. The same exercise can be carried out by measurement in the field on smaller streams where channel width or bankfull discharge can be estimated.

Table 1. Hydrological and meander data for gauging stations in the Derwent catchment

Site (Grid reference of gauging site)	Catchment Area above gauging site (km^2)	Meander wavelength (m) (mean of 7)	Instantaneous maximum flow (cumecs)	Maximum mean daily flow (cumecs)
Mosedale Beck (NY 351264)	8.1	131	ungauged	ungauged
St John's Beck (NY 313195	42	236	75	20
Glendermackin at Threlkeld (NY 322248	65	407	131	62
Greta at Low Briery (NY 285242)	146	440	400	152
Derwent at Portinscale (NY 251238)	235	475	402	118
Derwent at Ouse Brid (NY 198321)	363	774	395	160
Cocker at Southwaite Bridge (NY 130280)	117	400	201	83
Derwent at Camerton (NY 037305)	663	933	700	309

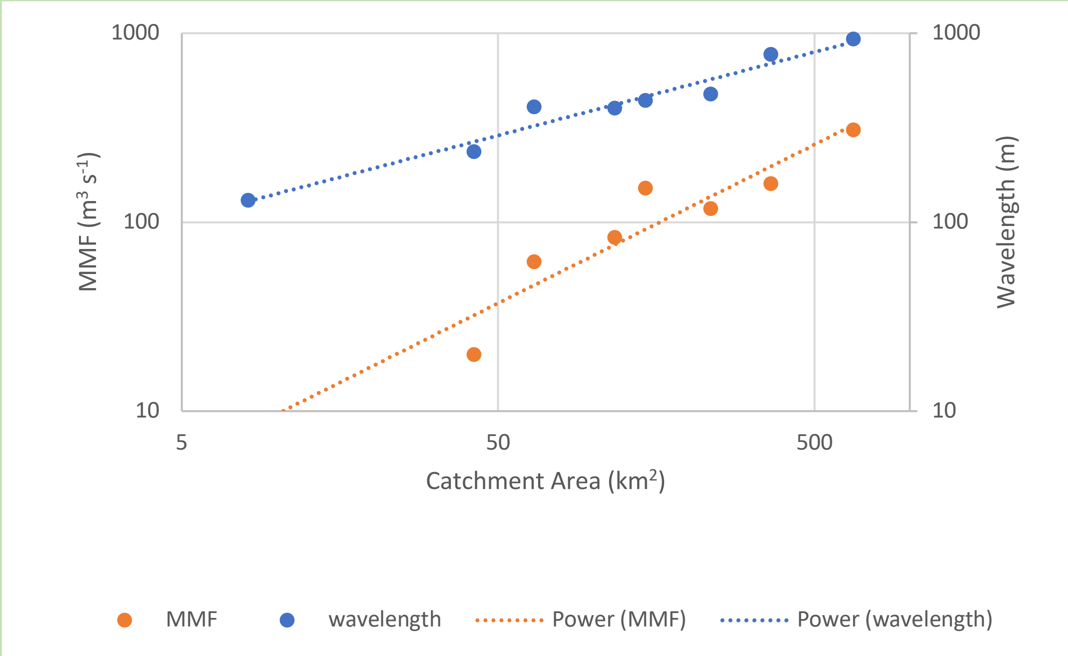

Figure 9. Data from Table 1 for gauging stations in the Derwent catchment. MMF: Maximum Mean Daily Flow (cumecs); Wavelength: meander wavelength (m).

Figure 9 shows a consistent relationship between discharge (MMF) and meander wavelength, and between catchment area and discharge. The plot allows us to estimate the discharge for the ungauged Mosedale Beck. Instantaneous Maximum Flow (Table 1) can also be plotted against area and wavelength.

OPPORTUNITIES FOR FURTHER FIELD WORK AND DATA ANALYSIS IN THE NORTHERN LAKE DISTRICT

In this short article, examples of field-based exploration and analysis of data have been discussed. Many of the projects are incomplete or could be extended into other areas. Frequently, exposures of sediments that were available some years ago, are now overgrown and in need of clearance. Alternative sites are often available, especially where fluvial erosion is active.

Use of soils and lichens for relative dating of landforms has rarely been used in the Lake District. On-going soil descriptive work is reported by McDougall et al. (2015) in the Pasture Beck valley and by Evans et al. (2015) near Wasdale Head. In both instances, B horizon thickness is used as a guide to moraine age. Work on rivers in the area can combine field measurements and estimates, with map analysis and use of the National River Flow Archive.

Suggested sites for field work

The Mosedale valley for soils, glacial sediments, flood deposits and lichen studies. This is Open Access land but without footpaths. Access is easiest from the Old Coach Road at Wolf Crags corrie with parking at High Row (NY 380220). The Old Coach Road is an off-road cycle route. Note: there are several ‘Mosedales’ in the Lake District.

Linewath. (NY 353334) A sequence of kames, kame terraces and an esker on Common land. Nearby is a good glacial till exposure at Barrow Beck (NY 368291).

The landforms of the Keswick lowland are eminently walkable from the starting point of the drumlin which forms Crow Park (NY 263230). The walk continues through an area of kames, drumlins, kettle holes and an esker and leads to Broom Hill Point (NY 267215) with its lakeshore till exposures. For a good overall view, the nearby small hill of Castlehead (NY 270227) formed by a dolerite intrusion is recommended (Boardman 1982 and 1996 pp 36-38.

Seathwaite valley. Alluvial fans including that at Stockley Bridge (NY 235111). Younger Dryas hummocky moraine and lateral moraines (Sissons, 1980). Rosthwaite and Thorneythwaite: terminal moraines of disputed age (Wilson et al., 2013).

Low-altitude scree slopes are accessible at Stone Ends (NY 354337) on the eastern flank of Carrock Fell (Clark and Wilson, 1997, 2002). Also, on the south facing slopes of Carrock Fell in the Caldew valley are opportunities to examine vegetation colonisation (juniper, heather and lichens), on moderately active scree slopes.

CONCLUSIONS

The specific instances of landforms and processes that have been presented address the theme of active and relict elements of the Lake District landscape. The distinction is not binary since many of the landforms inherited from the past are being modified by current processes. In some cases, the modification involves the recycling of sediments from one storage site to another: the moraines of Seathwaite transform to fluvial sediments or the fine-grained component into deltaic sediments. Thus, the concept of 'sediment cascades' is well illustrated in these slopes and valleys. The dating of landforms, albeit by ^{36}Cl (moraines), radiocarbon (fans) or lichenometry (flood deposits) adds to our understanding of rates of landform change and the residence time of sediments in storage sites.

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