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Published in:
Proceedings, Cumberland Geological Society

Publication Status:
Published (in print/issue): 01/08/2018

Document Version
Publisher's PDF, also known as Version of record

Proceedings, Cumberland Geological Society 2018, 8(4), 477-491.
ISSN 0967-2443

DRY STONE WALLS AS SEDIMENT TRAPS: EXAMPLE FROM RYDAL

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Introduction

The storms and devastating floods that have affected northern England in recent years have brought into sharp focus the ability of water to erode and transport large volumes of hillslope debris. This is no more so than in the Lake District, where intensive and/or prolonged precipitation in combination with steep relative relief can cause superficial debris to move considerable distances in short periods. The processes involved range from fluvial (water-dominated) flows to viscous debris flows in which water acts as a lubricant, reducing shear strength and causing materials to sludge downslope. Ultimately, upper slopes become denuded of their superficial debris covers while lower hillsides and valley floors accumulate materials. Sediment transfers of this nature have become important land-shaping processes since the ice of the main Late Devensian glaciation began to wane (~22-20 ka), exposing glacial debris to snow melt and rainfall. In upper valleys that hosted glaciers during the Loch Lomond Stadial (~12.9-11.7 ka), the reworking of slope debris began as those glaciers decayed. With climatic amelioration at the start of the Holocene (~11.7 ka), sediment transport rates are likely to have reduced significantly as vegetation colonised and provided a protective surface cover, and humus and root systems helped to bind materials and hold them in place. However, at various times throughout the Holocene, brief periods of climatic deterioration along with the introduction and later intensification of agriculture, and ground disturbance brought about by the mining and quarrying of rocks and minerals, probably caused short-term increases in transport rates.

Many Lake District hillslopes are seamed by gullies that cut into both superficial debris and bedrock. At the foot of these gullies a marked reduction in slope gradient occurs as valley floors are reached and it is there that much debris from the gullied slopes has been deposited. These accumulations of material often take the form of a fan, splaying out from the gully foot, and are termed either alluvial fans or debris/colluvial fans depending on their surface gradient and the dominant process of transport and deposition. In former glaciated regions like the Lake District most fans have been constructed by both fluvial flows and debris flows, and are essentially composite features.

In several Lake District valleys, some fans have been incised or trimmed along their distal margins by trunk streams and reveal organic horizons buried within the mineral sediment. These horizons testify to periods of fan stability, marked by vegetation growth on the fan surface and development of organic-rich soils. Subsequent burial of these organic soils is taken to indicate an increase in the intensity of hillslope erosion and the downslope transport of debris. Such stratigraphic sequences are indicative of episodic fan development.

Buried organic-rich soils have been recorded in fan exposures near Seathwaite in Borrowdale (Parker *et al.*, 1994; Wild *et al.*, 2001), at Iron Crag in the northern fells (Johnson & Warburton, 2006), in the Newlands valley, and at Blindtarn Moss near Grasmere (Chiverrell *et al.*, 2007), and in the Pasture Beck valley, above Hartsop (Clark *et al.*, 2007). Radiocarbon dates obtained from these organic horizons indicate some consistent patterns of recent fan stability/instability. Phases of fan aggradation may be allied to land-use changes brought about by Norse-Irish settlers ~1000 AD, and climatic deterioration in the 14th and 15th centuries AD, associated with the Little Ice Age, is also considered to have caused increased sediment input to fans. Therefore, although fans may have started to develop as the last glaciers decayed, they have continued to be active into the late Holocene.

Fans and walls

In some Lake District valleys, debris/colluvial fans have accumulated against the upslope side of dry stone walls that are aligned across slope, in mid-to-lower slope locations. As a consequence, the fans are perched on the valley sides rather than being at the slope foot. Examples of this phenomenon can be seen on the upslope side of walls that traverse the hillside at ~170-190 m above sea level (asl) between the Old Dungeon Ghyll Hotel and Raven Crag in Great Langdale (Fig. 1): "walls have acted as temporary dams to this down-slope creep of fan material" (Barringer, 1970, p.43). These walls are regarded as 'Statesmen Walls' constructed between the late 16th century and ~1750 AD (Lund & Southwell, 2002) and therefore fan accumulation to the full height of the walls (~1.5 m) has taken a maximum of ~300-350 years. Fan surface debris consists of unvegetated angular clasts and is continuous upslope with talus. At these locations, the rate of downslope movement may have been accentuated during the last 100 years or so as a consequence of human traffic along footpaths that cross the talus and lead to the rock climbing routes on Gimmer Crag, Middlefell Buttress and Raven Crag.

Clark (2001) referred to the build-up of soil to the crest of the lower walls as a result of soil creep accelerated by ploughing across slopes in the

Figure 1. Wall above the Old Dungeon Ghyll Hotel in Great Langdale overtopped by downslope movement of talus.

vicinity of Hartsop. He noted that some walls have been overtopped or pushed over and speculated whether the debris behind the walls might carry a record of accumulation rates, and episodes of relative stability or rapid downwash events. From the Lomond Hills of Fife, Scotland, Ballantyne and Eckford (1984) recorded an example of talus creep against a wall. The build-up of "soil" behind an old wall constructed across the lower hillslope was noted to have entirely buried the wall in places.

An additional Lake District location where dry stone walls have impeded the downslope movement of sediment is Dalehead Close in the upper Rydal valley. The perched fans in this valley were described briefly by Wilson (2010, p.148-149). In this paper we provide greater detail of the locations, dimensions and characteristics of these unusual and apparently little studied features, and consider their geomorphological significance.

Dalehead Close, Rydal

Dalehead Close (Grid Reference NY 363096; Fig. 2) is the name of the northernmost enclosure in the upper Rydal valley. It extends north - south for 1.4 km, has a maximum width of 0.65 km, and encompasses 0.75 km2 of the valley floor and lower slopes of Great Rigg (766 m), to the west, and Dove Crag (792 m), to the east. The enclosure rises from 300 m asl at its

southern end to 460 m asl near to its northern limit, and its boundary is defined by a dry stone wall 3 km in length. For most of its length the wall is aligned across the local hillslope or is slightly oblique to it and is therefore orthogonal to hillslope drainage routes. At nine locations on the upslope side of the western arm of the enclosing wall, and at two locations on the eastern arm, debris has been transported downslope and has accumulated against the wall. On the west side of the valley immediately south of Dalehead Close, another fan is also banked against the wall. At the margin of each fan the wall stands to heights of 1.25 - 1.9 m, but this rapidly diminishes towards the centre of the fans where the debris is level with the capstones of the wall, or very nearly so. In all cases a length of post and wire fencing has been erected parallel with the obscured section of wall in order to deter sheep from using the fan surface as a platform for jumping into the enclosure.

Fan details

Brief details of each fan as recorded in October 2016 are provided below. The fans are numbered 1 - 12 and their locations are indicated on Fig. 2.

Fan 1: This fan (Grid Reference NY 361090) is immediately south of Dalehead Close where the dry stone wall descends the hillside obliquely and meets the southwest angle of the Dalehead Close wall. Debris is banked against the wall for a distance of 47 m and has reduced the visible height of the wall to 0.25 - 1.1 m. To the south of the fan wall height is 1.85 m and to the north it is 1.4 m. The fan and its feeder gully are predominantly vegetated with only a few small areas of surface debris evident (Fig. 3).

Fan 2: At Grid Reference NY 361093 the Dalehead Close wall is totally obscured on its upslope side for a distance of 20 m, and for another 34 m the wall height is less than 1.5 m. Wall height on either side of the fan is 1.5 - 1.75 m. The fan surface is vegetated, with palaeochannels and levees evident, and current channel flow is along the margins of the fan. Figure 4 shows the fan from the opposite side of the valley, from where the upslope-facing height of the wall cannot be seen.

Fan 3: Wall height has been reduced to less than 1 m for a distance of 88 m around Grid Reference NY 361095, and debris obscures the wall entirely for a distance of 17 m. Wall height adjacent to the fan is 1.5 - 1.7 m. Open channel flow was observed along the north margin of the fan with the water percolating through the wall.

Fan 4: A 33 m length of wall is partly obscured by fan debris at Grid Reference NY 360097. The wall height has been reduced from 1.6 m at the margins of the fan to between 0.5 - 1 m where the debris occurs. The fan surface, with palaeochannels, is completely vegetated. No water flow was seen crossing the fan surface but open channel flow was evident higher on the slope.

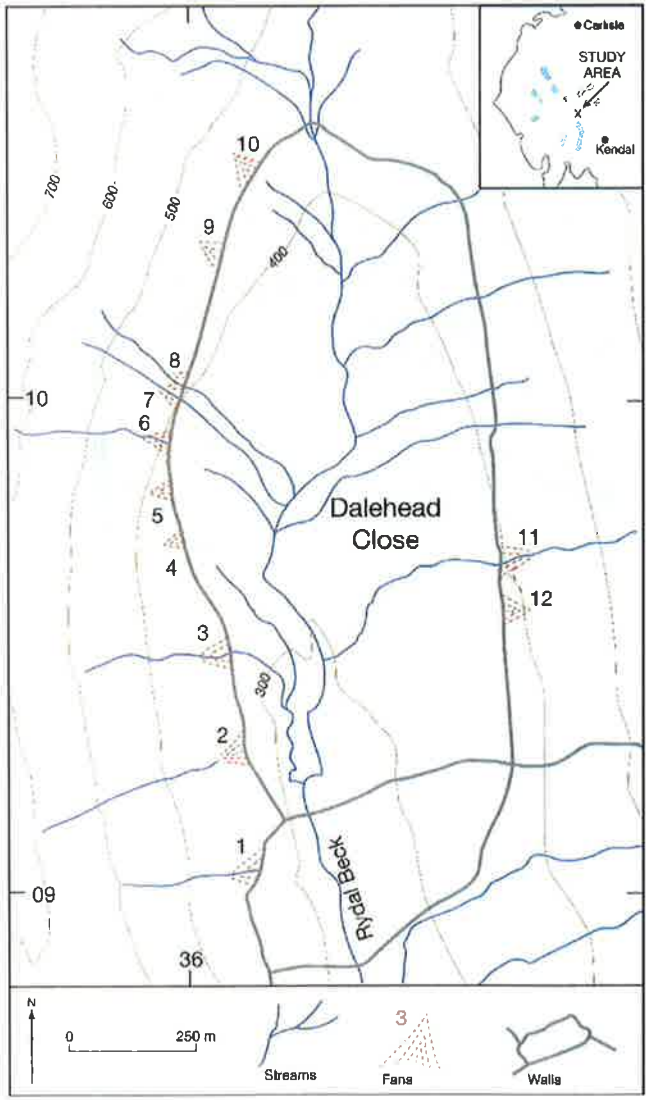

Figure 2. Map of Dalehead Close, Rydal, showing locations of the debris fans. Note that fans are shown schematically rather than at their true scale. Contours are in metres and grid line co-ordinates are given in the margins. © Crown copyright Ordnance Survey. All rights reserved.

Figure 3. Vegetated hillslope above Fan 1. There is no evidence of recent surface flow or sediment transport down this slope, although shallow palaeochannels are present.

Figure 4. Fan 2 as seen from across the valley. The fan surface is almost totally vegetated although palaeochannels and levees are still evident. Water flow is currently to south (left) and north (right) of the fan, as indicated by the rush-infested (darker vegetation) drainage lines.

Fan 5: Fan debris is banked against the wall for a distance of 24 m at Grid Reference NY 360098 and wall height has been reduced to 0.5 m. The fan surface and upslope gully were dry although the former has a cover of weathered boulders.

Fan 6: This fan, at Grid Reference NY 359099, has a cover of recent debris, 0.5 - 0.6 m in thickness, trapped by the post and wire fence (Fig. 5). Prior to this input of sediment, the vegetated fan surface stood slightly above the capstones of the wall, which were obscured for a distance of 20 m. The recent debris extended for 22 m along the fence and in plan it tapered upslope for 20 m to the foot of an incised channel. The debris is probably a product of the December 2015 storms. Wall height south and north of the fan is 1.3 - 1.6 m.

Figure 5. The surface of Fan 6 with recent debris from the December 2015 storms trapped against the fence. The vegetated surface of the fan to the left of the fence is slightly higher than the wall.

Fans 7 and 8: These two fans are adjacent at Grid Reference NY 360100 (Fig. 6). Prior to the storms of December 2015 water from both gullies was able to pass through gaps in the wall and carry fine sediment to the valley floor; the field evidence suggests that any pre-existing fans were of limited extent and thickness. As a consequence of the storms the wall was breached for lengths of 9 m (Fan 7) and 3.5 m (Fan 8), and at the latter site some debris remains level with the top of the wall adjacent to the breach. At both places the wall has been rebuilt and water is free to flow through as before.

Immediately upslope of Fan 7 is an incised channel 1 - 2 deep, and near the head of each gully there is a shallow landslip scar (Fig. 6). It is inferred that the saturated debris from these landslips was transported rapidly downslope and caused much coarse sediment to be trapped against the wall, and destroyed two short segments of the wall where the streams passed through.

Figure 6. Fans 6, 7 and 8. Shallow landslip scars (ringed) are present near the heads of the gullies that feed Fans 7 and 8. Prior to December 2015 debris accumulation upslope of the wall at Fans 7 and 8 was very limited in its extent and thickness.

Fan 9: At Grid Reference NY 361103 the wall is partly obscured by debris for a distance of 65 m, including a length of 20 m along which only the capstones are visible. Wall height to south and north of the fan is 1.6 m. Several vegetated palaeochannels can be seen on the fan surface but no recent sediment deposition was noted.

Fan 10: The wall is obscured by fan debris for a distance of 9 m and partly obscured for a further 22 m at Grid Reference NY 361104. Wall height beyond the fan margins is 1.7 m. A substantial rowan tree is rooted in fan debris where it abuts the wall (Fig. 7). The fan surface has vegetated palaeo-channels and scattered boulders. Active channels occur along the south and north margins of the fan.

Figure 7. Downslope view of Fan 10 showing a substantial rowan tree growing from the debris where it is level with the top of the wall.

Fans 11 and 12: These adjacent fans are on the east side of Dalehead Close (Grid Reference NY 366096) and on both the debris is unvegetated. Fan 11, fed by a single incised stream channel, has obscured the 1.5 m high wall for a distance of 18 m (Fig. 8). In contrast Fan 12 is a compound area of debris brought downslope by several shallow stream channels. Debris from these channels extends alongside the wall for ~150 m and in the past may have overtopped or breached the wall. The present wall in this area looks to have been rebuilt recently but does not rise more than 1 m above the debris. While both fans are likely to have had debris added to them during December 2015, they were first recorded as active fans in 2004 by one of the authors.

Figure 8. The debris of Fan 11 is level with the top of the wall and has spilt over into the enclosure. It has also disturbed the fence that was built to maintain the boundary and prevent sheep from jumping into the enclosure.

Age of dry stone walls and Dalehead Close

Dry stone walls are an integral part of the upland landscapes of northern England and have been used as boundaries since late prehistoric or Romano-British times. However, the walled landscapes of the present-day have their origins in the medieval and post-medieval periods (Rollinson, 1972, 1998; Winchester, 2016). For some walls documentary evidence relating to their age may be available; in other cases, wall age may be ascribed to a certain period based on construction style (Lord, 2004). Establishing the age of the Dalehead Close wall would be useful as it would define the maximum period during which the fans had accumulated. However, over time walls may have been destroyed and rebuilt several times so that using them to determine sediment accumulation rates is fraught with difficulty.

Dalehead Close is listed by John Bankes, Steward of the Rydal Estate, in a valuation list of 1655 (Armitt, 1916), indicating that it was a defined area of land and was probably walled. However, no reference to a wall at Dalehead Close has been found in the account books of Sir Daniel Fleming (1633-1701), titleholder of the Rydal Estate from 1653 (Blake Tyson, pers. comm. 2005).

In the absence of documentary records, an alternative means of determining when a wall was constructed is by examination of the shape of the wall profile, where lengths of wall survive in good condition. The profile of the Dalehead Close wall from the footings at its base all the way up to the top stones is visible in the wall head at a gateway near the southwest corner. The wall head shows that it is a double wall with the outer edges of the stones placed on either side of the wall so that the width of the wall gets narrower towards the top. It is an example of a narrow-top double wall (Lord, 2004) where the width of the face stones beneath the top stones rarely exceeds 45 cm. In the Yorkshire Dales it has been suggested that this style of double wall construction was a post-medieval innovation replacing the earlier wide-top double wall forms of the sixteenth century. It is considered that narrow-top double walls in the Lake District are of a similar age (Rollinson, 1972, 1998; Pearsall & Pennington, 1973; Whyte, 2003; Winchester, 2016).

Another aspect of the structure of the Dalehead Close wall enables it to be dated more precisely. Clearly visible in lengths of the structure are two rows of carefully placed through stones that project from the wall (Fig. 9). Narrow-top double walls with regular arrangements of one or more rows of through stones are documented in eighteenth century specifications for new build walls (Raistrick, 1946). It is very likely that the Dalehead Close wall was built sometime between the mid-eighteenth and early nineteenth century, and very likely built to specifications by a professional walling contractor.

Figure 9. A section of the downslope-facing Dalehead Close wall with rows of projecting through stones at 0.5 m and 1.2 m above base. The survey pole divisions are at intervals of 0.2 m.

Figure 10. Remains of a former wall downslope of the extant wall at Dalehead Close. The survey pole divisions are at intervals of 0.2 m.

There is some evidence for a precursor wall, as implied by the 1655 valuation (Armitt, 1916), at several locations on the downslope side of the extant wall along its western arm. At these sites, banks of large boulders aligned parallel with the extant wall are visible (Fig. 10). In some places, the extant wall is directly on top of the boulder bank, in others the boulder bank is 1-2 m downslope of the wall. From this field evidence an inference might be that wholesale rebuilding of the Dalehead Close wall as a narrow-top double wall took place no earlier than the middle of the eighteenth century and no later than the middle of the nineteenth century.

Problems determining sediment accumulation rates

Although an approximate age may be assigned to the Dalehead Close wall, deriving and reporting sediment accumulation rates as annual averages is not easy. The surface area of each fan and the underlying slope gradient would need to be measured in order to ascertain debris volume. A representative value for sediment porosity would have to be established and then subtracted to obtain net volume. Most of this could be done by detailed surveying, although coring or trenching of the fans, or geophysical profiling, would also provide valuable data. If this detail was obtained and dates of 1750 AD and 1850 AD assigned as maximum and minimum ages of wall construction, average annual rates of sediment accumulation could be determined for each fan.

However, as was demonstrated in December 2015 at Fans 7 and 8, and probably Fans 11 and 12, large quantities of debris may be added to the fans in single, short-lived events that can cause breaching or overtopping of the wall and result in some debris being transported farther downslope. Therefore, the fans do not necessarily retain all the debris brought down the hillside since the wall was built. Even on those fans (the majority) that appear not to have been affected by the 2015 storms, we cannot assume that they accumulated by small additions of debris on a regular (annual) basis. It is more likely that they too experienced storm-related inputs of debris in the past and that on some of those occasions the wall was destroyed and subsequently rebuilt. Without detailed information concerning the magnitude and frequency of storms during the last 170-270 years and a record of wall rebuilds, reporting accumulation rates in terms of annual averages is not recommended and therefore has not been attempted. A summary of specific storms and destructive flood events in other Lake District valleys is provided by Johnson & Warburton, 2002). From this it may be surmised that Rydal has also been affected by destructive storms in the past, but for which there are no records.

Nevertheless, a crude estimate of the minimum volume of debris trapped by the wall has been made. This is based on the total length of wall against which debris has accumulated (~600 m) and assumes the average thickness of debris to be ~1 m. It also assumes that although debris thickness declines upslope, for the first 10 m it is of an approximate uniform (1 m) thickness. These values indicate 6000 m^3 of debris. By applying a sediment porosity value of 25% (cf. Carling, 1987) this reduces to 4500 m^3. Using a rock density of 2.65 g/cm^3 (2.65 t/m^3) this volume converts to ~12,000 tonnes of debris, for the lower reaches of the 12 fans.

Significance of the fans

Although the Dalehead Close fans are small landforms they are significant in at least three ways. First, irrespective of the age of the wall, they indicate that small fans can form rapidly if runoff is sufficient and sediment is available. This has implications for larger fans which are sometimes assumed to represent sediment accumulation over several millennia. Rather, some large fans may have developed in response to extreme climatic events and an abundant sediment supply in relatively short periods (several centuries). Second, because several of the fans do not appear to have been affected by the storms of December 2015 and are now considered to be inactive, it may be inferred that the sediment supply in their source areas has been exhausted. If that is so, then it is only because of the wall that a record of debris flows at those sites is preserved. Without the wall the debris is likely to have been transported and deposited farther downslope. In such circumstances it would be unlikely that debris deposition could be ascribed to the last few hundred years. Third, the active fans demonstrate that on some hillslopes in Rydal sediment supply has not been exhausted and during episodes of intense or prolonged precipitation debris flows continue to be effective means of sediment transport, and can cause temporary disruption and costly repairs for land users.

Conclusions

Dry stone walls in the upper Rydal valley have acted as effective traps to the downslope movement of coarse debris. The age of the wall constrains the age of the fans, which in turn enables debris volumes to be estimated. Field evidence indicates that some of the fans are no longer active and this may be because the sediment supply above these sites is now exhausted. Other fans remain active with the debris flow process continuing to add material during storm events. The fans have accumulated within the last 270 years and although of small size are testimony to the continuing downslope movement of debris and its ability to cause short-term economic impacts.

Acknowledgements

We thank Anna Ratcliffe for preparing Figure 2.

References

Armitt, M. L. 1916. *Rydal.* Titus Wilson, Kendal.

Ballantyne, C. K. & Eckford, J. D. 1984. Characteristics and evolution of two relict talus slopes in Scotland. *Scottish Geographical Magazine* 100, 20-33.

Barringer, J. C. 1970. *Lakeland landscape: a geographical approach.* Dalesman, Clapham.

Carling, P. A. 1987. A terminal debris-flow lobe in the northern Pennines, United Kingdom. *Transactions of the Royal Society of Edinburgh: Earth Sciences* 78, 169-176.

Chiverrell, R. C., Harvey, A. M. & Foster, G.C. 2007. Hillslope gullying in the Solway Firth – Morecambe Bay region, Great Britain: responses to human impact and/or climatic deterioration? *Geomorphology* 84, 317-343.

Clark, R. 2001. The management of water in the Lake District farming landscape. Year Book and Transactions 2001, *Matterdale Historical and Archaeological Society* 8, 9-13.

Clark, R., Parker, A. G., D. E. Anderson & Wilson, P. 2007. Late Holocene debris cone development and vegetation and land-use history in the Pasture Beck valley, Lake District, NW England. *Proceedings of the Yorkshire Geological Society* 56, 235-243.

Johnson, R. M. & Warburton, J. 2002. Flooding and geomorphic impacts in a mountain torrent: Raise Beck, Central Lake District, England. *Earth Surface Processes and Landforms* 27, 945-969.

Johnson, R. M. & Warburton, J. 2006. Variability in sediment supply, transfer and deposition in an upland torrent system: Iron Crag, northern England. *Earth Surface Processes and Landforms* 31, 844-861.

Lord, T. C. 2004. "One on two, and two on one": preliminary results from a survey of dry stone walls on the National Trust Estate at Malham. In: White, R. & Wilson, P. (eds), *Archaeology and historic landscapes in the Yorkshire Dales.* Yorkshire Archaeological Society Occasional Paper No. 2, 173-186.

Lund, J. & Southwell, C. 2002. *An archaeological monitoring report for the Great Langdale valley.* National Trust.

Parker, A. G., Anderson, D. E. & Boardman, J. 1994. Seathwaite valley: buried organic deposit. In: Boardman, J. & Walden, J. (eds), *Cumbria: Field Guide.* Quaternary Research Association, Oxford, 146-151.

Pearsall, W. H. & Pennington, W. 1973. *The Lake District: a landscape history.* Collins, London.

Raistrick, A. 1946. *The story of the Pennine walls.* Dalesman, Clapham.

Rollinson, W. 1972. *Lakeland walls.* (2nd edition). Dalesman, Clapham.

Rollinson, W. 1998. *Making drystone walls.* Smith Settle, Otley.

Whyte, I. 2003. *Transforming fell and valley: landscape and Parliamentary enclosure in north west England.* Centre for North-west Regional Studies, University of Lancaster.

Winchester, A. J. L. 2016. *Dry stone walls: history and heritage.* Amberley Publishing, Stroud.

Wild, C., Wells, C., Anderson, D, Boardman, J. & Parker, A. 2001. Evidence for Medieval clearance in the Seathwaite valley, Cumbria. *Transactions of the Cumberland and Westmorland Antiquarian and Archaeological Society* 1 (3rd series), 53-68.

Wilson, P. 2010. *Lake District Mountain Landforms.* Scotforth Books, Lancaster.

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