Geomorphological Assessment of Bedshiel Kaims

Report No: F02LJ24

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Preface

Background

The Geological Conservation Review (GCR) documents the most important earth heritage sites in Britain. A small number of new sites continues to be added to the GCR each year once their national significance has been established. Bedshiel Kaims is a prominent esker located at Greenlaw Moor, Berwickshire. The aim of this study was to prepare an initial assessment of the geomorphological significance of the esker as a candidate for inclusion in the Quaternary of Scotland site network of the GCR.

Main findings

The Bedshiel Kaims is assessed to be of high scientific and conservation value and should be considered for inclusion in the GCR.

- It is the best example of a single-ridged, upland esker in Scotland. It is largely undisturbed by quarrying and complements the existing esker landforms in the GCR site network, which comprise multiple, branching ridges.
- A unique aspect of the Bedshiel esker is its close association with subglacial meltwater channels of the same age. The spatial continuum of these landforms provides clear evidence of waning discharge and sediment carrying capacity due to changes in subglacial bed slope.
- Unlike the larger esker systems at Carstairs and Kildrummie, which accumulated during the more advanced stages of glacier melting in valley bottoms, the Bedshiel esker documents the early stages of englacial and subglacial meltwater drainage.
- A number of research questions about the esker and its role in subglacial meltwater drainage remain imperfectly answered and therefore highlight its value for further scientific research and demonstration purposes.

Introduction

A single 4km long gravel and sand esker, locally known as "The Kaims", forms a simple meandering ridge that stretches across Dogden Moss and Polworth Moss on the south slopes of the Lammermuir Hills in Berwickshire (Figure 1). Unusually for a geomorphological feature "The Kaims" has been clearly identified on Ordnance Survey maps, probably due to its very striking morphology (Figure 2). Indeed, Gregory (1926) summarized the feature as "…the most remarkable… [kame]… in southern Scotland…". It has been cited in previous literature as one of a number of glacifluvial landforms in the region (Geikie 1863; Stevenson 1868; Goodchild 1899; Carr 1938) and has received more detailed attention from McGregor (1974). The esker is unusual in the Scottish, and to some extent British, glacial landform legacy in that it is a single ridge feature. Most eskers in Britain are composed of multiple or anabranched ridges (e.g. Auton 1992; Gordon 1993a, b; Gordon & Auton 1993; Merritt et al. 1995; Thomas & Montague 1997). The esker also occupies an upland site, on the northern flank of the Tweed, documenting subglacial or englacial drainage within the marginal ice of the Tweed Valley ice stream of the last (Dimlington Stadial) ice sheet (Clapperton 1971).

Description

The Bedshiel "Kaims" esker occupies a 2km wide col on the southern slopes of the Lammermuir Hills, lying between the local slopes of Dirrington Little Law to the north and Greenlaw Moor to the south. The low lying terrain between these two

upland areas is a relatively featureless moorland called Dogden Moss and Polworth Moss. "The Kaims" rises from this moorland up to a maximum height of 15m and constitutes a striking local feature (Figure 3); a ridge that meanders across the moorland for more than 4km with side slopes as steep 45°. It rises abruptly in the west at [NT 678504] and terminates at a series of low amplitude knolls in the east at [NT 711512]. The limited extent of the esker, specifically the fact that it was restricted to the col, was regarded by Carr (1938) as unusual for eskers in the region. Except for two 500m straight sections to the east of Fangrist Burn, the esker meanders relatively tightly. The straight sections are notable also in that they are composed of flat-ridges as opposed to the undulatory long profiles of the rest of the esker. Gregory (1926) refers to specific names for different parts of the esker, thereby explaining the use of the plural on Ordnance Survey maps. Specifically, the easternmost 4.5-9m high sector is called the "Horse Kaim". Moving west, the next 200m is called the "Green Kaim" and has a relatively consistent height of 12m along its entire length. Between the sharp bend and the Fangrist Burn is the 7.5-9m high "Covert Kaims". West of Fangrist Burn lies the "Long Kaim" which varies from 3-9m high and meanders more tightly than the rest of the kaims. The esker is continuous except for short breaks where local streams have broken through during postglacial times. The largest of these breaks is where Fangrist Burn drains Dogden Moss southwards into Blackadder Water. This particular breach would have brought to an end a period of localized drainage damming by the highest and most continuous section of the Bedshiel kaims. Prior to the breakthrough by Fangrist Burn, local slopes and streams fed sediments into the depression lying to the north of the esker ridge. This has given rise to the accumulation of sediments and peat in the depression.

At its eastern end, the esker has been quarried but the excavation, located in one of the small subsidiary knolls, has now been completely re-vegetated. Very few natural exposures are available but the constituent sediments can be viewed in numerous sheep rubs. They are characterised by poorly sorted sandy gravels with numerous large calibre boulders. Most clasts are rounded to well rounded in form and dominated by sedimentary lithologies. Stevenson (1868) refers to the gravel being derived from Silurian and Devonian rocks to the west and northwest. He also describes the sand and gravel at the site as being stratified in chaotically inclined strata, and notes that the esker sediments appear to fine eastwards. Gregory (1926) describes a stratigraphy at the breach by the Fangrist Burn that comprises Old Red Sandstone bedrock overlain by till and then sands and gravels. He also cites evidence of a pit in the Long Kaim in which variably dipping beds of sands and gravels display an overall fining-upwards trend but with no cyclicity. Many of the boulders that he documented at the pit were of Dirrington Law felsite, located to the north and northwest. However, Gregory noted that no felsites occurred at the western end of the Long Kaim, the clast lithologies there being Silurian grit (60%), Old Red Sandstone (36%), Silurian slate (2%) and basalt (2%).

McGregor (1974) undertook clast form analysis on the gravels of the esker at Bedshiel. The sphericity of greywacke and sandstone clasts showed no trends with distance along the esker. However, clast roundness values for both lithological types rise in an easterly direction. The trends in clast lithological content reveal a general decrease in sandstone and increase in greywacke clasts (>20mm) from west to east but an abrupt reversal of that trend at the easternmost end of the esker.

A small meltwater channel extends from the eastern end of the esker for a distance of a few hundred meters around the northern slopes of Kyles Hill. Further meltwater channels were mapped by McGregor (1974), many of which are presently occupied by modern streams (Figure 4). A large meltwater channel runs from Westruther Mains and Cammerlaws southwards to Hexpath and south-eastward to Greenlaw but has no obvious connection with the esker. A large spread of glacifluvial sediment (kame) was mapped by McGregor (1974) on the east flank of the meltwater channel, on west Dogden Moss. Between Halliburton and Hexpath the channel contains some small esker fragments which connect with a spread of glacifluvial (kame) deposits. McGregor (1974) also identifies a shallow channel beneath the peat and running parallel to the southern slope of Dogden Moss. To the east of the esker a large meltwater channel is now occupied by upper Langton Burn and connects with a system of large meltwater channels and glacifluvial landform assemblages around Raecleugh Head. The Bedshiel esker does not clearly link to any of these features and McGregor (1974) consequently provided alternative interpretative scenarios with respect to subglacial channel occupation and channel network evolution.

Interpretation

Stevenson (1868), as was fashionable amongst diluvialists of the period, preferred a marine origin for the "The Kaims", and proposed that it accumulated as a spit. A glacial origin for the kames and eskers of Berwickshire was preferred by Goodchild (1899) and a specific reference to the "The Kaims" at Bedshiel as being possibly the finest example of an esker in southern Scotland was made by Carr (1938). He proposed that the esker accumulated between two ice masses located on the southern slopes of the Lammermuir Hills. Gregory (1926) had previously preferred an ice-marginal kame origin for the feature rather than an esker, suggesting that it had accumulated along the margin of a glacier that flowed south from Dirrington Law. This was one type of kame that, according to Gregory, was produced wherever glacier advance had interfered with local drainage to produce a lake.

The lack of cyclicity or rhythmic depositional sequences in the esker, together with evidence of poor sorting and large calibre boulders in otherwise sandy gravels, indicates rapid deposition by a short-lived high discharge meltwater event. Additionally, the occurrence of only one esker ridge suggests that the meltwater did not exploit other subglacial or englacial pathways or tunnels and so therefore did not persist for long. The lack of associated glacifluvial forms at the two ends of the esker suggests that it marks the location of a single tunnel within the former glacier. It is possible that the tunnel opened out at both ends into large ice cavities but there is no sedimentary evidence for this in the landscape (see below).

Although the west to east rising trend in clast roundness values reported by McGregor (1974) is statistically insignificant, it does however indicate a west to east transport direction. The decrease in sandstone and increase in greywacke clasts from west to east indicates that the sandstone clasts were subject to a greater degree of wear during transport and hence a greater proportion of greywackes were sampled in the >20mm size range chosen by McGregor (1974). Clast fabrics undertaken by McGregor confirmed a west to east palaeocurrent direction.

McGregor (1974) identified a variety of glacifluvial landforms and sediments in the area around Bedshiel but could not find direct linkages between the esker and its surrounding features. However, the fact that glacifluvial deposition appears to have taken place at the same altitude (ca. 210m) over a distance of 10km prompted McGregor (1974) to suggest that the Bedshiel esker was part of an integrated subglacial and submarginal drainage network on the north part of the Merse. This was the location of the northern margins of the former Tweed Valley ice stream. The meltwater channel that runs south from the centre of the esker and carrying the present day Fangrist Burn is thought by McGregor (1974) to have been contemporaneous with the Cammerlaws to Greenlaw channel. He proposes two scenarios for the evolution of the Bedshiel esker: a) the blockage of the main channels, perhaps by ice creep south of Greenlaw, led to the deposition of extensive spreads of glacifluvial sediment at 210m on Dogden Moss and the switching of subglacial drainage, perhaps only for a short period, to produce the Bedshiel esker; b) the upper sections of the main channels around Westruther Mains and Cammerlaws drained directly across Dogden Moss to produce the esker because the lower stretches of the main channels between Halliburton and Greenlaws were not in existence. Sedimentation occurred in the subglacial tunnel over Dogden Moss because of a reduction in carrying capacity by the meltwater as it was forced upslope.

Intriguing research questions about the esker remain imperfectly answered. For example: why does such a prominent esker start and terminate so abruptly?; what is the significance of the very poorly sorted sediments in the esker?; why is the esker a single ridge feature?; does the esker record a single, abrupt pulse of meltwater drainage, perhaps from a decanting subglacial or marginal ice-contact lake located in the upland terrain that was being uncovered by early deglaciation to the northwest? These research questions reflect the high scientific value of the Bedshiel esker.

Although the esker ridge is relatively small compared to other esker systems in Scotland, it has a high conservation value because of its isolated location and its association with subglacial meltwater channels of the same age. It is the best example of a single-ridged esker in Scotland and is unique in the region in that it clearly links up with erosional glacifluvial landforms. Furthermore, unlike the larger esker systems at Carstairs and Kildrummie which accumulated during the more advanced stages of glacier melting in valley bottoms, the Bedshiel esker documents the early stages of englacial and subglacial meltwater drainage on the upper slopes of an ice stream draining the Scottish sector of the Dimlington Stadial ice sheet. Moreover, the spatial continuum of meltwater channels and esker provides clear evidence of waning discharge and sediment carrying capacity due to changes in subglacial bed slope. The landform is particularly valuable in that quarrying has resulted in only cosmetic changes to morphology. It therefore constitutes an excellent example of a single-ridged, upland esker that complements the existing esker landforms covered by the GCR in Scotland.

Conclusion

Despite its most conspicuous morphology and inclusion on Ordnance Survey maps, the esker at Bedshiel called "The Kaims" has received little attention in previous research on glacial geomorphology in southern Scotland. Because of its location on the southern flanks of the Lammermuir Hills and at the northern margin of the former Tweed Valley ice stream, the esker constitutes important evidence for the glacial meltwater drainage conditions during the Dimlington Stadial ice sheet glaciation. The most intensive research on the area by McGregor (1974) concluded that the esker forms part of an integrated subglacial or submarginal drainage network that developed during the downwasting of the northern margins of the Tweed Valley ice stream. He proposed two working hypotheses to explain the occurrence of the Bedshiel esker: 1) it accumulated during the early stages of subglacial drainage when the main meltwater channels in the area drained directly west to east from Westruther Mains and Cammerlaws across Dogden Moss; 2) it was produced when the major meltwater channels draining NW-SE and around Dogden Moss became blocked, perhaps by stagnant ice, south of Greenlaw, and subglacial drainage switched to a W-E direction across Dogden Moss. In both scenarios the esker sediments accumulated in the subglacial tunnel over Dogden Moss because of a reduction in carrying capacity by the meltwater as it was forced upslope.

The Bedshiel esker ridge has a high conservation value as the best example of a single-ridged esker in Scotland. It also complements the larger GCR esker systems at Carstairs and Kildrummie which accumulated during the more advanced stages of glacier melting in valley bottoms. The landform is particularly valuable in that quarrying has resulted in only cosmetic changes to morphology. Based upon its uniqueness and scientific value, the Bedshiel esker should be added to the GCR list of sites. A minimum site boundary should follow a nominal line just beyond the base of the ridge slopes.

Executive summary of scientific reasons for conservation value

The Bedshiel Kaims are regarded as of high scientific and conservation value and should be considered for inclusion in the GCR. Its scientific value can be summarised as follows:

- Unlike other esker systems covered by the GCR for Scotland, the Bedshiel esker is relatively small, and isolated.
- A unique aspect of the Bedshiel esker ridge is its close association with subglacial meltwater channels of the same age.
- It is the best example of a single-ridged esker in Scotland.
- Unlike the larger GCR esker systems at Carstairs and Kildrummie, which accumulated during the more advanced stages of glacier melting in valley bottoms, the Bedshiel esker documents the early stages of englacial and subglacial meltwater drainage.
- The spatial continuum of meltwater channels and esker provides clear evidence of waning discharge and sediment carrying capacity due to changes in subglacial bed slope.
- Localised quarrying has resulted in only cosmetic changes to esker morphology.
- The Bedshiel esker, as a single ridged, upland esker, complements the existing esker landforms covered by the GCR in Scotland.
- A number of research questions about the esker and its role in subglacial meltwater drainage remain imperfectly answered and therefore highlight its conservation value.

List of figures

Figure 1: Location and geomorphology maps of the Bedshiel Kaims. The map of Bedshiel Kaims and surrounding area was produced by S. B. Wilson, Department of Geography and Topographic Science, University of Glasgow. Aerial photographs, from 1988, were supplied by Scottish Natural Heritage in printed form. These were scanned using a desktop scanner and the digital images planimetrically rectified and georeferenced using ArcGIS software. Planimetric scale distortion in the aerial photographs was therefore corrected before mapping. Ground control for this process was

obtained from 1:10 000 scale Ordnance Survey digital data supplied by SNH. Place names on the maps were also taken from the OS 1:10 000 map. No other Ordnance Survey data were used to produce the map. All features mapped were digitised from the rectified aerial aerial photograph images, using ArcView 3.2 GIS. software.

Figure 2a: vertical aerial photograph of the Bedshiel Kaims showing the whole landform.

Figure 2b: oblique aerial photograph of the Bedshiel Kaims viewed from the west.

Figure 2c: oblique aerial photograph of the Bedshiel Kaims viewed from the east.

Figure 3a: view of Horse Kaim from the east.

Figure 3b: view from west along Green Kaim and Horse Kaim, showing flat-crested sections separated by isolated mounds.

Figure 3c: view from west along flat top of Green Kaim.

Figure 3d: view from west along the flat top of the central section of the Bedshiel Kaims in the vicinity of Fangrist Burn.

Figure 3e: view from east along Long Kaim.

Figure 3f: view from east along west end of Long Kaim.

Figure 4: Map of glacifluvial geomorphology in the area of the Bedshiel Kaims (from McGregor 1974). The buried channel on Dogden Moss is marked by the broken parallel lines.

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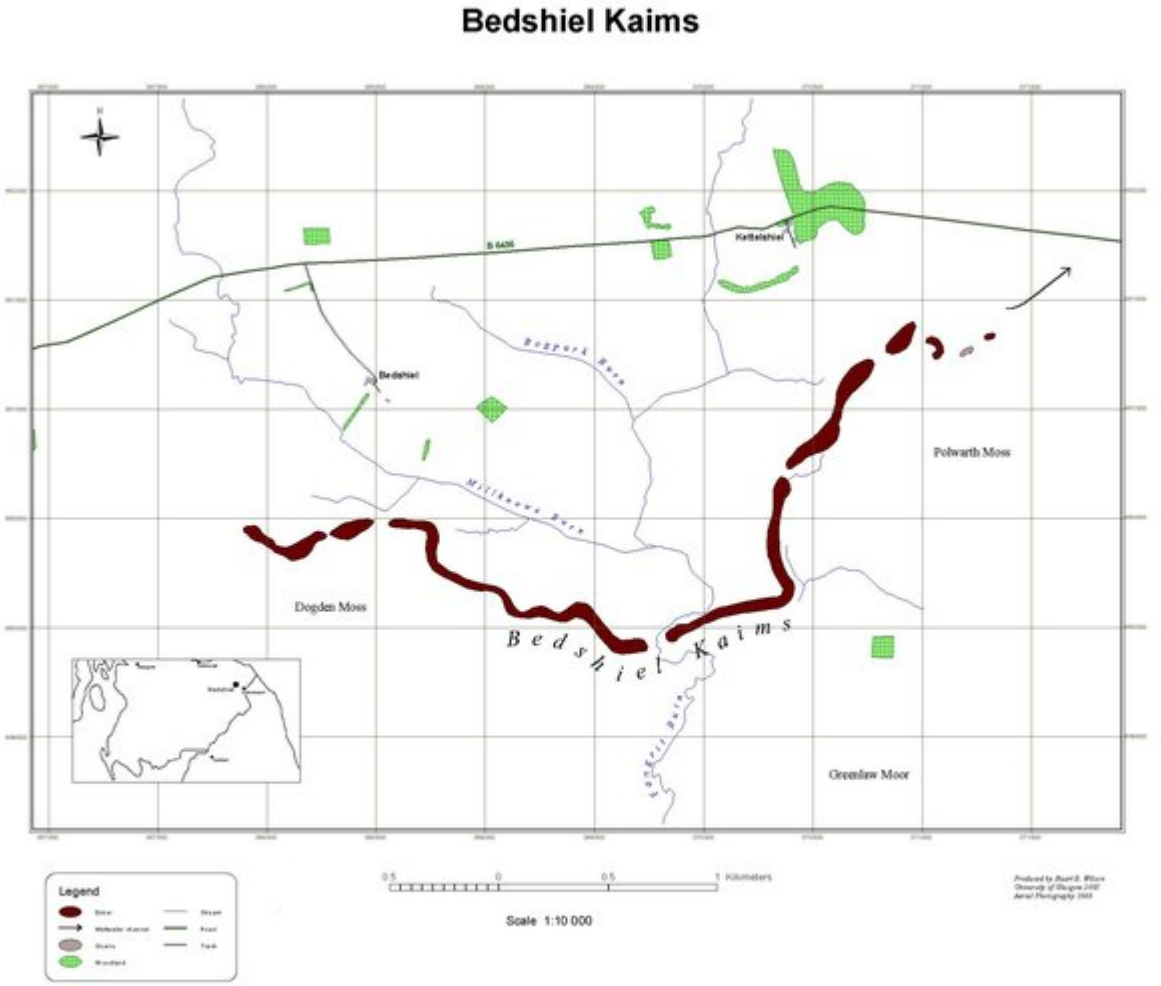

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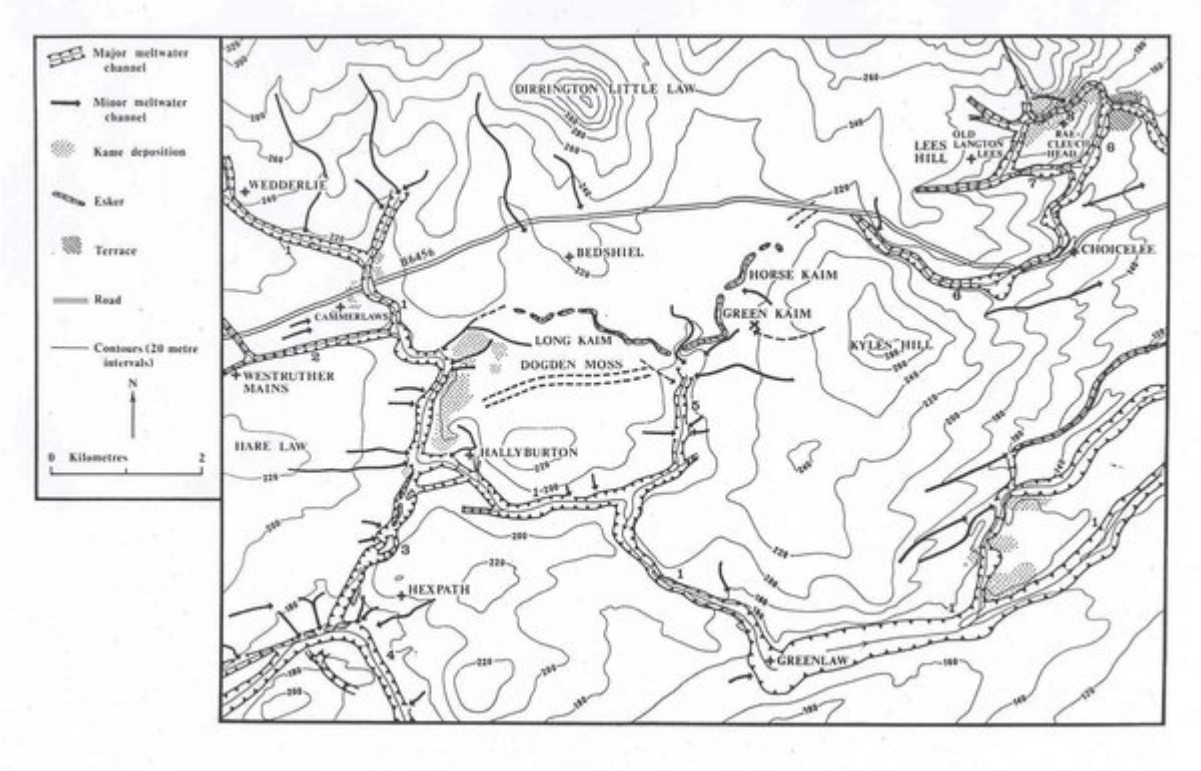

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