Newtondale and Hole of Horcum

[SE 820 930], [SE 845 935]

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Introduction

Newtondale and Hole of Horcum are both classic geomorphological features of importance to our understanding of Quaternary glacial and periglacial events in northern England. Newtondale is one of the largest and most spectacular glacial meltwater channels in Great Britain, forming a deeply incised, continuous channel for over 10 km across the North York Moors (Figure 5.50). The channel at Newtondale is also significant to the history of the development of geomorphological thought because of its role in the debate concerning the nature of ice dynamics during recession. Various origins have been proposed for the channel, including an overflow channel from a large Late Devensian pro-glacial lake and a subglacial channel pre■dating the Late Devensian. Kendall (1902, 1903) originally described the glacial lakes surrounding the North York Moors and their supposed drainage patterns. Other published accounts of the site include the description of Sewell (1904), and the re-interpretations of Smith (1932) and Gregory (1962a, b, 1965).

The nearby Hole of Horcum is a large amphitheatrical hollow cut into the North York Moors. Its origin is controversial, and mechanisms involving glacial meltwater, spring sapping and nivation have been proposed to explain its existence.

Description

Newtondale

Newtondale is a 10 km long meltwater channel crossing the main watershed of the North York Moors at 228 m OD (Figure 5.51). The channel is flat-floored and steep-sided for much of its length with a meandering channel pattern (Figure 5.52). The maximum depth of the channel is over 60 m at its head in the Eller Beck valley but the average gradient of the channel floor is low (1:1250). The altitude of the channel floor falls consistently southward along its length with no reverse (northward-facing) slope segments. At its southern end, the channel narrows before entering the Pickering Beck and draining into the Vale of Pickering. The southern extent of the channel is marked by a spread of gravel described by Kendall (1902) as a delta formed by meltwater entering Lake Pickering.

Hole of Horcum

The Hole of Horcum is a large amphitheatrical hollow cut into the flanks of the North York Moors to the east of the Newtondale channel. A long valley drains southward from the Hole of Horcum towards the Vale of Pickering.

Interpretation

Newtondale

Kendall (1902) identified numerous glacial lakes around the fringes of the North York Moors, including a large lake that he named Lake Pickering and several smaller ice-dammed lakes pinned against the northern flanks of the moors. Kendall's view was that during the Late Devensian glaciation, ice in the lowlands was wrapped around the upland area of the North York Moors but did not override them. Ice extended into Eskdale in the north but at its nearest was at least 8 km from Newtondale. Eskdale was blocked by ice at its eastern end and Kildale (NZ 60 09, 30 km west of Whitby) was blocked by ice at its western end, creating separate glacial lakes in both valleys. The large Kildale–Eskdale lake formed when sufficient meltwater was impounded to overtop the divide between the two valleys. This lake gradually expanded before finally overflowing across the North York Moors through Newtondale at the lowest point in the Cleveland anticline. Meltwater from Newtondale then collected in a larger lake, glacial Lake Pickering, which occupied the area to the south of

the North York Moors. Kendall's work had three central principles:

1. that glaciers decay actively;
2. that active ice margins provide impermeable barriers and that where ice sheets block natural lines of drainage ice-dammed lakes form;
3. that meltwater channels form on cols and spurs where there is drainage from ice-dammed lakes via overspill channels.

Kendall therefore regarded Newtondale as one such 'overflow' channel cut by meltwater draining these lakes. Overflow channels are essentially pro-glacial channels formed where water decants from ice-dammed or pro-glacial lakes over a col or low point in the topography. Spillways can be cut over a long period of time by regulated overflow water or by the catastrophic release of water during jökulhlaups. Kendall's original (1902) paper had a profound effect on British glacial geomorphology, primarily because he made a convincing argument that ice sheets were watertight and therefore could act as dams and allow the formation of lakes in valleys not actually occupied by ice.

Kendall's ice-dammed lake and overflow channel paradigm was accepted and reiterated by subsequent workers both in the immediate geographical area (Sewell, 1904; Elgee, 1908; Smith, 1932; Radge, 1939), and also in other areas of Britain (Charlesworth, 1926, 1955; Edwards, 1937; de Boer, 1945; Dean 1947, 1953; Williamson, 1952; Twidale, 1957). Subsequently, glacial lakes were envisaged to have occupied large areas of lowland Britain during deglaciation. These lakes include Lake Humber, Lake Fenland, and Lake Lapworth in north-west England (Jones and Keen, 1993). Other workers (e.g. Best, 1956) also embraced the concept of ice-dammed lakes in later accounts of the deglaciation of the North York Moors, although they began to question the relatively simple model of Kendall. Best (1956) recognized that two glaciations were required to account for the complex pattern of meltwater channels present in the area.

The 'overspill' theory eventually was challenged by Sissons (1958b, 1960b, 1961), who demonstrated that many of the meltwater channels identified as overspills were in fact sub-glacial in origin. Drawing on a growing body of literature from Scandinavia that stressed ice-sheet stagnation during recession, Sissons argued that glaciers need not decay actively and that ice need not provide an impermeable barrier to drainage. In a series of papers on the former ice-dammed lakes of the Scottish Highlands (Sissons, 1977, 1978, 1979a, 1982) he went on to establish more rigorous criteria for the recognition of ice-dammed lakes. These include the need for unequivocal evidence of former shorelines, deltas and lacustrine sediments.

Gregory (1962a, b) described the landforms of deglaciation in Eskdale and noted numerous lines of evidence in this area to support Sissons' theory of ice stagnation. Gregory (1962a, b, 1965) disputed Kendall's claims that Newtondale is an overspill channel through his study of the glacial lakes of Eskdale, to the north of the Newtondale channel. His work showed that much of the meltwater in fact drained sub-glacially to the north-east. Gregory (1965) noted that of the four lines of evidence used by Kendall to support the existence of a pro-glacial lake (overflow channels, lacustrine deposits, deltas and lake shorelines), there was little of this evidence to support the existence of a pro-glacial lake in Eskdale. This led Gregory to propose that although Newtondale is undoubtedly a meltwater channel, it is unlikely that it was created purely by overflow of an Eskdale–Kildale glacier lake during the Devensian. Support for this theory comes from the gravel spread at the southern end of the channel. Catt (1977c) suggests that the size of this gravel spread is anomalously small and fine-grained to have resulted from the high discharge required to cut a channel the size of Newtondale. Catt (1977c) therefore argued that although Newtondale may have been used by meltwater during the Late Devensian, it was probably cut in a pre-Devensian glaciation. There is, however, no lithostratigraphical or chronostratigraphical evidence to prove this theory.

Since the 1960s, descriptions and interpretations of other meltwater channel systems in Great Britain have confirmed that channels can form in a variety of ways and that a number of different meltwater landforms exist (Clapperton, 1968, 1970, 1971a, b; Russell, 1995; Sambrook Smith and Glasser, 1998; Glasser and Sambrook Smith, 1999). This work has been supplemented by descriptions of glacial lakes in modern glacial environments. There is evidence that some of the criteria suggested by Sissons may be too rigid because the record of former ice-dammed lakes depends to a great extent on the nature and topographical setting of the lake (Bennett *et al.,* 1998). For example, ice-dammed lakes that occupy supraglacial positions are entirely capable of producing large spillways of the type originally envisaged by Kendall,

without leaving significant shorelines, deltas or lacustrine sediments (Bennett *et al.,* 1998). Newtondale is, however, still cited in modern textbooks as a good example of a 'spillway' (Benn and Evans, 1998).

Hole of Horcum

Several processes can be invoked to explain the large hollow at this site, including erosion by glacial meltwater, spring sapping and nivation. The first of these theories, glacial meltwater erosion, appears unlikely given the morphological dissimilarity between the Hole of Horcum landform and the adjacent Newtondale channel. Glacial meltwater may have helped to enlarge the valley downstream of the Hole of Horcum but it is difficult to see how this process could have cut the hole itself The role of spring sapping in the evolution of the landform is perhaps more important. 'Spring sapping' is the name given to the process of erosion where groundwater flow is concentrated in more permeable zones within bedrock (Summerfield, 1991). This encourages chemical weathering or dissolution of the bedrock, which, in turn, leads to an increase in hydraulic conductivity and a further increase in the rate of water movement. This positive feedback mechanism leads to headward erosion as the spring retreats by gravitational undermining and slumping of the slope. Spring sapping is favoured in situations where a permeable lithology overlies an impermeable lithology. This process can create large amphitheatre-like valleys known as 'steepheads' or 'pocket valleys' (Ford and Williams, 1989). These can be significant landscape features, measuring several kilometres across (Small, 1965; Issar, 1983).

The last of these possible processes is that of nivation, or snow-patch erosion. 'Nivation' is an all-encompassing term now used to describe the processes of weathering and transport that are accelerated or intensified by the presence of snow patches. These processes include intensive freeze–thaw activity, enhanced chemical weathering, slopewash, transport of debris by snow creep and accelerated solifluction through saturation of regolith downslope by melting snow (Thorn and Hall, 1980; Thorn, 1988; Ballantyne and Harris, 1994). Using modern examples in Greenland, Christiansen (1998a) concludes that the main nivation processes are backwall failure, sliding and flow, niveo-aeolian sediment transport, supra- and en-nival sediment flows, niveo-fluvial erosion, development of pro-nival stone pavements, accumulation of alluvial fans and basins, and pro-nival solifluction. Combinations of these processes are responsible for the creation of a number of erosional landforms, ranging from small hollows (Nicols, 1963), through medium size features (Nyberg, 1991; Caine, 1992; Raczkowska, 1995; Christiansen, 1996, 1998b) to nivation hollows tens of metres in size (Ballantyne, 1978; Dohrenwend, 1984; Rapp, 1984; Gullentops *et al.,* 1993).

Nivation processes operating in periglacial environments can, however, be augmented by large amounts of surface runoff in subaerial fluvial streams, especially in the summer months. This type of permafrost runoff has been invoked to explain the form of similar large landforms such as the dry valleys of the neighbouring Yorkshire Wolds (Cole, 1879, 1887; Mortimer, 1885; Lewin, 1969; de Boer, 1974). A particularly fine example of this is the chalk dry valley at Millington Pastures (Waltham *et al.,* 1997). Similar features occur in the chalk of southern England at the Manger (Paterson, 1977) and the Devil's Dyke (Small, 1962). These valleys may have been excavated by a combination of solifluction and subaerial fluvial action under periglacial conditions. Sediment removal and valley incision were aided by snow meltwater flowing over permafrost in the annual melt season.

Despite a long history of periglacial research in this country, however, Ballantyne and Harris (1994, p. 248) have commented that 'Relict nivation and cryoplanation landforms rank amongst the most inadequately documented of all periglacial phenomena in Great Britain'. The largest landforms attributed to nivation processes are the so-called 'nivation cirques' that have been mapped in upland Britain. Nivation cirques represent forms transitional between small-scale nivation hollows and mature glacial cirques and these features have been identified by various authors in the Cairngorm Mountains (King, 1968), on Skye (Birks, 1973), the Cheviot Hills (Douglas and Harrison, 1985) and the Ystwyth Valley in mid Wales (Watson, 1966).

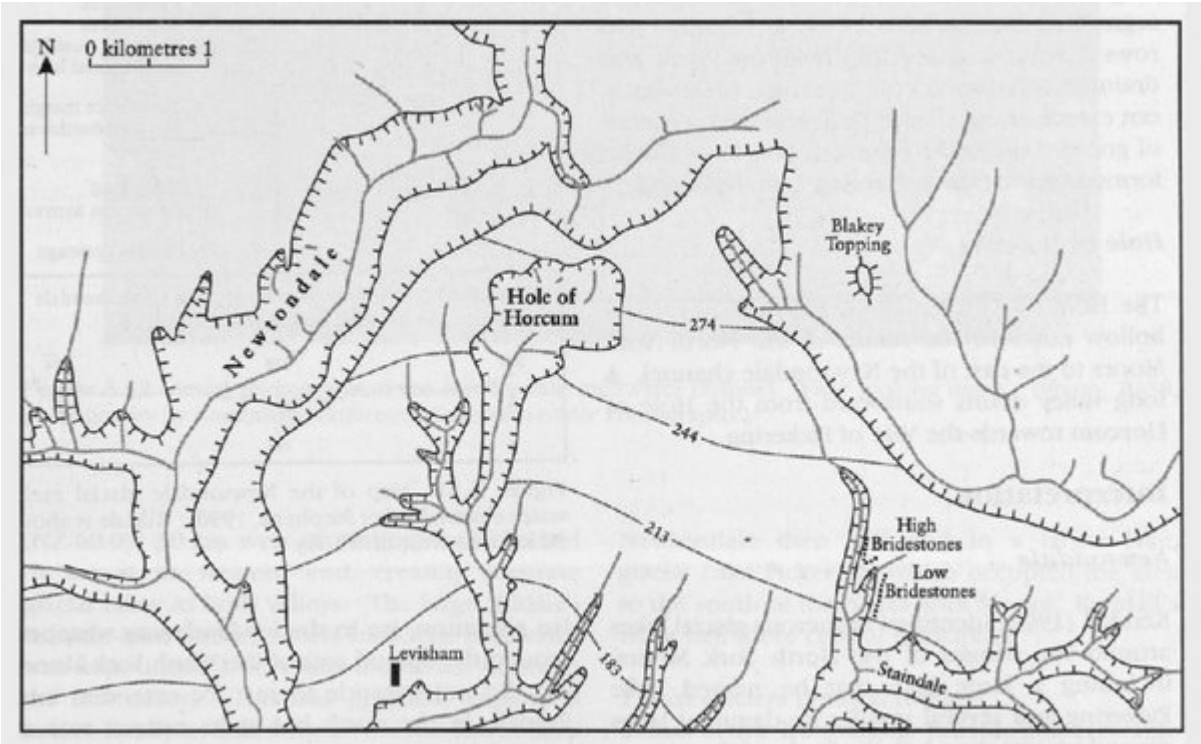
Ballantyne and Harris (1994) consider that many of the larger features mapped in upland Britain that often are attributed to nivation processes, such as cryoplanation terraces and nivation cirques, are in fact inherited features such as immature glacial cirques. Nivation cirques 300 to 500 m in diameter and up to 200 m deep would take prohibitively long time periods to form given the slow rates of nivation erosion (Thorn, 1976; Nyberg, 1991; Caine, 1992). The large, steep snow patches required to excavate such hollows would quickly turn to glacier ice, because there is a threshold length between snow patches and glaciers of 30–70 m from backwall to toe (Ballantyne and Benn, 1994). Finally, and perhaps

most conclusively, is the fact that the dimensions of these relict nivation cirques are an order of magnitude larger than active nivation hollows found in the present-day Arctic area. In light of the above, it appears unlikely that nivation processes alone are sufficient to account for a feature the size of the Hole of Horcum. These large features therefore are most probably pre-Pleistocene erosion surfaces or structural benches that have merely been modified by subsequent nivation and frost action processes. Alternatively, features such as the Hole of Horcum may represent immature glacial cirque forms occupied during the build up and decay of the Quaternary ice sheets.

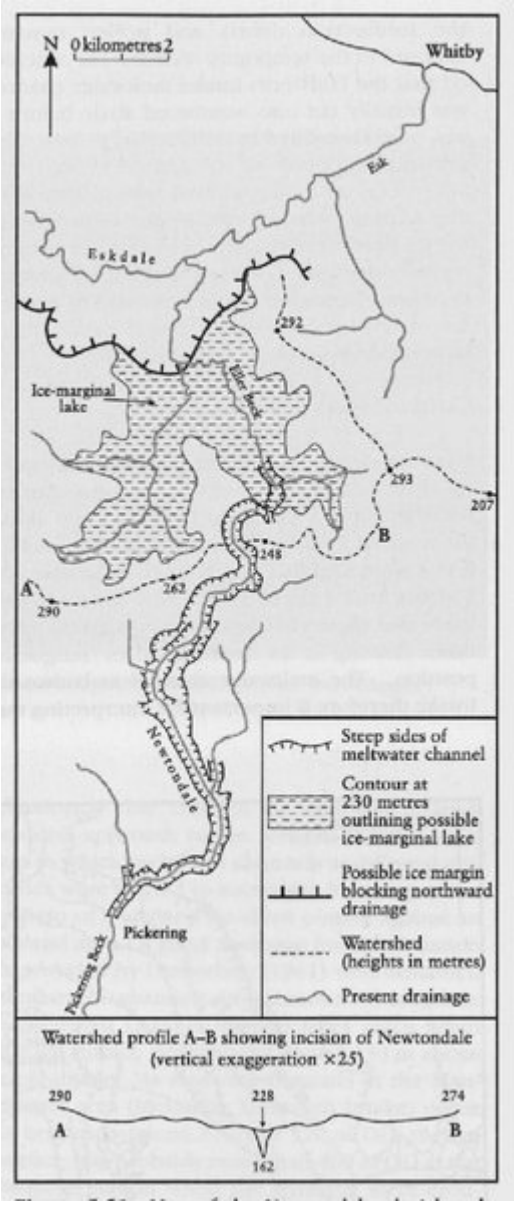
Conclusions

Together, Newtondale and the Hole of Horcum are important for interpreting the Quaternary history of North Yorkshire and for the study of glacial and periglacial processes operating in Britain during the Quaternary Period. Newtondale is a spectacular glacial meltwater channel created either as a spillway from a large ice-dammed lake or in a glaciation pre-dating the Late Devensian. Interpretation of the genesis of the channel is important because of the implications for the wider Quaternary history of this part of northern England, including the existence and stability of postulated ice-dammed lakes. The origin of the Hole of Horcum also is unclear, although it appears likely that the feature is an immature glacial cirque or a nivation hollow, possibly exploiting structural weaknesses in bedrock.

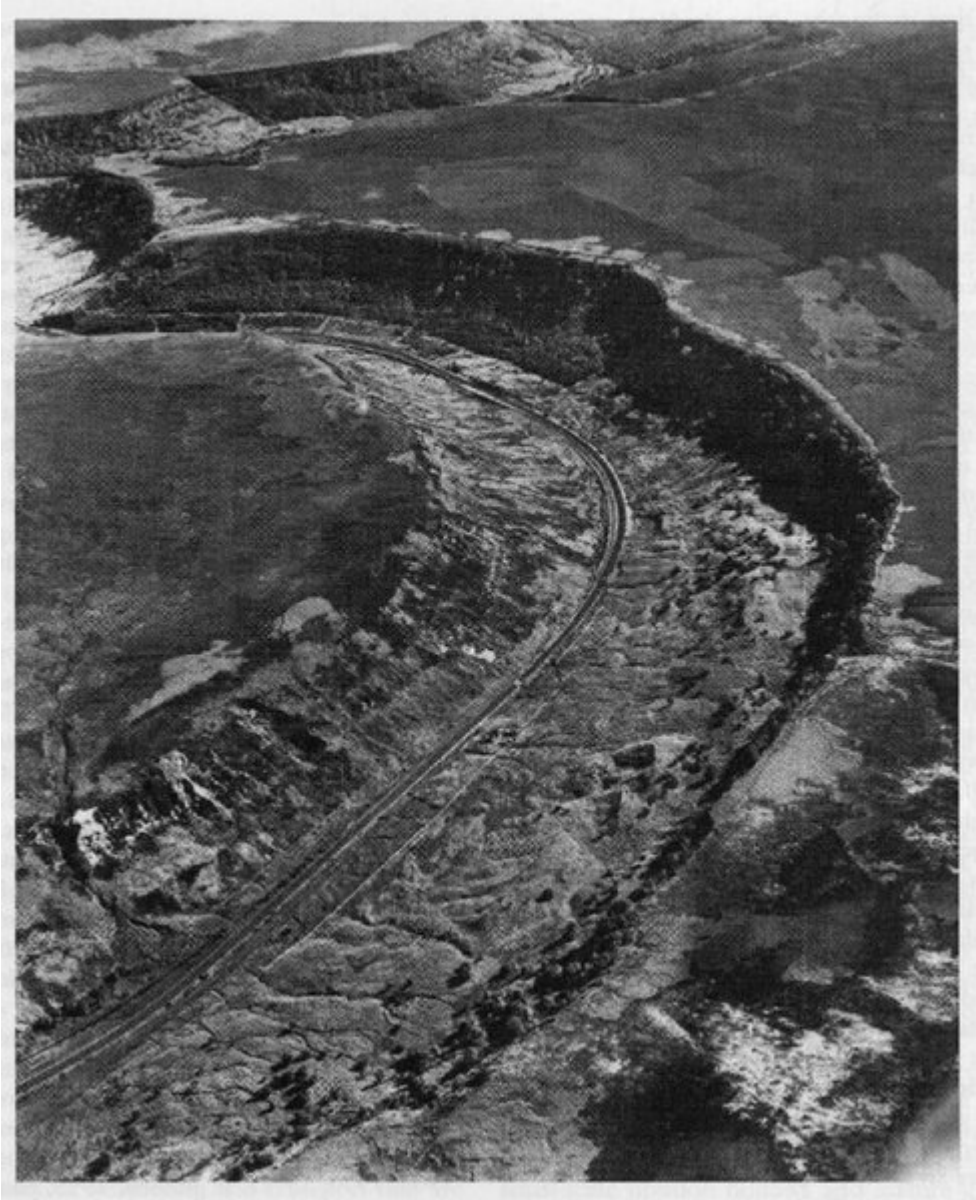
References



(Figure 5.50) Map of the southern part of the North York Moors showing the location of Newtondale, Hole of Horcum and the Bridestones (modified from Palmer, 1956).



(Figure 5.51) Map of the Newtondale glacial meltwater channel (after Stephens, 1990). Kildale is about 30 km due west of Whitby.



(Figure 5.52) Aerial photograph of the Newtondale meltwater channel. View looking north. (Photo: BA30, photography by Cambridge University Collection of Air Photographs.)