Langholm–Newcastleton Hills, Dumfries and Galloway and Scottish Borders

[NY 423 901]–[NY 452 940]

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Introduction

The earliest phase of volcanic activity in the Northumberland, Solway and Tweed basins is probably Courceyan (early Tournaisian) in age and occurs stratigraphically at the base of the Lower Border Group, where it is represented by both the Birrenswark Volcanic Formation and the Kelso Lavas (see Lintmill Railway Cutting GCR site report) (Figure 3.2). Other than a minor occurrence of basaltic lava and tuff at Craiglockhart Hill in Edinburgh, these are also the earliest known examples of Dinantian volcanism within the Carboniferous–Permian Igneous Province of northern Britain.

The Langholm–Newcastleton Hills GCR site is located approximately 7 km north-east and 5 km north-west of the towns of Langholm and Newcastleton respectively. It exposes a representative section through the Birrenswark Volcanic Formation, consisting of up to 90 m of basaltic lavas with thin intercalations of reddened siltstone and sandstone. The formation extends from Annandale eastward for about 22.5 km, to the north of Newcastleton, and takes its name from exposures on Birrenswark Hill [NY 185 787], several kilometres to the west of the GCR site. However, as the level of exposure and range of lithologies and structures there are comparatively poor, this site has been selected in preference (Figure 3.9).

Though these volcanic rocks received passing mention in Teall (1888) and Geikie (1897), they were referred to as contemporaneous 'porphyrites' of Early Carboniferous age on the one-inch scale primary geological map of the area (Langholm, Sheet 11, 1883), and described as the 'volcanic rocks of Tarras Water and Birrenswark' by Peach and Horne (1903). McRobert (1920) outlined the distribution and nature of these rocks, and fuller accounts, particularly of the petrography, were given by Pallister (1952) and Elliott (1960). Details of the Birrenswark Volcanic Formation were included in the Geological Survey memoir (Lumsden *et al.,* 1967). Leeder (1974) discussed the lavas in some detail in relation to the origin and overall development of the Early Carboniferous sedimentary basins. More recently, the petrology and geochemistry of these rocks have contributed to wider-ranging studies of the genesis of magmas in this tectonic setting by Macdonald (1975) and Smedley (1986a,b, 1988a).

Description

The Langholm–Newcastleton Hills is a poorly defined area of upland situated between Eskdale and Liddesdale in the foothills of the Southern Uplands. The area covered by the GCR site contains peaty moorland and rough hill grazing with incised river valleys and erosional gullies on the principal escarpment. The Birrenswark Volcanic Formation forms a persistent bench-like feature along the scarp slopes on the eastern side of the valley of the Tarras Water (Figure 3.10).

In the GCR site, the Birrenswark Volcanic Formation overlies Upper Old Red Sandstone (ORS) facies rocks unconformably, though elsewhere the volcanic rocks rest directly on base ment rocks of Silurian (Wenlock) greywackes, siltstones and mudstones. The ORS facies sequence, now designated the Kinnesswood Formation, is dominated by red, cross-bedded sandstones, but a distinctive compact, light-grey-brown, calcareous sandstone overlain by 1.2 m of red calcareous mudstones, immediately underlies the lavas in Kapleston Sike [NY 4409 9203]. Similar sandstone beds are also present below the base of the lavas in the Tod Sike section at NY 4284 9061. These rocks are believed to have been deposited as fluvial sediments in a hot and semi-arid environment (Leeder, 1971, 1974). The basalts are succeeded by a sequence of predominantly fine- to medium-grained arenaceous strata that is over 300 m thick in the Langholm district, where it is known as the Whita Sandstone Formation' (Nairn, 1956, 1958; Lumsden *et al.,* 1967). Conglomerates within the lower parts of this sequence contain basalt clasts.

In the Langholm–Newcastleton Hills the Birrenswark Volcanic Formation comprises a sequence of olivine basalts and hawaiites, with a maximum composite thickness of just over 61 m (Lumsden *et al.,* 1967). However, Leeder (1974) has demonstrated considerable variation over the whole outcrop: the basalts may be up to 90 m thick but are absent locally west of Langholm. Individual basalt sheets, interpreted as lava, are generally less than 30 m thick and may be massive, amygdaloidal or glassy. Many parts are vesicular and vein breccias are a characteristic feature of some flows. Thin reddened carapaces occur on some lavas and, rarely, lateritic palaeosols are developed on the upper surfaces. Sedimentary intercalations of reddened siltstone and sandstone are present locally. Most exposures are extremely weathered, and spheroidal weathering is common.

The better sections through the formation were described by Lumsden *et al.* (1967). Three of these, at Tod Sike [NY 4294 9070], Howgill Hill [NY 4365 9190] and Hartsgarth Fell [NY 4470 9350], fall within the GCR site (Figure 3.9).

Tod Sike

In Tod Sike, on the south side of Cloak Knowe, there is intermittent exposure of 24.4 m of highly weathered basaltic lavas. There are probably several lavas or lava-flow units present, perhaps up to seven, though the tops and bases of these are often difficult to distinguish. Only two flows can be identified with any confidence. These are an olivine-microphyric basalt with a few scattered feldspar phenocrysts ('Dalmeny' type of MacGregor, 1928) that occurs at the base, and a glassy, macroporphyritic olivine basalt with phenocrysts of both feldspar and olivine ('Markle' type) that occurs higher in the sequence. Lumsden *et al.* (1967) recorded the presence of a single thin sedimentary intercalation some 18.3 m above the base of the section, but did not give further lithological details.

Howgill Hill and Kapleston Sike

A 22 m-thick complete section through the Birrenswark Volcanic Formation is exposed in the stream section of Kapleston Sike on the north-eastern side of Howgill Hill (Figure 3.9). Four lavas are present, ranging in thickness from 3.66 m to 7.32 m. All are deeply weathered and red-stained, amygdaloidal olivine-microphyric basalts ('Dalmeny' type), but the middle two flows may be distinguished by their glassy and compact nature. A thin sedimentary unit comprising 1.5 m of red silty sandstone separates the top two lavas.

Around Howgill Hill the basal lava forms a strong, readily mapped feature. The flow forming this feature is a highly weathered olivine- and feldspar-microphyric basalt ('Jedburgh' type) which does not appear to be represented in the Kapleston Sike section.

Hartsgarth Fell

North of Kapleston Sike the lavas crop out along Kapleston Hill and extend into the deep valley at the head of the Tarras Water under Hartsgarth Fell. There are several excellent sections here and the formation is about 29 m thick. The basal flow is a 7.6 m-thick, coarse-grained, olivine-clinopyroxene-plagioclase-macrophyric basalt ('Dunsapie' type). As elsewhere, the rest of the succession is dominated by olivine-microphyric basalts ('Dalmeny' type), some of them glassy, and at least three flows have been identified. A thin sandstone unit up to 0.6 m thick, overlies the lowest 'Dalmeny'-type flow.

Although the sections described above are relatively close to one another, exact correlation between them is difficult. For example, the different types of lava at the base of each section clearly demonstrate a considerable degree of overstep of various early flows by later olivine-microporphyritic types. Sections around Watch Hill [NY 436 908] also show this contrast in basal flow types.

Numerous volcanic necks and attendant intrusions are associated geographically with the more easterly outcrops of the Birrenswark Volcanic Formation. They cut Lower Carboniferous strata up to the level of the Glencartholm Volcanic Beds (see River Esk, Glencartholm. GCR site report) and so it is clear that many have no possible connection with the Birrenswark Volcanic Formation. However, it has been suggested that the large Strait Hill–Cooms Fell Neck [NY 433 899] may have been one of several in the near vicinity that erupted the basalts of the Birrenswark Volcanic Formation

(McRobert, 1920; Elliott, 1960; Lumsden *et al.,* 1967; (Figure 3.9)). Here, pyroclastic breccia, in an outcrop approximately 350 m by 400 m, is intruded by a small plug of olivine-augite-microphyric basalt that does not match any of the lavas within the GCR site. Other examples within the GCR site occur on the south-west flank of Watch Hill [NY 433 904] and to the south of Howgill Hill [NY 436 916]. The necks mainly comprise unbedded basaltic tuff and pyroclastic breccia containing clasts of igneous rock, especially much decomposed basaltic glass and olivine basalt; there is also a variable proportion of sedimentary rock debris. The intrusions are usually plug-like bodies of basalt or dolerite that are compositionally similar to the lavas. The Howgill Sike Plug, which intrudes the Howgill Hill Neck, is larger than that of Strait Hill. It is a porphyritic basalt with zoned, partially resorbed phenocrysts of plagioclase and corroded phenocrysts of augite and olivine. Orthopyroxene and spinet are rare components of both the Strait Hill and Howgill Sike plugs, though it is unclear whether these are partially resorbed high-pressure phenocrysts, or xenocrysts, derived from disaggregating lherzolite inclusions carried in the magma from deep crustal levels (Upton, 1982).

The basalts of the Birrenswark Volcanic Formation provide some of the best data on the earliest Dinantian phase of volcanic activity in northern Britain. Earlier field-orientated studies suggested that they are entirely basaltic. However, Smedley (1986a) referred to the lavas of the Birrenswark Volcanic Formation collectively as transitional basalt and hawaiite, and the sequence on Kirk Hill [NY 462 864] some 6 km to the south-east of the GCR site comprises mainly basaltic hawaiites and hawaiites. More evolved compositions have not been reported from the GCR site, but mugearite occurs elsewhere, for example at Middlebie Burn [NY 216 767] near Birrenswark. Both Macdonald (1975) and Smedley (1986a) have shown that the basalts of the Birrenswark Volcanic Formation, being relatively low in alkalis and predominantly hypersthene ± quartz-normative, are among the most transitional to tholeiitic of all the Dinantian volcanic sequences in northern Britain; only the Cockermouth Lavas are more tholeiitic. However, Smedley (1986a) also found that some of the basalts of the Birrenswark Volcanic Formation are nepheline-normative.

Interpretation

Eruption of the Birrenswark Volcanic Formation probably occurred during Tournaisian times, though the biostratigraphical evidence for this is far from certain (e.g. Elliott, 1960; Lumsden *et al.,* 1967; Chadwick *et al.,* 1995). A contrary view was put forward by Nairn (1956) who, in his study of the Lower Carboniferous rocks west of the River Esk, considered that the base of the Carboniferous System should be placed at the base of the sedimentary rocks overlying the Birrenswark Volcanic Formation. The Upper Old Red Sandstone facies rocks conformably underlying the volcanic rocks were formerly regarded as Late Devonian, but are now considered to be of Tournaisian age (Lumsden *et al.,* 1967; Day, 1970; Leeder, 1971). The succeeding sedimentary rocks are known to be younger than earliest Tournaisian age.

All of the lavas appear to have been erupted in a subaerial environment and there is no record of either pillow lavas or the development of hyaloclastites. Pahoehoe structures have not been seen and most lavas are probably as type; some show reddened oxidized tops and possible lateritic palaeosols (boles). Sedimentary inter-beds up to 10 m thick show that the volcanism was often punctuated by long periods of quiescence that allowed the establishment of localized fluvial and lacustrine systems. The number, thickness and composition of the lavas in any one section vary over comparatively short distances. This probably indicates that most of the lavas were small in volume, originating from a series of small volcanoes or fissures rather than from one large composite fissure system, in contrast to the extensive flood-basalts of the Clyde Plateau Volcanic Formation, for example (see Chapter 2). The overall form of the lava field appears therefore to be one of a shallow-dipping plateau that was constructed as a series of overlapping flows of restricted lateral extent.

The basalts of the Birrenswark Volcanic Formation are considered to be penecontemporaneous with the Kelso Lavas that crop out farther to the north-east (e.g. Eckford and Ritchie, 1939), but were almost certainly erupted as a geographically separate lava field. Nairn (1956) noted thinning to both the east and west from the type locality at Birrenswark. The conclusion of Lumsden *et al.* (1967) that the volcanic formation in the area east of Tarras Water, which includes the Langholm–Newcastleton Hills GCR site, does not thin significantly in any direction, has subsequently been shown to be incorrect. The most significant advance in our understanding of the palaeogeography of these times was made by Leeder (1971, 1974). He demonstrated, using isopachytes, that the volcanic formation thins overall to the north and northeast (Leeder, 1974). He also concluded that the succession thins south-west, but evidence for this is indirect and is based on thinning south westwards of the later Glencartholm Volcanic Beds into the Bewcastle anticline.

Leeder (1974) considered three hypotheses to explain the pattern of isopachytes. First, the current distribution could be the erosional remnants of a larger volcanic field of unknown extent. He thought this unlikely because of the conformable relationship between the lavas and overlying sedimentary rocks, and because basalt pebbles in the basal sedimentary rocks above the lavas are only present locally. His second hypothesis involved eruption from a line of fissures orientated along the line of maximum thickness. Though he considered this to be attractive, there is little support from the distribution of the volcanic necks, many of which are some distance from the maximum lava thickness. The third, and most likely, hypothesis is a relationship between the geometry of the lava pile and the pre-existing Upper Old Red Sandstone facies sedimentary basin, which is known to have had a south-west–north-east orientation (Leeder, 1974, fig. 4). Locally, within the basin, the lavas are absent and this may have been due to the presence of a palaeohigh. Leeder (1971) also concluded that emplacement of the lava field had a profound effect on sediment distribution in the area: prior to the eruptions the mean sediment transport direction was north-eastwards, but subsequently this changed to south-eastwards. However, such a change may be related more to the initiation of the Northumberland, Solway and Tweed basins and thus a change in basin geometry.

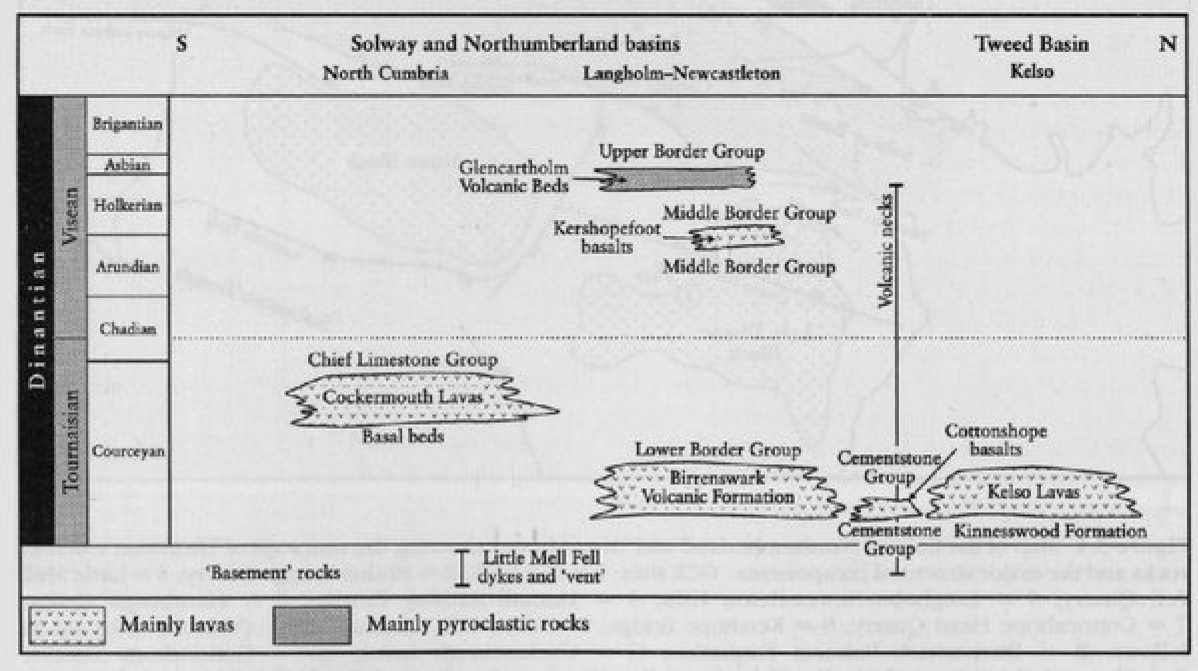
On a regional scale, the Birrenswark Volcanic Formation lavas are quite localized along the northern margins of the Northumberland and Solway basins, and are an integral part of the early basin development. According to some (e.g. Leeder, 1974), they probably do not extend far into the sub-surface beneath the basins, and Chadwick *et al.* (1995), in considering the seismic reflection data of Kimbell *et al.* (1989), pointed out that although there may be lavas at the base of the sequence elsewhere in the basins, there is no proof of this. A time interval of unknown duration is implied between emplacement of the last lava of the Birrenswark Volcanic Formation and deposition of the fluvio-deltaic sandstones of the Whita Sandstone Formation. As deposition of such thick sequences of strata requires the creation of considerable 'accommodation space', a significant degree of basin subsidence is implied, following the volcanism.

Conclusions

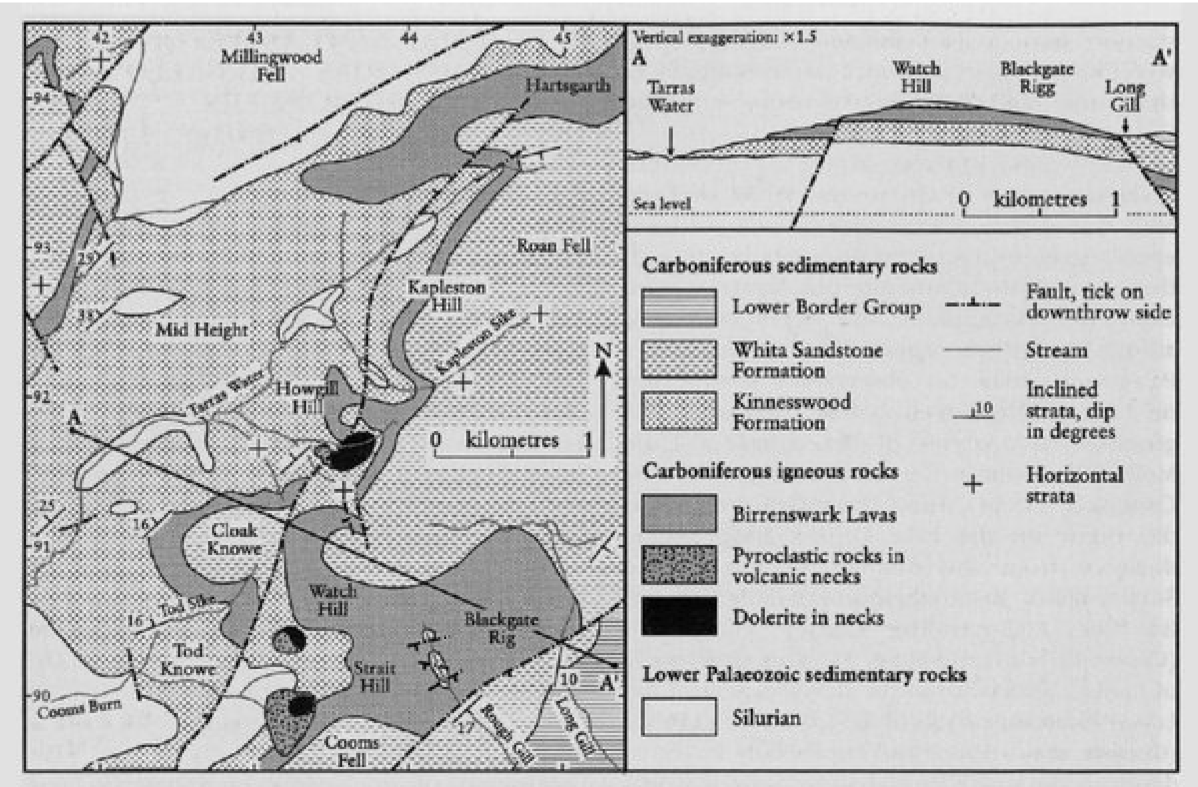
The Langholm–Newcastleton Hills GCR site is representative of the Tournaisian Birrenswark Volcanic Formation, a lava succession consisting of up to 90 m of basalt, basaltic hawaiite, hawaiite and rare mugearite. The GCR site neatly demonstrates many of the key features of the formation, including evidence for the structure of the lava field, form of flows, details of the rock-types present and the variations in local successions. Associated volcanic necks of tuff and pyroclastic breccia, intruded by basalt plugs, may have been the sites of eruption for some of the lavas. The conformable stratigraphical relationships with sedimentary strata above and below the lavas are particularly clear.

The lavas of the Birrenswark Volcanic Formation are an important feature of the Early Carboniferous development of the Northumberland and Solway basins and are among the earliest manifestations of volcanic activity within the Carboniferous–Permian Igneous Province of northern Britain. Their position in space and time clearly illustrates the close association of basic volcanism with the early phases of development of sedimentary basins. They have formed an integral part of petrological and geochemical studies of the igneous province and will continue to provide an important source of material for any such studies in the future.

References



(Figure 3.2) Stratigraphy of the volcanic rocks of the Solway, Northumberland and Tweed basins. The range of strata cut by intrusions and volcanic rocks is also shown. After Gawthorpe et al. (1989).



(Figure 3.9) Map and cross-section of the area around the Langholm-Newcastleton Hills GCR site. Based on Geological Survey 1:63 360 Sheet 11, Langholm (1968).

(Figure 3.10) View from the bank of the Tarras Water, towards the slopes of Cloak Knowe in the Langholm–Newcastleton Hills GCR site. Lavas of the Birrenswark Volcanic Formation form the distinct feature with scattered exposures midway up the slope; the lower slopes are till covered, and river terraces occupy the foreground. (Photo: K.M. Goodenough.)