Gill Beck, Cumbria

[NY 149 342]

D. Millward

Introduction

The Lower Carboniferous (Dinantian) Cockermouth Lavas are probably best displayed in the Gill Beck GCR site, south of Blindcrake and about 4.5 km north-east of Cockermouth (Figure 3.3). There, a sequence of basalt lavas, approximately 67 m thick, overlies basal Carboniferous conglomerates referred to formally as the Basal Beds. Above the lavas are bedded mudstone, limestone and sandstone at the base of the Chief Limestone Group. The Cockermouth Lavas are the only known example of effusive basaltic volcanism focused upon the southern hinge-zone margin of the Solway Basin. In general, the volcanic rocks are poorly exposed and this GCR site is especially valuable in providing good stream exposure.

The presence of amygdaloidal 'greenstones' in Gill Beck was recorded by the primary geological survey of the area during the 19th century, and the stream exposures are mentioned in accounts of the Cockermouth Lavas by Eastwood (1928), Eastwood *et al.* (1968), and Macdonald and Walker (1985). The GCR site is included within the British Geological Survey's 1:50 000 Sheet 23, Cockermouth (1997). The age of the Cockermouth Lavas is tightly constrained to the Courceyan (C.E. Butcher, pers. comm. in Mitchell *et al.,* 1978). This is indicated by the presence of CM Zone miospore assemblages in sedimentary rocks from the Chief Limestone Group overlying the lavas at Gill Beck. Nearby, exposures of the Basal Beds underlying the lavas have also yielded spores of the same zone.

The geochemistry of the Cockermouth Lavas has been described and interpreted by Macdonald and Walker (1985); a single whole-rock analysis from Gill Beck is cited by these authors. Tholeiitic andesite has been recognized within the sequence at Gill Beck and this has implications for the petrogenesis of the Cockermouth Lavas (Macdonald and Walker, 1985) (see Bothel Craggs Quarry GCR site report).

Description

The following description is based on the published accounts listed above. The lithostratigraphical nomenclature follows that used on the British Geological Survey's Sheet 23, Cockermouth (1997). The site consists of a stream section, within which the Carboniferous rocks dip gently to the NNW (Figure 3.3). The base of the lava succession is not exposed, though a small exposure of conglomerate is seen beneath its inferred position (Figure 3.4). The top of the succession is also not exposed, though mudstones and thin limestones near the base of the Chief Limestone Group are seen along the stream close to the highest exposure of the lavas (Eastwood, 1928). Here the Cockermouth Lavas are about 67 m thick.

On field maps in the British Geological Survey archive, T. Eastwood recorded the basalts as variably massive to highly scoriaceous. He described most of the rocks as compact to slightly amygdaloidal, but especially amygdaloidal and scoriaceous rocks are characteristic of the top and base of the flows; in some places he described the distribution of scoriaceous rock as 'haphazard' (Eastwood, 1928). Though vesicles are commonly distorted, there is little evidence for linear structures indicating directions of flow. The vesicles are mainly filled with carbonate or various forms of silica. The more massive rocks in the centres of the lavas are dark blue or grey and finely granular. Intercalations of pyroclastic or sedimentary rocks have not been recorded from the sequence, but the presence of at least four lavas may be inferred from the distribution of scoriaceous basalt within the section.

The petrography of the Cockermouth Lavas was first outlined by H.H. Thomas (in Eastwood, 1928; Eastwood *et al.,* 1968). The microcrystalline basalts typically comprise plagioclase, augite and iron oxide with variable amounts of olivine microphenocrysts; some rocks contain plagioclase and/or augite phenocrysts. Most of the rocks have ophitic or sub-ophitic texture, and in some of these the tabular plagioclase laths form a sub-parallel fabric; intergranular texture is seen sporadically. Geochemical analyses reported by Macdonald and Walker (1985) show that both basalt and andesite are present in the Gill Beck succession. They described the andesite from Gill Beck as aphyric and fine grained, comprising plagioclase laths, granular, partially serpentinized augite and abundant iron oxide; interstitial quartz, alkali feldspar and chlorite are also present. The plagioclase defines a marked flow texture in the andesite.

The basalts are noted for their pervasive secondary alteration. Olivine is entirely replaced by an aggregate of 'serpentine', chlorite, green mica, quartz, opaques and carbonate. The pyroxene is partially fresh in places, though it is normally altered to 'serpentine' and, in some cases, carbonate. The plagioclase is generally much fresher though it may be albitized or replaced by carbonate. Loveland and Bendelow (1984) reported celadonite-like grains in highly altered basalt nearby at Bridekirk; this was the first recorded occurrence of the mineral in England. Macdonald and Walker (1985) also noted that, as a result of the alteration, Ca-poor pyroxene has not been identified in these rocks even though its presence may be suspected by analogy with compositionally similar rocks in the Dinantian lavas of Derbyshire.

Despite the intense mineralogical alteration of the basalts, magmatic characteristics are retained, particularly with respect to the incompatible minor- and trace-element abundances (Ti, P, Zr, Nb, Ce, Y) (Macdonald and Walker, 1985). The Cockermouth Lavas have a relatively small range in silica saturation, attributable to magmatic processes rather than alteration. This is indicated by the negative correlation of the ratios Zr/Y and Nb/Y, and positive correlation of Zr/Nb with increasing silica saturation, which is typical of basalts as a whole. The basalts are quartz- and hypersthene-normative and may be described as quartz tholeiitic. Plots of incompatible elements show that the Cockermouth Lavas form a very coherent suite of genetically related rocks. However, the range of variation for some elements is very wide (e.g. Nb 9–32 ppm and Zr 70–258 ppm) (Macdonald and Walker, 1985).

Interpretation

The Cockermouth Lavas were considered to be of Ordovician age by J.C. Ward and J.G. Goodchild who made the primary geological survey of the Cockermouth area, late in the 19th century. These basalts were thought to be part of the same volcanic episode that produced the widespread Eycott and Borrowdale volcanic groups (at this time these two groups were included under the latter name). By contrast, a Carboniferous age was assigned to the more extensive conglomerate, now formally the Basal Beds. Exposures of the conglomerate, for example in Gill Beck, which are apparently located below the basalts, were considered to be faulted against the base of the basalts.

In re-surveying the area, Eastwood (1928) found that, although the junction is not exposed, the basalts undoubtedly overlie the conglomerates conformably. He then contemplated that if the lavas were Ordovician in age, the conglomerate must be of 'early Borrowdale age' and thus also Ordovician. However, the petrographical descriptions by H.H. Thomas (in Eastwood, 1928) showed that the basalts contain phenocrysts of olivine and thus differ markedly from the Eycott and Borrowdale volcanic group rocks. Eastwood noted that there are also other lithological differences between the volcanic rocks, but that the conglomerate has some similarity with the Mell Fell Conglomerate farther east in Cumbria. Considering these observations, Eastwood (1928) then proposed that the basalts are probably Carboniferous in age and should be designated as the Cockermouth Lavas. A Dinantian (Courceyan) age has since been confirmed from spore assemblages obtained from the sedimentary rocks, both beneath and above the basalts (C.E. Butcher, pers. comm. in Mitchell *et al.,* 1978).

The variably clinkery and scoriaceous character of the basalt sheets supports the widely held interpretation of these rocks as lavas. Furthermore, the occurrence in a stream [NY 128 327] to the north-east of Wood Hall of 'a roughly lenticular mass of red and green marl...interspersed with lumps of very rotten amygdaloidal rock' was interpreted by Eastwood (1928) to be bole-like, indicating subaerial weathering of the basalt. No evidence has come to light that contradicts this interpretation. However, in the absence of unequivocal evidence for the nature of the uppermost contacts of the sheets, it is possible that some sills may be present. One piece of evidence that may be pertinent to the method of emplacement of the sheets is described by Eastwood *et al.* (1968). Near Redmain, south-west of the GCR site, they reported that the upper zone of a basalt sheet is cut by narrow veins and irregular patches of dark-purple flinty material that die out downwards, while some appear to pass upwards into 'bole'. Eastwood *et al.* offered no explanation, but it is possible that these are sedimentary enclaves.

The apparent absence of volcaniclastic rocks from the sequence suggested to Eastwood (1928) and Macdonald and Walker (1985) that Carboniferous volcanism in the area was mildly effusive and perhaps from fissure-type vents. Possible eruption sites have not been identified in the field, though Eastwood *et al.* (1968) suggested that they lay to the west of the outcrop, and Macdonald and Walker (1985) inferred a fissure or series of vents along the outcrop. However, if the volcanism is associated with crustal extension and basin formation, then the hinge-line faults such as the Maryport and Gilcrux faults located to the north of the Cockermouth Lavas outcrop (Figure 3.1) must be considered as potential magma channels. Effusive to mildly explosive volcanism with extensive lavas is typical in extensional tectonic regimes such as in the Solway and Northumberland basins. The apparent absence of pyroclastic rocks from the subaerial Cockermouth Lavas does not necessarily indicate that none were erupted; any accumulated tephra deposits would have been localized as small cones, and would have been subjected to rapid erosion and possibly complete removal. Further, if the vents were located along the basin hinge-line fault system, then the present outcrop of the Cockermouth Lavas is at least 2 km from these, mostly well outside the depositional range for mildly explosive eruptions.

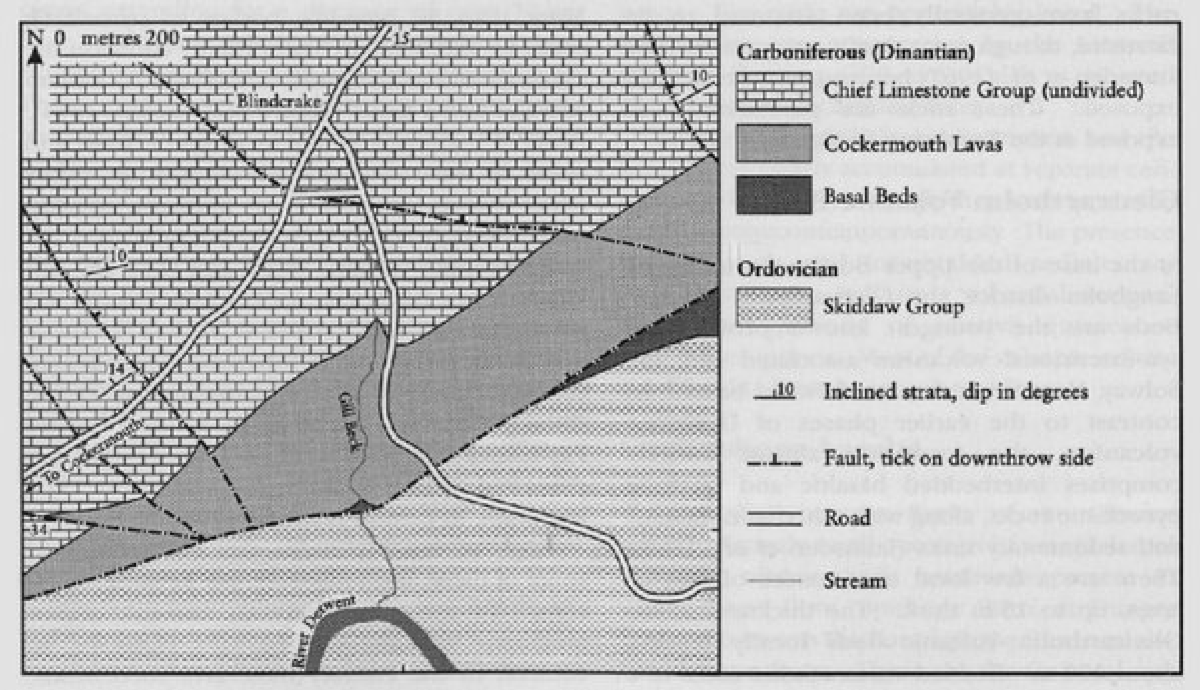
The Cockermouth Lavas are unlikely to represent primary basalts because of their characteristically low Mg numbers (100 × Mg/(Mg + Fe) 60). Furthermore, on the diopside–olivine–hypersthene–nepheline–quartz phase diagram, representing the crystallization of basaltic liquids, the normative compositions of the Cumbrian rocks plot close to the cotectic at 1 atmosphere. However, Macdonald and Walker (1985) argued that the basalts cannot represent a simple low-pressure fractionation series, because the levels of incompatible elements, such as Zr, Nb, P, Ce and Y, do not decrease systematically with MgO, which is used as an index of fractionation. On the contrary, the most magnesian rocks contain the highest levels of K, Ti, P and incompatible trace elements. Thus, in addition to low-pressure fractionation, the chemical variation in the Cockermouth Lavas must have resulted from variable amounts of partial melting, or from fractionation at higher pressures.

Macdonald and Walker (1985) concluded that the Cockermouth Lavas were probably generated from upper-mantle sources; immobile trace-element ratios such as Zr/Nb, Zr/Y and Ce/P_2O_5 do not suggest that the source region was heterogeneous. Macdonald and Walker (1985) also suggested that, like the Dinantian lavas of Derbyshire, compositional variations in the Cockermouth Lavas resulted from a two-stage process involving variable degrees of partial melting to produce parent liquids with a range of silica saturation, followed by low-pressure fractional crystallization, probably in the upper crust.

Conclusions

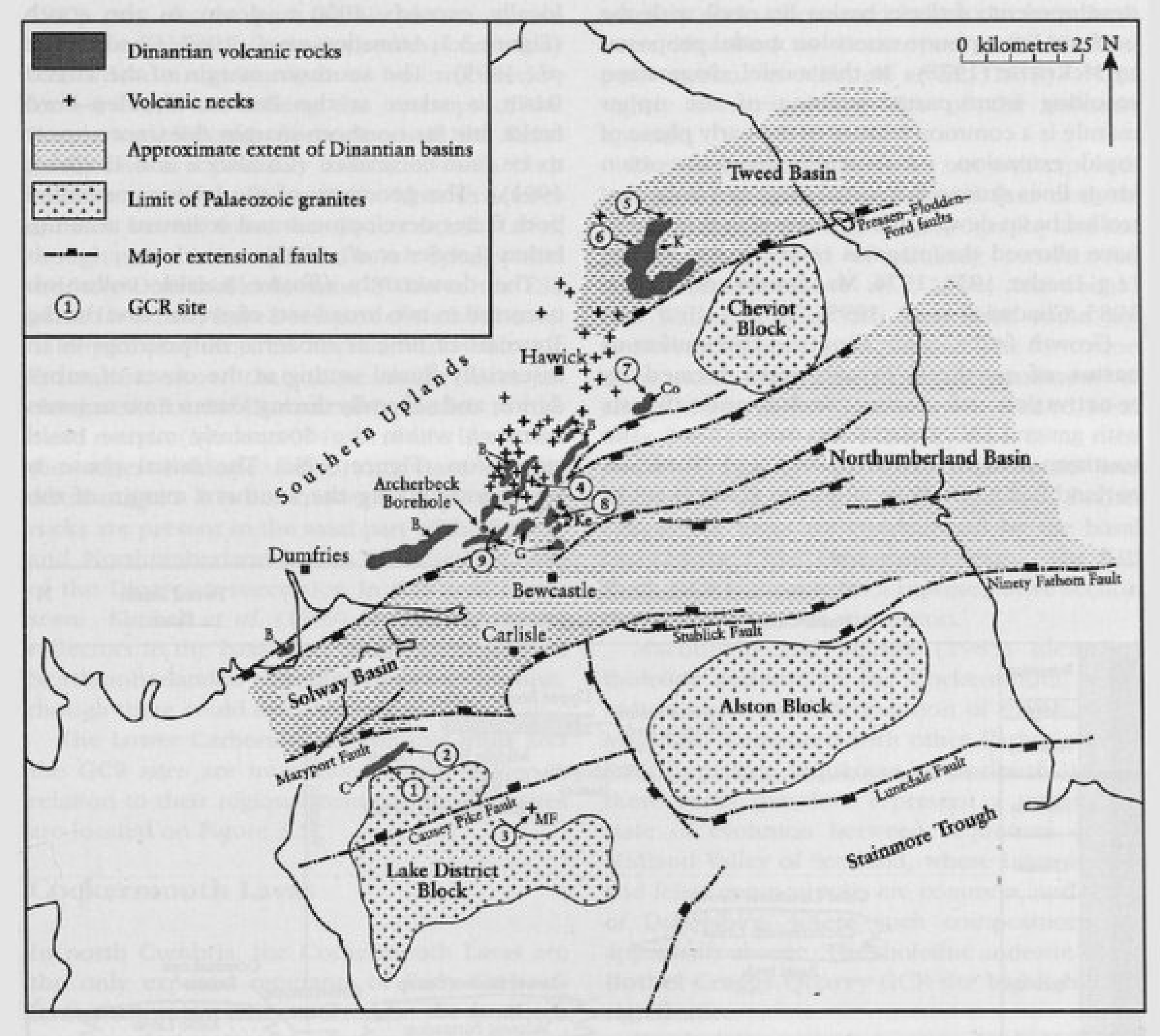
The Gill Beck GCR site is representative of the Tournaisian Cockermouth Lavas, the only exposed example of volcanic rocks of this age along the southern margin of the Solway Basin. The formation comprises tholeiitic olivine-phyric basalt and aphyric andesite, and is approximately 67 m thick. At least four lavas are present, but no pyroclastic rocks are preserved. The volcanic rocks conformably overlie conglomerates at the base of the Carboniferous succession in Cumbria (the Basal Beds), and are overlain by sedimentary rocks of the Chief Limestone Group. The basalt magmas are thought to have evolved through variable degrees of partial melting of upper-mantle source rocks, followed by moderate- to low-pressure crystal fractionation.

References



(Figure 3.3) Map of the area around the Gill Beck GCR site. Based on British Geological Survey 1:10 000 sheets NY 13 SE; and NY 13 SW (both 1991).

(Figure 3.4) An exposure of conglomerate, belonging to the Lower Carboniferous Basal Beds, below the base of the Cockermouth Lavas in Gill Beck. The hammer shaft is 40 cm long. (Photo: D. Stephenson.)



(Figure 3.1) Map of the Solway, Northumberland and Tweed basins showing the outcrops of Dinantian volcanic rocks and the major structural components. GCR sites: 1 = Gill Beck; 2 = Bothel Craggs Quarry; 3 = Little Mel Fell Quarry; 4 = Langholm–Newcastleton Hills; 5 = Lintmill Railway Cutting; 6 = Hareheugh Craigs; 7 = Cottonshope Head Quarry; 8 = Kershope Bridge; 9 = River Esk, Glencartholm. (Volcanic units are as follows: B = Birrenswark Volcanic Formation; C = Cockermouth Lavas; Co = Cottonshope Basalts; G = Glencartholm Volcanic Beds; K = Kelso Lavas; Ke = Kershopefoot Lavas; MF = Mell Fell Vent.) Information from published sources including Chadwick and Holliday (1991); Chadwick et al. (1995); Leeder (1974); and British Geological Survey (Tectonic map of Britain, Ireland and adjacent areas, 1996).