Barrow Hill, Dudley

[SO 911 896]

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Introduction

Barrow Hill, about 3 km west of Dudley, has been selected for its spectacular demonstration of complex inter-relationships between basalt and agglomerate of a volcanic vent, tuffs and volcaniclastic breccias deposited on the margins of the vent, and dykes of volcaniclastic material and basalt intruded into adjacent alluvial sedimentary rocks. The site is also of importance for the presence of the oldest anatomically preserved, conifer-like stems, which were buried by ash falls associated with eruptions from this volcanic centre.

The Barrow Hill Complex represents one of numerous small outcrops of igneous rocks of Westphalian age distributed widely across the West Midlands. The Barrow Hill GCR site is notable as it demonstrates explosive volcanic activity, whereas all the other outcrops, including the Clee Hill Quarries GCR site, are dolerite intrusions with no evidence of having reached the surface. The Barrow Hill GCR site occupies two disused quarries at Barrow Hill, described by Whitehead and Eastwood (1927) and Marshall (1942; 1946), and a clay pit located at Tansey Green, described by Galtier *et al.* (1992) and Glover *et al.* (1993).

Description

The Barrow Hill GCR site comprises a volcanic vent, located at Barrow Hill [SO 917 896], and volcaniclastic deposits at Tansey Green Clay Pit [SO 910 896] (Figure 7.14). The vent has a maximum dimension of about 400 m, broadly parallel to SW-trending faults, which mark the north-west and south-east margins of the vent. The volcaniclastic deposits occur interbedded with alluvial mudstones and sandstones of the Etruria Formation, which dip locally up to 30° to the south-west. These deposits are cut by several normal and reverse faults.

The Etruria Formation is of Bolsovian (Westphalian C) age (approximately 311 Ma according to Claoué-Long *et al.,* 1995) (Figure 7.2). The vent breccias and dolerite intrusions, which were emplaced in the lower part of the Etruria Formation, show such striking petrographical similarities to, and are so near to, the volcaniclastic deposits that the two are undoubtedly linked genetically and are of the same age. A K-Ar whole-rock date of 308 ± 10 Ma (*c.* 314 Ma using new constants) determined on a dolerite from Barrow Hill probably represents a close minimum for the true intrusive age (Fitch *et al.,* 1970).

Barrow Hill Vent

The quarries at Barrow Hill expose a fault-bound volcaniclastic breccia, very weathered and yellow-brown with large blocks of Etruria Formation and Coal Measures mudstones, coal clasts (up to 30 cm), rounded masses of basalt and rounded quartzite pebbles (up to 10 cm) in a tuffaceous matrix containing shards. Basalt forms pipe-like, markedly transgressive and commonly fault-bound intrusions within the vent agglomerates and the Etruria Formation country rock (Marshall, 1942, 1946). In the upper part of the main quarry [SO 9149 8958] a 1–2 m-thick sill extends from the basalt pipe and intrudes the adjacent vent agglomerate. The overall geometry of the intrusion has been complicated by post-intrusive faulting (Figure 7.14).

The basalt is typically fine grained and micro-porphyritic, containing abundant xenoliths. An example of an analcime-bearing olivine basalt was described in detail by Marshall (1946). Feldspar microphenocrysts, typically labradorite ($Ab_{35}An_{65}$) but with more sodic rims, are up to 0.5 mm in diameter. They commonly occur clustered around serpentinized olivine crystals up to 0.7 mm in diameter, or as single crystals showing flow alignment. The groundmass comprises small laths of labradorite-andesine ($Ab_{50}An_{50}$ to $Ab_{60}An_{40}$) showing flow alignment, granular and prismatic augite, granular magnetite and some interstitial analcime. A coarser-grained variation of this is characterized by the presence of relatively few xenoliths, a greater proportion of analcime, more prominent flow alignment of feldspar laths, and locally tends toward a sub-ophitic texture. Towards the contacts of the intrusion the basalt is generally finer grained with phenocrysts up to 0.3 mm in diameter, and markedly heterogeneous, in part due to the very abundant, minute xenoliths.

Coal Measures and Etruria Formation xenoliths up to 4.5 m in diameter are numerous. The smaller clasts (up to 0.4 m) are typically rounded and highly altered with a glassy appearance, whereas the larger blocks, which tend to be present in the lower part of the exposed mass, are rounded or irregular and show rims of alteration, 0.6 m to 0.9 m wide (Marshall, 1942, 1946).

Veins of calcite, chlorite, quartz, chalcedony and haematite are common, and calcite and chlorite infill vesicles in the dolerite at the margins of the intrusion (Marshall, 1946).

Tansey Green volcaniclastic deposits

A stratigraphical section from Tansey Green Clay Pit, recorded by Glover *et al.* (1993), is shown below.

	Thickness (m)
Volcaniclastic breccia, poorly sorted, faintly bedded in lower part; contains beds rich in bombs of amygdaloidal basalt (especially near the base) and beds with abundant lithic fragments of Coal Measures and Etruria Formation (up to 1.5 m long); tuffaceous matrix with scoriaceous textures and fresh glomeroporphyritic plagioclase, angular quartz grains, carbonate nodules, lithic fragments	*c.* 30.0
Tuffaceous mudstone and siltstone, green-grey, finely laminated with small-scale asymmetric folds; lacks in-situ conifer stems	0.4
Lapilli-tuff, scoriaceous, centimetre-scale parallel lamination, plagioclase laths commonly glomeroporphyritic, feldspar microlites and sub-angular grains of volcanic beta-quartz; sharp based with conifer stems in growth position	0.6

The conifer stems present in the lapilli-tuff are 5 mm to 15 mm in diameter and up to 250 mm in length, occurring with a vertical or near-vertical orientation (Galtier *et al.,* 1992). The stems are partly converted to coaly material (fusain) with the outer bark commonly absent.

Both the volcaniclastic deposits and the underlying Etruria Formation are cut by discordant tuffisite veins (Figure 7.15), ranging from millimetres to 0.2 m in thickness. The veins are generally orientated parallel to the dominant east-west and north-west-south-east fault trends. They are composed predominantly of fragments of probable Coal Measures origin, in particular quartz grains, coal, plant fragments, carbonaceous siltstone and sideritic nodules. Sparse, rounded clasts of altered basalt similar to those seen in the volcaniclastic breccia are also present. The veins may show alignment of clasts parallel with the dyke wall and a broad decrease in grain size from the centre to the margins. Associated with the tuffisite veins is a single agglomerate pipe, up to 10 m in diameter, and a NW-trending alkali basalt dyke, approximately 0.3 m wide. The agglomerate pipe contains rounded clasts similar in composition to the tuffisite veins, although with a greater abundance of basaltic clasts. The basalt dyke is extensively altered to chlorite and calcite, though it displays a relict ophitic texture. Amygdales of chlorite and calcite are common, being larger and more abundant towards the margins of the dyke.

Interpretation

The presence of igneous rocks at Barrow Hill was first recorded by Jukes (1859), though reference was made only to the presence of a mass of basalt. Whitehead and Eastwood (1927) suggested that the basalt has a laccolithic form, intrusive into the lower part of the Etruria Formation. The first detailed descriptions of the Barrow Hill intrusion were provided by Marshall (1942, 1946), in which the vent-like geometry was established and the presence of abundant country-rock xenoliths was recorded. The vol-caniclastic rocks became well exposed as a consequence of excavations at Tansey Green Clay Pit. Galtier *et al.* (1992) described the volcani-clastic deposits in the context of their importance in preserving delicate conifer-like stems. A more thorough description of these deposits and associated volcaniclastic and basaltic intrusions was provided by Glover *et al.* (1993).

The complex of agglomerates and dolerite intrusions present at Barrow Hill are interpreted as a vent, with the igneous rocks in some cases intruding along pre-intrusion or penecontemporaneous faults (Marshall, 1942, 1946). The basalt pipes and vent agglomerates are thought to be near coeval. The country rock appears to have been relatively wet and unlithified at the time of intrusion, suggesting emplacement at or near the penecontemporaneous ground surface (Glover *et al.,* 1993). The surface expression of the vent is not preserved but is thought to have been a tuff-cone.

Glover *et al.* (1993) provided a complex history of evolution of the volcaniclastic deposits developed marginal to the vent. The lapilli-tuff, which formed the first volcanic material erupted from the vent, is interpreted as ash fall that accumulated rapidly in an alluvial floodplain environment, with each laminae representing a distinct pulse. Temperatures were sufficient to char the conifer stems, removing the outer cuticle (bark) layer (Galtier *et al.,* 1992). This charring can result from an initial hot, gaseous, base surge, which precedes the passive fall of lapilli-tuffs from a convective turbulent cloud. The tuffs were succeeded by tuffaceous mudstone and siltstone, in turn followed by highly explosive, gaseous, phreatomagmatic eruptions, which deposited the volcaniclastic breccia. The absence of impact craters beneath large clasts in the breccia may suggest that the deposit had undergone some reworking as debris flows, though the preservation of delicate euhedral plagioclase crystals and glomeroporphyritic texture suggest that the breccias could not have been transported far from the volcanic source.

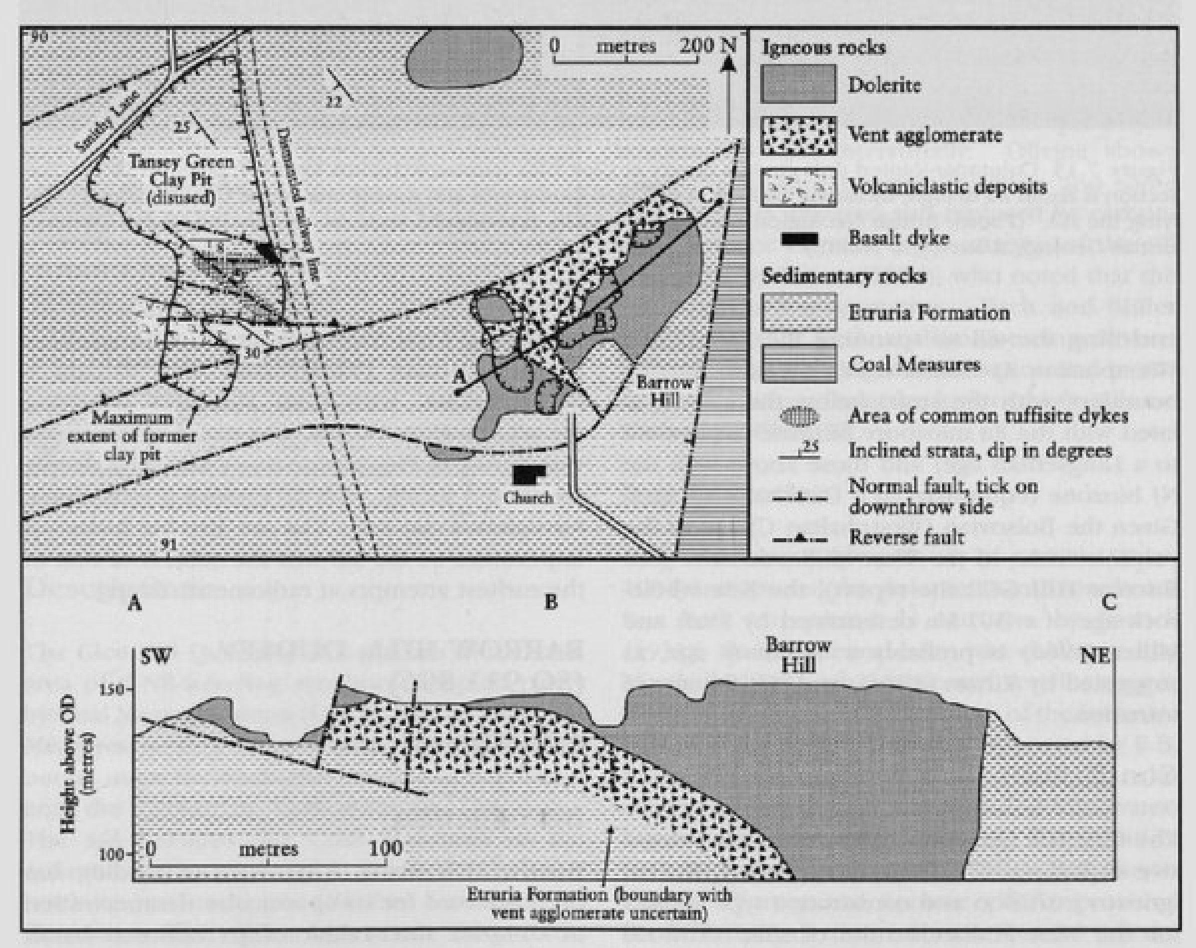
The tuffisite dykes and the agglomerate pipe are interpreted as the product of phreato-magmatic activity. Interaction of hot, gaseous magma and groundwater resulted in the explosive vaporization of the water and the fragmentation of the country rock, with a rapid upward migration of gas, transporting fragments of Coal Measure material and injecting them into the overlying Etruria Formation. The tuffisite dykes, agglomerate pipe and basalt dyke probably represent lateral feeders from the main Barrow Hill Complex. The orientation of the tuffisite and basalt dykes parallel with the main faults in the area, suggest that emplacement of the complex occurred coeval with a phase of extensional faulting.

Conclusions

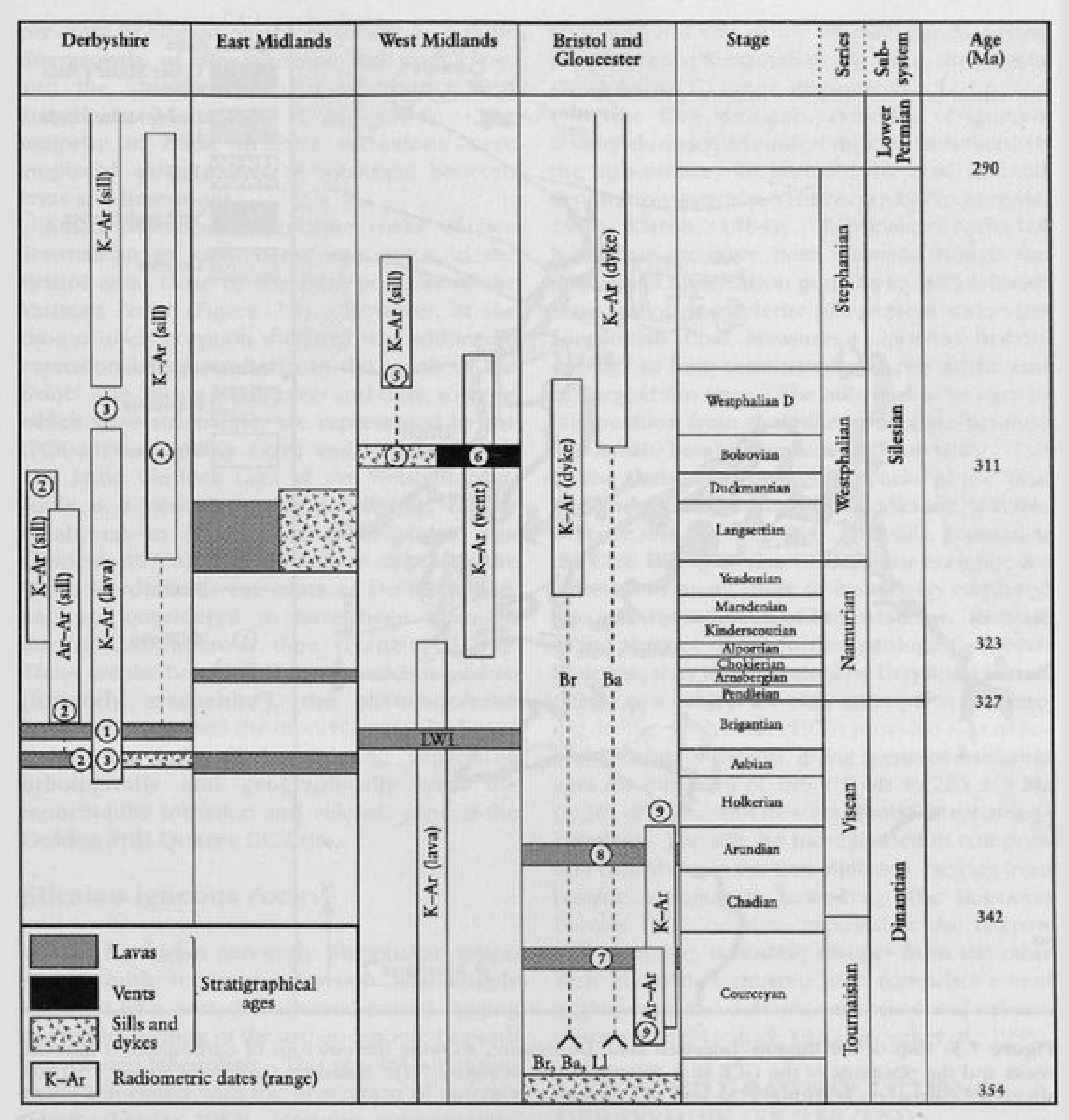
The Barrow Hill GCR site is nationally important for the spectacular demonstration of the relationship between a volcanic vent and adjacent volcanic deposits erupted from that vent around 307 million years ago. The vent comprises a breccia of igneous and sedimentary clasts intruded by basaltic rocks, which contain abundant fragments and blocks of Upper Carboniferous sedimentary rocks. The level of erosion seen in the vent at Barrow Hill appears to be at or near to what was the ground surface at the time of eruption. Hot, gassy magma penetrated wet and largely unconsolidated sediments, and the interaction with groundwater resulted in explosive activity in which dykes of sedimentary and igneous material were forced underground for some distance marginal to the vent. The surface expression of the explosive activity is seen as ash-fall deposits, hot, gaseous lateral surge deposits and a thick breccia, similar in composition to that present in the vent.

The ash-fall deposits preserve the oldest anatomically preserved conifers found to date. The excellent preservation of the wood, pith and xylem make these stems of considerable importance in the understanding of the evolution of gymnosperms and provides constraints on the environment of growth of conifers during the Carboniferous Period.

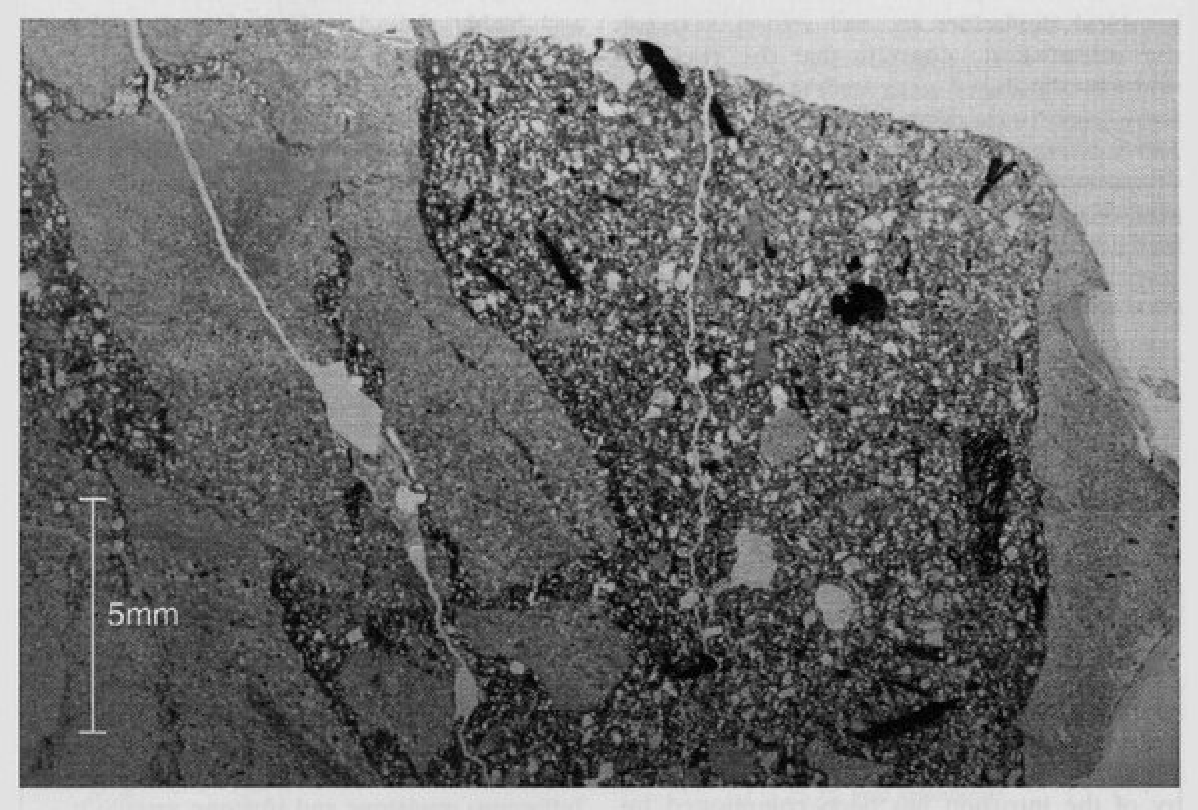
References



(Figure 7.14) Map of the Barrow Hill GCR Site. After Glover et al. (1993); and British Geological Survey 1:10 000 Sheet SO 98 NE (1989). Cross-section from Marshall (1946).



(Figure 7.2) Approximate ages and stratigraphical distribution of selected igneous rocks from central England and the Welsh Borderlands. The GCR sites are numbered as for (Figure 7.1). (Ba = Bartestree Dyke; Br = Brockhill Dyke; Ll = Llanllywel Monchiquite Dyke; LWL = Little Wenlock Lavas.) After Francis (1970a); and Kirton (1984). The timescale is that of Gradstein and Ogg (1996).



(Figure 7.15) Photomicrograph showing details of a tuffisite vein cutting through mudstones, from Tansey Green Clay Pit, Barrow Hill. Grain alignment occurs parallel with the vein and grain size decreases toward the vein margin. Plane-polarized light. (Photo: from Glover et al., 1993.)