Tideswell Dale, Derbyshire

[SK 154 740]

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Introduction

The Tideswell Dale GCR site provides a good section through a dolerite sill, spatially associated with the Dinantian lavas of Derbyshire. It includes the contact with underlying limestones, which have been affected by thermal metamorphism. The Tideswell Dale Sill, as is the case with the Water Swallows Sill (see Water Swallows Quarry GCR site report), was intruded at the level of the Lower Miller's Dale Lava, of Asbian age (Figure 7.2), but has yielded K-Ar radiometric dates significantly younger than the stratigraphical age of the lava.

The sill is slightly discordant, transgressing from below the lavas in the east to above the lavas in the west of the dale (Wilkinson in Neves and Downie, 1967) (Figure 7.8). The Lower Miller's Dale Lava is thought in this area to occur as two distinct flows separated by a thin limestone parting (Stevenson and Gaunt, 1971). The northern and southern margins of the sill are truncated by WNW-trending faults. The site has been variously described by Arnold-Bemrose (1899, 1907), Sargent (1917), Wilkinson (in Neves and Downie, 1967), Macdonald *et al.* (1984) and Aitkenhead *et al.* (1985).

Description

The Tideswell Dale Sill was first described by Geikie (1897). Arnold-Bemrose (1899, 1907) provided the first petrographical details. He recognized a broadly symmetrical succession, about 17 m thick. The central zone, 1.8 m thick, was referred to as ophitic olivine-dolerite in which augite predominates. Above and below this zone he described 3.4 m of coarse-grained olivine-dolerite in which feldspars predominate. A fine-grained olivine-dolerite, 4.3 m thick, was described by Arnold-Bemrose (1899, 1907) as occurring at the base and top of the intrusion. Aitkenhead *et al.* (1985) provided detailed descriptions of the petrography from the central part of the intrusion to the basal contact and were unable to identify dolerite with ophitic texture. They described the central part as medium grained, comprising phenocrysts and possible xenocrysts of olivine (12%) and augite (0.8%), set in a random intergrowth of plagioclase laths (49%), augite (20%) and opaque minerals (3.7%) with abundant interstitial devitrified glass (9%). The plagioclase is of approximate composition An_{70}. A progressive chilling is observed toward the base of the sill and at the basal contact there is extensive argillization of silicates and development of a slight flow foliation.

The Tideswell Dale GCR site comprises two former quarries located on the east side of Tideswell Dale (Figure 7.8). The main exposure [SK 155 738] (Location A; (Figure 7.8)) comprises about 25 m of spheroidally weathered dolerite, the upper 2.6 m containing scattered calcite amygdales. At the southern end of this quarry [SK 1547 7378], beneath the sill, there is a vesicular basalt, up to 1 m thick, which is probably a part of the Lower Miller's Dale Lava. This has been seen in temporary sections (e.g. Location B; (Figure 7.8)) to be underlain by at least a metre of red clay with well-developed columnar or prismatic structures, up to 6 cm in diameter (Arnold-Bemrose, 1899; Wilkinson in Neves and Downie, 1967; Aitkenhead *et al.,* 1985) (Figure 7.9). The clay has an extremely fine 'net-veined' fabric with veinlets of phyllosilicate a few microns across, in a microcrystalline matrix; the dominant mineral is an expanding-lattice mixed-layer clay (Aitkenhead *et al.,* 1985). Marmorized limestone of the Bee Low Limestones is evident below the sill on the western side of the dale [SK 1539 7410], although it is not exposed in direct contact with the sill (Wilkinson in Neves and Downie, 1967; Aitkenhead *et al.,* 1985). Arnold-Bemrose (1899) described this alteration as extending up to 3.9 m below the contact with the overlying clay and dolerite. Marmorized limestone is white, breaking with saccharoidal fracture.

Wilkinson (in Neves and Downie, 1967) described further sections in three roadside quarries at the entrance to the picnic site [SK 154 743] (Location C; (Figure 7.8)). These expose about 9 m of very spheroidally weathered, non-vesicular dolerite (referred to as lava by Wilkinson) with microphenocrysts of andesine and augite. This is in contact with a highly altered vesicular dolerite with pseudomorphs after olivine, flow-orientated feldspar laths and microlites of dominantly

oligoclase composition. The vesicular dolerite is geochemically enriched in alkalis, especially sodium (Na_2O = 4%), in comparison with other Derbyshire lavas and sills.

The geochemical analysis of the Tideswell Dale Sill provided by Macdonald *et al.* (1984) is very similar to that of the Lower Miller's Dale Lava, with relatively high SiO_2 (51.2%) and low MgO (6.24%) in comparison with other Carboniferous lavas and sills from the region. The dolerite is quartz-hypersthene-normative.

The lava was extruded onto beds of the Bee Low Limestones, which have faunal assemblages indicative of late Lower *Dibunophyllum* (D_1) Zone of Asbian age (around 334–330 Ma on the timescale of Gradstein and Ogg, 1996) (Figure 7.2). The Lower Miller's Dale Lava, mistakenly referred to as Upper Miller's Dale Lava, has been radiometrically dated at this locality, with a whole-rock K-Ar age of 315 ± 12 Ma (*c.* 321 Ma with new constants) (Fitch *et al.,* 1970). Fitch *et al.* concluded that this age is a close approximation to the age of hydrothermal alteration. The sill yielded a whole-rock K-Ar age of 287 ± 13 Ma (*c.* 293 Ma with new constants), which Fitch *et al.* interpreted as a minimum age of hydrothermal alteration.

Veins of fibrous material present in the sill comprise chlorite, highly altered to amesite and montmorillonoids and intimately admixed with quartz (Sarjeant, 1967).

Interpretation

Macdonald *et al.* (1984) analysed 15 samples from the Tideswell Dale Sill and provided a single representative analysis. The analyses were presented on a Zr-Nb plot that is based upon stable incompatible trace elements less prone to mobility during secondary alteration. The plot showed the presence of internal chemical differentiation in the sill, although the range of Nb and Zr abundances for the sill is small in comparison with the full range of analyses of Derbyshire basalts. The plot also showed that, with respect to Nb and Zr, the Tideswell Dale Sill is compositionally similar to both the Upper and Lower Miller's Dale lavas.

Sargent (1917) interpreted the altered vesicular lava present beneath the sill as spilitic owing to the high alkali content (greater than 6%), though Walters and meson (1981) considered this to be more a reflection of deuteric and hydrothermal alteration, especially during the intrusion of the sill.

The Tideswell Dale GCR site shows the effects of thermal metamorphism on the country rock adjacent to the sill. Metamorphism of the limestones is seen only beneath the sill and only where the sill directly intrudes the limestone; no marmorization has been identified where the Lower Miller's Dale Lava intervenes between the sill and the limestone. The red clay with prismatic structures beneath the sill (Figure 7.9) was interpreted by Wilkinson (in Neves and Downie, 1967) as a volcanic ash, metamorphosed as a result of sill emplacement. However, this does not explain how the ash has been so thoroughly altered to clay, whereas the lava between the clay and the sill is relatively unaffected by thermal metamorphism. It is also unusual for the effects of baking at the margins of Carboniferous sills in central England to have developed more than a few centimetres into the country rock. The prismatic structures within the red clay resemble cooling joints developed within lavas or sills, and their sigmoidal nature suggests magma flow during cooling. The absence of joints from the upper and lower parts of the clay may indicate rapidly chilled margins, with the columnar joints forming only in the more slowly cooling core of the sheet. A possible explanation of this enigmatic section is that the red clay represents a basalt lava that was thoroughly altered by humid weathering during emergence and erosion, giving an irregular upper surface, which was subsequently buried by a further lava. The sill then intruded at the level of the Lower Miller's Dale Lava, exploiting the weak layer of weathered lava.

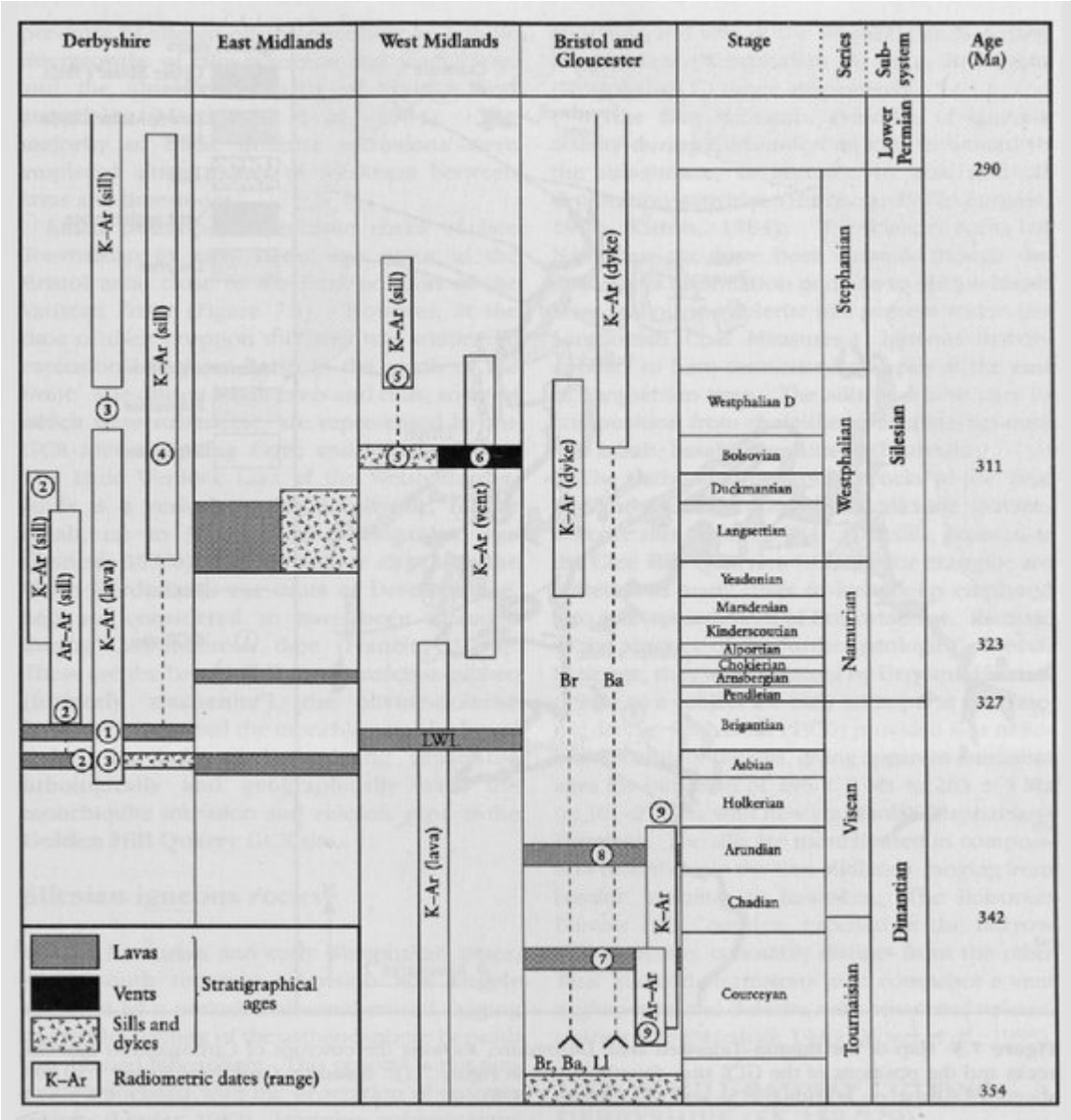
Conclusions

The Tideswell Dale GCR site provides exposures of the Tideswell Dale Sill, which intrudes Asbian (Visean) limestones and the Lower Miller's Dale Lava, erupted around 330 million years ago. The dolerite sill appears to have been intruded preferentially along or near to the planar contact between limestones and lavas, locally exploiting the relative weakness of deeply weathered lava. The site also demonstrates several features typical of intrusive bodies, namely a reduction in

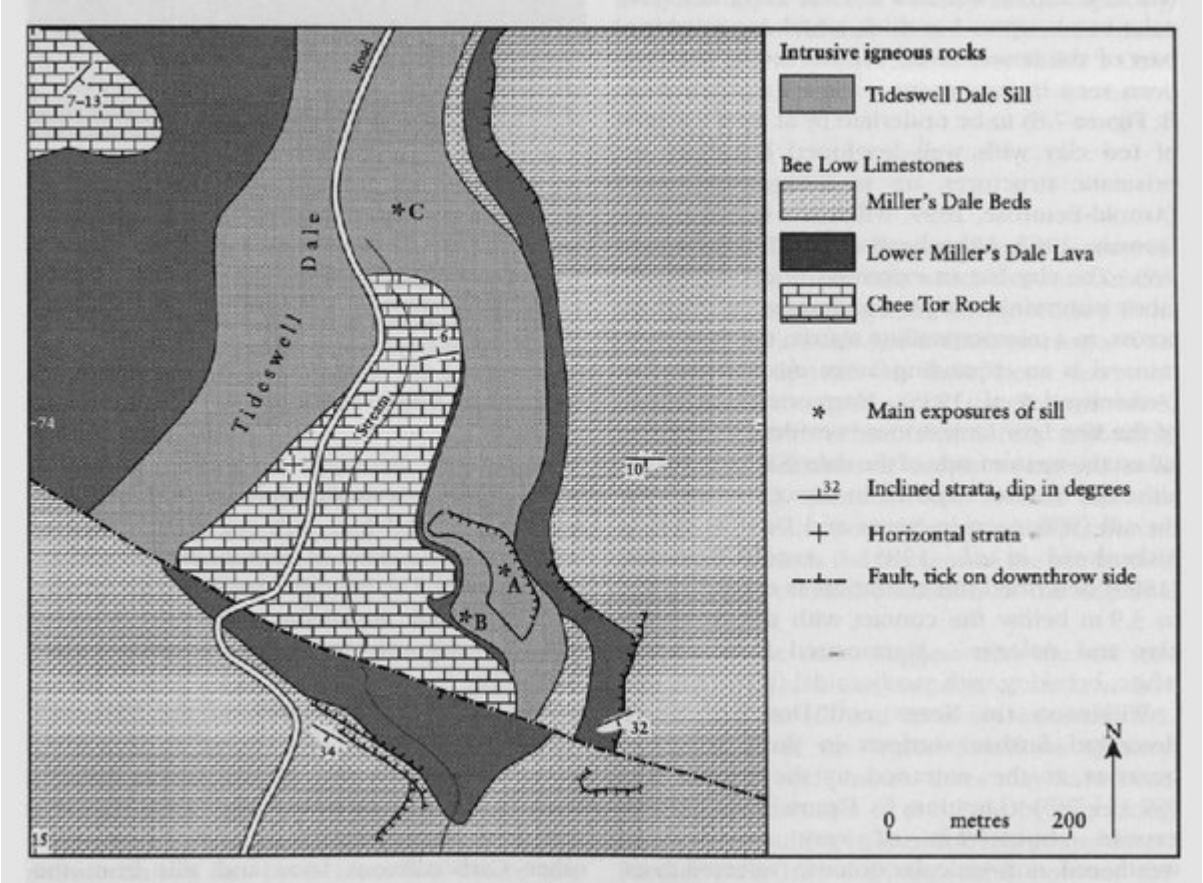
grain size towards the margins of the sill, chilled margins and thermal alteration of the adjacent country rocks.

Radiometric dares suggest that the sill was intruded well after the eruption of the lavas and hence that the sill and lavas are unconnected. However, as at the Water Swallows Quarry GCR site, the radiometric dates may have been affected by alteration of the rocks by circulating hot fluids, resulting in anomalously young dates. Further study into the relationship between the lava and sill is required, particularly to assess their relative ages.

References



(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 7.8) Map of the Tideswell Dale GCR site. Based on Geological Survey 1:10 560 Sheet SK 17 SE (1972).

(Figure 7.9) Temporary exposure (July 2002) at the base of the Tideswell Dale Sill, on the east side of Tideswell Dale (Location B on (Figure 7.8)). The sill forms the massive natural exposures at the top of the picture and is underlain by altered basalt lava in the centre. Beneath this is a red clay with sigmoidal prismatic joints that is interpreted as a thoroughly altered lava. See text for further discussion. The cutting is 0.8 m deep. (Photo: M. Murphy.)