Cliffe Hill Quarry

[SK 475 106]

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Introduction

The disused Cliffe Hill Quarry near Markfield (Figure 2.19), now commonly referred to as the 'Old Cliffe Hill Quarry', provides extensive exposures that include up to 80 m of stepped vertical sections, enabling a three-dimensional view of the Precambrian rocks (Figure 2.20). It is unique in showing the relationships between Charnian strata containing Precambrian fossils (described in Chapter 8), and the youngest Precambrian intrusive rocks in Charnwood Forest. The quarry serves as the type locality for these intrusions, whose current formal name of 'South Charnwood Diorites' was proposed by Worssam and Old (1988). The same intrusions were classified as syenites by early workers (Hill and Bonney, 1878), but were subsequently named 'markfieldite' by Hatch (1909), after the quarried outcrops by Markfield village 1 km farther east. The informal usage of this name persists today, despite the fact that Wills and Shotton (1934) urged a change to the more correct term 'granophyric diorite'. The most significant aspect of the South Charnwood Diorites is their similarity, both in petrography and geochemistry, to the intrusion of granophyric diorite in Judkins' Quarry at Nuneaton (Chapter 3). This correlation, if confirmed, would imply that the minimum age of the Charnian Supergroup and its included fossils is 603 Ma, as discussed in the introductory section of this chapter.

The site includes impressive sections representing the westernmost exposures of strata equated with the Bradgate Formation (Worssam and Old, 1988), in which the Ediacaran fossils referred to above are found. It also shows excellent profiles through palaeovalleys, or Vadis', developed along the Triassic unconformity surface.

Description

The South Charnwood Diorites intrusion is exposed over a width of about 320 m and vertical height of 80 m (Figure 2.19). Except for its immediate contact zone, it is a massive, grey-weathering lithology whose appearance changes little across the entire outcrop. Freshly cut surfaces show a grey, coarsely mottled texture consisting of three principal components. Dark green-grey mafic minerals, mainly augite together with alteration products, comprise about 30 per cent of the rock and form aggregates or individual stubby laths up to 5 mm long. Pale green-grey plagioclase feldspar forms a further 40 per cent, as aggregates or equant to lath-shaped euhedra up to 5 mm long (average 2–3 mm). A finely granular mesostasis, forming the remainder of the rock, represents the granophyric component whose extent of development is the main distinguishing feature of the South Charnwood Diorites; it ranges from grey-green to pink in colour, depending upon the degree of secondary alteration. At the eastern end of the quarry ((Figure 2.19), Locality 1) the pink variety forms planar zones up to 0.2 m wide, their orientation reflecting that of the prevailing Charnian cleavage.

Details of the petrography and geochemistry of the South Charnwood Diorites are given in Worssam and Old (1988). The rocks are less sheared and more leucocratic than the North Charnwood Diorites (also of Precambrian age), from which they are also distinguished by the abundance of interstitial, radiating graphic quartz and K-feldspar intergrowths. Chemical analyses suggest a range of compositions including granodiorite, quartz diorite and monzodiorite, with quartz monzodiorite the most common type.

The contact between the South Charnwood Diorites and the Bradgate Formation at this site was described as faulted by McIlroy *et al.* (1998); however, it is tectonically displaced only in the central part of the exposure (Figure 2.19). Elsewhere, as noted by Worssam and Old (1988), the intrusion darkens and fines progressively in grain size within about 10 m of the contact, indicative of chilling. At localities 2 and 3, the present authors found that the intrusion develops a dark grey, very fine-grained, porphyritic selvage, about 1.5 m thick, immediately adjacent to the country rock, a feature also seen at the contact of the Nuneaton granophyric diorite in Judkins' Quarry (Chapter 3). A thin section shows this selvage to consist of about 50–60 per cent of small (2–3 mm) plagioclase euhedra, pseudomorphed by albite and white

mica, and about 10–15 per cent of chloritized and epidotized mafic phenocrysts; these are enclosed within a turbid, finely microcrystalline and locally flow-foliated groundmass. The country rocks are bleached to a pale cream, fine-grained lithology over several centimetres adjacent to this chilled zone (Locality 2), and farther north, bedding is sharply truncated at the margin of the porphyritic intrusive facies (Locality 3). Contact-related 'metasomatism' was described from Cliffe Hill by Boulter and Yates (1987). It is seen as thermal spots that are sporadically developed over several metres adjacent to the chilled diorite margin at Locality 2. The millimetre-size grey-green spots are restricted to certain laminae within the country rocks, and in places are slightly deformed into elliptical structures by the regional Charnian cleavage.

Evidence for Precambrian folding of the Charnian sequence is based on the diorite intrusive margin representing a structural reference plane. For example, in the upper quarry face, to the east of Locality 2, the south-facing limb of a steep flexure in the Bradgate Formation is truncated at the contact. Similarly, the range of dip attitudes in the Bradgate Formation along parts of the northern contact suggests folding unrelated to any later structures affecting the intrusion.

Present exposures of the Bradgate Formation fringe the northern and eastern margins of the intrusion (Figure 2.20). The 1974–1975 BGS survey (Old, 1982), however, showed a large 'xenolith' of these strata enclosed within the intrusion near the central part of the quarry, which is now flooded. In the east of its outcrop (around and to the north of Locality 2), the Bradgate Formation typically consists of green to grey, parallel-laminated, volcaniclastic mudstones and siltstones. They show normal grading and some beds display contorted lamination; one fallen block contains a highly contorted bed, about 0.2 m thick, which has sharp margins against adjacent strata. Erosional structures are seen at Locality 4, where the upper surface of a laminated siltstone bed contains a number of shallow (several centimetres deep) channels; they are infilled by mudstones and siltstones showing slump-folded laminae with pronounced inwards dips with respect to the channel margins. In the same sequence, sporadic intercalations of graded, fine- to coarse-grained volcaniclastic sandstone have sharp, erosive bases that incorporate flames, rafts and slivers of the underlying strata. There is a change of lithology in the northern part of the quarry (Locality 5) to amalgamated beds of crystal-rich, volcaniclastic sandstone, each about 4–5 m thick. They are graded from granule sandstone and breccia at the base to medium-grained sandstone at the top of each unit.

Interpretation

Strata of the Bradgate Formation give a unique insight into the nature of sedimentation of the rocks in the south-west of the Maplewell Group outcrop. In the east of the site, most beds are graded, or form parts of thick, graded sequences, suggesting that they represent a diverse, though predominantly distal, turbidite succession. Such an environment was favourable at times to the preservation of fossils, although these may have been transported from their life-sites. The succession contains distinctive, finely laminated beds that are thicker than those found elsewhere in the Bradgate Formation. It also displays unusual sedimentary structures that include sharply bounded convoluted beds, possibly indicative of slumping caused by synsedimentary seismic activity, and shallow siltstone-filled channels. The latter are severally developed along a single bedding plane, and could represent scours formed by swarms of discrete vortices generated by bottom currents in the interval before deposition of the next overlying turbidite bed. A major episode of proximal turbidite deposition is reflected by the incoming of very coarse-grained, thick-bedded sandstones in the north-west of the exposure.

As discussed in the introduction to Chapter 2, the South Charnwood Diorites represent the end-stage of Charnian activity. They are the products of high-K, calc-alkaline magma that was emplaced into an arc of increased maturity, subsequent to further subduction-enrichment of the mantle source region (Pharaoh *et al.,* 1987b). Although they are different from the rest of the Charnian sequence, and the North Charnwood Diorites, they nevertheless appear very similar to granophyric diorite at Nuneaton whose age of emplacement is dated at 603 Ma. This correlation, if correct, would suggest that the fossils of Cliffe Hill must be older than that date (but see discussion in introductory section). The former observation of a large sedimentary raft at Cliffe Hill Quarry suggests that magmatic stoping may have been part of the intrusion process. From textures observed at the chilled intrusive margin, it can be suggested that the plagioclase and mafic mineral components were fully crystallized at the time of emplacement, i.e. the magma was initially porphyritic. The granophyre component of the intrusion therefore represents the wholesale, in-situ crystallization of the liquid remaining between these crystals. The apparently uniform development of the granophyric residuum in the South Charnwood

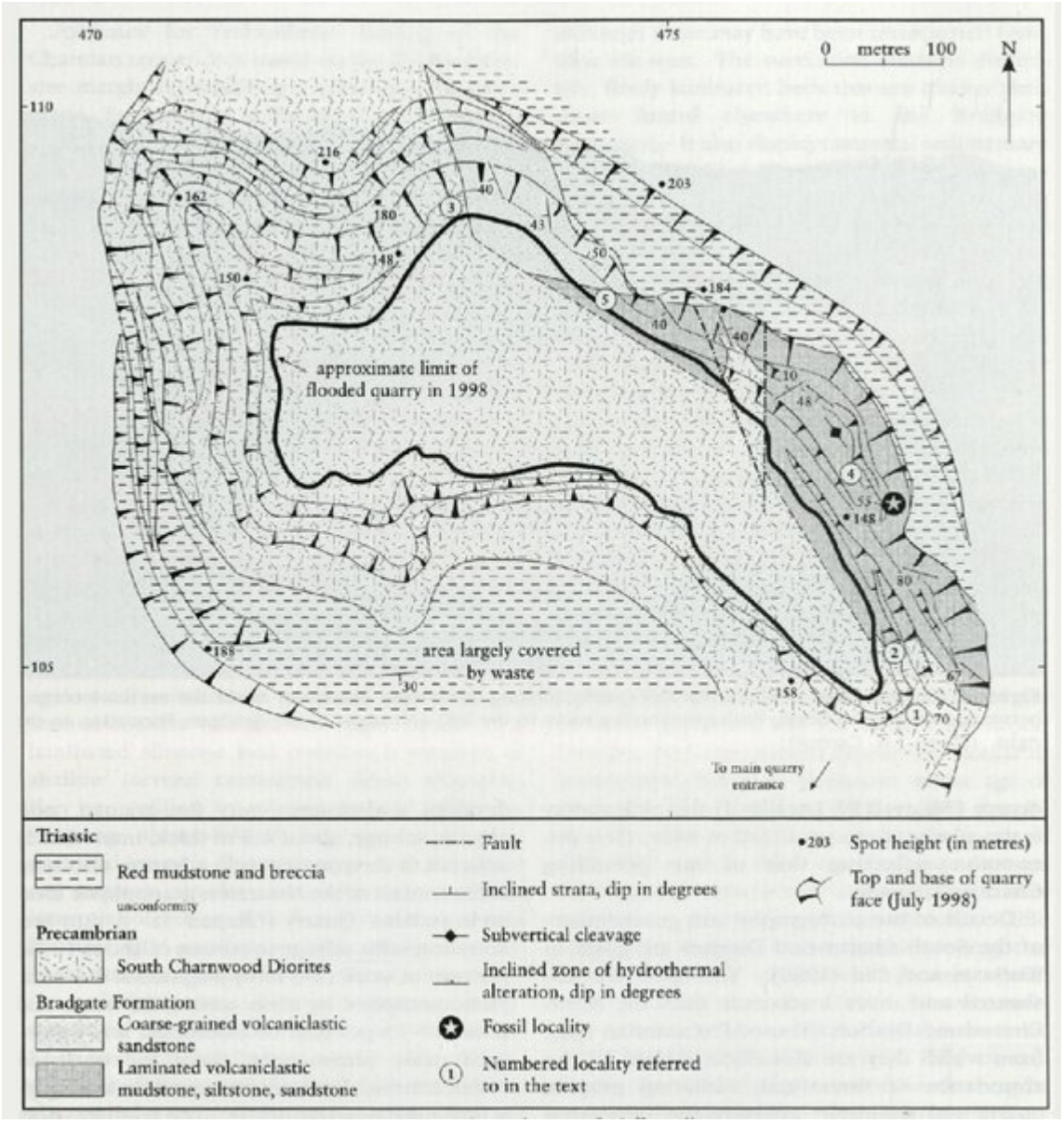
Diorites is not entirely reflected under the microscope, which reveals a variety of textures ranging from vermicular to cuneiform (micrographic) types (Smith and Brown, 1988), commonly in a single thin section. Such textures would indicate crystallization during moderate degrees of under-cooling of the magma (e.g. Bouloton and Gasquet, 1995).

The exposures at Cliffe Hill suggest that the change in magma type represented by the South Charnwood Diorites was preceded by unspecified deformation, involving flexuring of the Bradgate Formation country rocks. It may be speculated that the cessation of extrusive arc activity closely coincided with this tectonism.

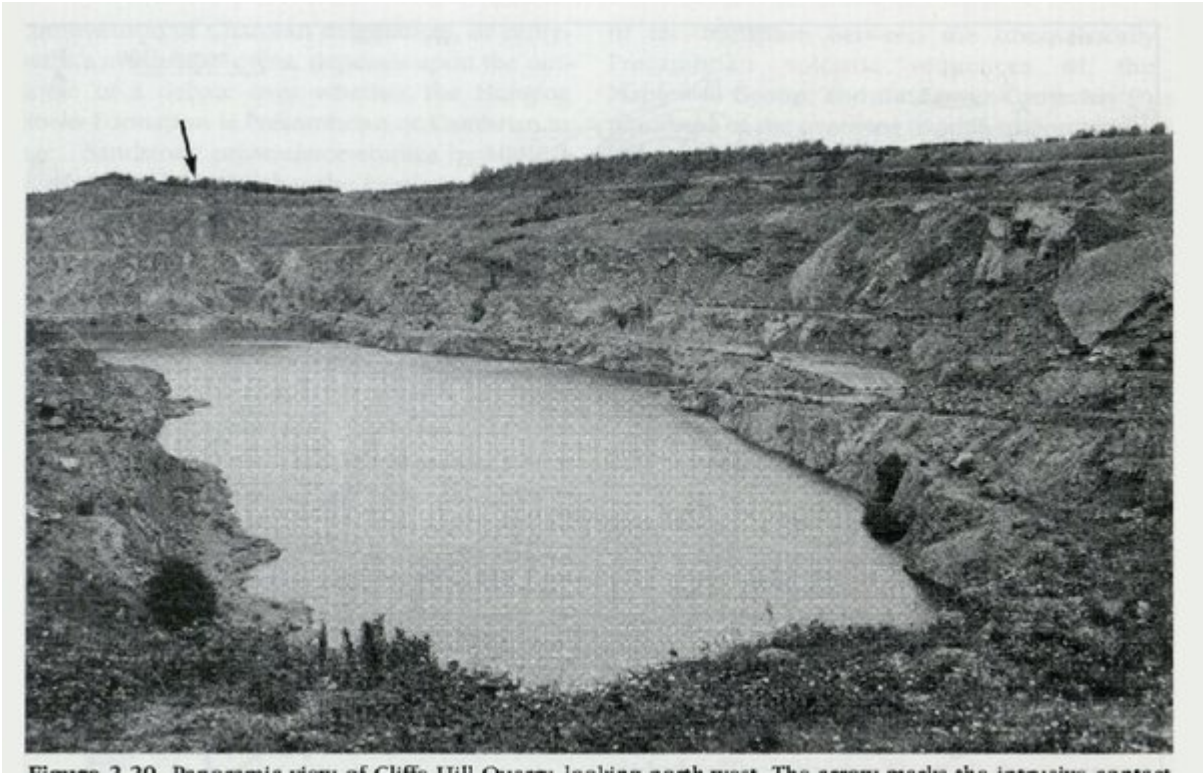
Conclusions

Cliffe Hill Quarry contains important exposures unequivocally showing that the South Charnwood Diorites are intruded into strata of the Bradgate Formation. The latter forms a diverse sedimentary sequence, with thick packages of turbidites of both distal (mudstones, siltstones, rare sandstones) and proximal (very coarse-grained, graded sandstones) facies, the former containing the Precambrian fossils described in Chapter 8. The varying dips of these strata indicate that they had been flexured and possibly folded by the time they were intruded, providing important evidence for a mild deformational event occurring around the time of magmatic cessation of the Charnian arc. Thickening of the crust of the Charnian arc had also occurred by this time, and is indicated by the different geochemistry of the South Charnwood Diorites, relative to the rest of the Charnian sequence and intrusions of North Charnwood Diorites. The date for the intrusive event is 603 Ma, but this value is based on long-range correlations and may be challenged in the light of further work. At the time of intrusion the South Charnwood magmas were partly crystallized and charged with plagioclase phenocrysts, which survive within the narrow porphyritic chill zone of the intrusion. Their distinctive granophyric residuum formed when the magma became undercooled after emplacement. The heat of the intrusion caused the local development of thermal spots within adjacent sedimentary strata.

References



(Figure 2.19) Geological map of Cliffe Hill Quarry



(Figure 2.20) Panoramic view of Cliffe Hill Quarry, looking north-west. The arrow marks the intrusive contact between granophyric diorite (paler-weathering rocks to the left) and strata of the Bradgate Formation to the right. (Photo: J.N. Carney.)