Aspects of Charnian geology. An evening field excursion to: Calvary Rock, Ratchet Hill, Mt. Saint Bernard and Beacon Hill

J N Carney and T C Pharaoh

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 This report was compiled to accompany an evening Field excursion by the East Midlands Branch of the Geological Society, on July 5th, 2000.

Itinerary

For localities and routes, see (Figure 1).

Assemble 1800 at Mt. Saint Bernard Abbey car park [SK 4590 1615]

1815–1845 Locality 1: Calvary Rock

1900–1945 Locality 2: Ratchet Hill

2000–2020 Locality 3: Mt. Saint Bernard Abbey

2030–2100 Locality 4: Beacon Hill

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Introduction

This excursion commences with a visit to the north-west of Charnwood Forest, to view some of the lesser-known, but nonetheless spectacular, exposures of late Precambrian volcanic rocks belonging to the Charnian Supergroup. To set the scene, the general distribution of Charnian Supergroup units in northern Charnwood Forest is indicated on the simplified, pre-Triassic geological map of (Figure 2). This incorporates new information, gained as a result of the recent BGS re-survey of the Loughborough (No.141) geological sheet, the details of which can be found in Carney (1994, and in press).

The Charnian Supergroup (Moseley and Ford, 1985) is a sequence of volcanic and volcaniclastic rocks, which are the products of a volcanic arc (Pharaoh et al., 1987) whose magmas were generated above a subduction zone bordering the late Precambrian Gondwana supercontinent. The rocks that will be viewed at localities 1–3 are important to theories concerning the origins of the Charnian magmatism and the various modes of magma emplacement and extrusion. They comprise a diverse assemblage of massive to brecciated igneous lithologies belonging to the Whitwick Volcanic Complex, and a thick succession of volcanic breccias and lapilli tuffs that comprise the Charnwood Lodge Volcanic Formation. The main subdivisions and correlations of the various units are shown in (Figure 3).

It has long been recognised that these lithologies were formed in close proximity to the volcanic centres that gave rise to the Charnian sequence, but their actual mode of origin has been the subject of controversy in the past. On-going research is now suggesting that many of the coarsely fragmental extrusive rocks in the Charnwood Lodge Formation can be matched both petrographically and chemically with certain massive lithologies of the Whitwick Complex, and that the latter represents the root zones of magmatic feeder bodies that supplied these fragmental rocks. Today, we will explore this 'genetic' link on the ground by examining exposures in two of the most important associations that have been recognised, namely the Cademan Breccia/Grimley Andesite association (Association 1 of (Figure 3)) and the Swannymote Breccia/Sharpley Dacite association (Association 2).

All of these north-west Charnwood lithologies are the lateral equivalents of considerably finer-grained, volcaniclastic strata that characterise the Maplewell Group in the southern and eastern outcrops (Figure 2). Exposures of these more distal facies tuffaceous rocks will be visited at Beacon Hill, the last locality of the excursion.

Excursion details

Locality 1. Calvary Rock, Cademan Wood nr. Whitwick; [SK 4338 1717]

These exposures illustrate the Cademan Volcanic Breccia Member, a unit up to 450 m thick which is a component of the Charnwood Lodge Volcanic Formation and also forms part of Association 1 (Figure 3). Unlike other members of the Charnwood Lodge Formation, the Cademan Breccia is unbedded. Typically it consists of abundant, angular to slightly rounded blocks of petrographically uniform, fine-grained volcanic rock whose average composition is low-silica dacite. On weathered surfaces the blocks stand out from the lapilli-grade matrix. This matrix is lithic- and crystal-rich, and although it seldom constitutes more than 30% of the rock, there are exposures showing that in places, the matrix is dominant over the block-sized clasts. Most volcanic blocks are between 10 and 50 cm across, but some exposures show evidence for 'outsized' blocks, up to a few metres in size. The interpretation of the Cademan Breccia is given after the description of Locality 2.

Locality 2. Ratchet Hill nr. Whitwick; [SK 4477 1638]

We are most grateful to Aggregate Industries (Bardon), and to the Company's grazier, Mrs Woolliscroft, for allowing access to this land.

Much of the structural geology of Ratchet Hill (Figure 4), in particular the major north-west shear zone, can be deduced from exposures in the north-eastern face of the immediately adjacent Whitwick Quarry.

Locality A (Figure 4) There are typical exposures of Sharpley Porphyritic Dacite, which forms a component of Association 2 of the Whitwick Volcanic Complex (Figure 3). The Sharpley Dacite is massive and commonly silver to white-weathering. It is characterised by large (up to 1 cm) white plagioclase phenocrysts and similarly large greenish-grey, rounded quartz phenocrysts, the latter generally 15–20% of the rock. The groundmass is dark grey to lavender-grey and has a homogeneous, microcrystalline texture in all thin sections examined to date.

Locality B exemplifies the rocks forming Association 2 (Figure 3), in that it shows a sharp contact between Sharpley Porphyritic Dacite and the Swannymote Breccia Member of the Chamwood Lodge Formation. The breccia contains abundant rounded to angular blocks of highly porphyritic (plagioclase-quartz) rhyolite, which are enclosed in a medium- to coarse-grained crystal- and lithic-rich matrix. Unlike the Cademan Breccia, most of these blocks have margins that are recessed in to the matrix on weathered surfaces. The blocks have the same green quartz phenocrysts as the Sharpley Dacite, and in many other respects they strongly resemble the latter; they are also chemically similar, although their silica contents are higher, and appropriate to rhyolite compositions. It is noted that immediately north of the Swannymote Breccia contact, the Sharpley Porphyritic Dacite has a rather diffuse, pseudobreccia structure; this fades farther to the north, towards the exposures in massive Sharpley Dacite.

Locality C(Ratchet Hill proper). The whole of this outcrop is in Swannymote Breccia. In addition to the usual porphyritic dacite blocks, however, it contains raft-like fragments, in excess of 1 m length, consisting of pale grey, laminated volcaniclastic siltstone. The rafts have sharp, locally irregular margins, with contorted bedding commonly truncated against the breccia. There is no evidence of pre-consolidation mixing between sediment and breccia matrix, although this is demonstrated at the Swannymote Rock type locality, about one kilometre north of here.

Locality D. Between C and D a major shear zone intervenes; the evidence for this is in the north-eastern face of Whitwick Quarry, where the shear zone appears as a subvertical sequence of highly foliated and phyllonitised andesites, dacites and volcaniclastic sedimentary strata. Locality D consists of dark grey-weathering exposures of Grimley Andesite. The lithology looks massive, but in detail the weathered surfaces show the presence of fractures and freshly-hammered surfaces show that the rock is full of small andesite inclusions. In many other outcrops in this region, the Grimley Andesite has a brecciated or autobrecciated structure.

Interpretation of the Calvary and Ratchet Hill exposures

Interpretation of the Cademan Breccia and Grimley Andesite (Association 1 of (Figure 3)).The angularity and abundance of blocks in the Cademan Breccia suggests it represents a highly immature, rapidly deposited lithology. Texturally it is closely similar to certain modern debris avalanche deposits that originated as a result of catastrophic collapse of the volcano flanks following an explosive eruption. However, there is no evidence for volcaniclastic lithologies occurring as fragments, which would be the case if parts of the crater flanks were incorporated into the deposit. Instead, the blocks in the member are all of one type of dacite. Chemical and petrographical studies have shown that the blocks in the Cademan Breccia have slightly higher silica contents than the Grimley Andesite, but otherwise compare very closely with that unit. This suggests a genetic link between the two, which could have arisen in the following ways:

a) The Grimley Andesite represents lava flows, with the Cademan Breccia a complementary autobreccia or flow breccia.

b) The Grimley Andesite represents material extruded as volcanic domes, with the Cademan Breccia representing the deposits of ash and block pyroclastic block flows that originated from the collapse and disintegration of unstable domes.

Exposures in this part of Charnwood are too incomplete to differentiate between the two hypotheses. With alternative a), however, one would expect a more regular alternation between massive volcanic rock (Grimley Andesite) and breccia, with the latter developed more thinly than the Cademan Breccia. The balance of evidence could therefore support alternative b), and this scenario is shown in the model depicting the types of processes that may have operated along the axis of the Charnian arc (Figure 5). A modern analogy for this style of Charnian volcanism may be the current (1995 to present-day) activity of the Soufriere Hills Volcano on Montserrat. The considerable thickness of the Cademan Breccia is unusual for block and ash pyroclastic flows, but it is possibly that the unit represents an amalgamation of sequentially erupted flows. Such sequences could have built up at the foot of the main edifice in the form a subaqueous pyroclastic fan, as seen on Montserrat. Alternatively, thickening may have occurred as a result of `ponding' within troughs, or perhaps against the wall of a caldera.

It is worth noting here the prescient comment of Watts (1947), who stated that in this part of Charnwood Forest volcanic rock masses of part-intrusive and part-fragmental aspect could be '*...of the nature of the "spine" intruded and extruded in* *the later stages of the eruption of Mont Pelee in 1902, the breaking up of it, such as then occurred, would give rise to aggregates of great "bombs"... '.*

The Grimley Andesite, considered alone, betrays little evidence of its origins. As noted, however, it is both lithologically and compositionally related to the blocks forming the Cademan Breccia. Its commonly fractured and brecciated appearance is an integral feature of the lithology, rather than being a superficial structure caused by later faulting, suggesting that in large part it may be considered as a type of autobreccia. If as suggested above, the Grimley Andesite represents the root zone of a consolidated andesite dome (Figure 5), the brecciation may be attributed to brittle failure and hydrofracturing as the dome was extruded through a volcanic edifice. On further expansion the dome would have collapsed, shedding the blocky material that avalanched down the volcano flanks as ash and block pyroclastic flows, these now forming the Cademan Volcanic Breccia Member.

Sharpley Porphyritic Dacite and Swannymote Breccia(Association 2 of (Figure 3)): The massive nature and apparent wide extent of the Sharpley Porphyritic Dacite suggests that it in large part it is a very homogeneous body, resembling an intrusive sheet. The porphyritic dacite blocks of the Swannymote Breccia are nevertheless very similar to Sharpley lithologies, and may indicate that the margins of the Sharpley Porphyritic Dacite had locally disintegrated, a process that contributed the fragments to the Swannymote Breccia. The occurrence of 'exotic' volcaniclastic sediment rafts, and the mixing relationships between Swannymote Breccia and sediments seen farther north at Swannymote Rock, is evidence that this marginal disaggregation involved physical interaction between the Sharpley Porphyritic Dacite and an unconsolidated to partly consolidated sedimentary host rock. Thus the Sharpley Dacite may represent an intrusive sheet, or perhaps a cryptodome, that was intruded at shallow levels within a sedimentary carapace (Figure 5). In many young island arcs, such a mode of intrusion gives rise to peperites or hyaloclastite breccias, which could be analogues for the Swannymote Breccia.

Stop 3. Mount Saint Bernard Abbey

Here we will examine the wall of the Abbey, to see excellent specimens of the third member of the Whitwick Complex - the Peldar Dacite Breccia. Though it appears massive, this lithology is actually fragmental throughout its large exposure in nearby Whitwick Quarry. It consists of three components:

Rounded fragments of dark grey to black, microcrystalline porphyritic dacite.

1. Small, greenish-grey fragments of medium-grained quartz microdiorite
2. The matrix, consisting of abundant fragments of spherulitic-textured, fine-grained dacite.

Interpretation: The Peldar Dacite Breccia is interpreted as a hyaloclastite breccia formed by the rapid quenching and subsequent quench-induced brecciation of dacitic magma, remnants of which now constitute the porphyritic dacite fragments. This quenching was most probably caused by physical interactions between the magma as it encountered unconsolidated sediments. Such a process is demonstrated at Whitwick Quarry, where mixing phenomena have been observed at the margin of a sedimentary raft incorporated into the breccia. The host sediments probably formed a carapace to the Peldar Dacite Breccia, and their unconsolidated condition suggests that the latter was emplaced at shallow depths, possibly as an intrusive sheet or a cryptodome (Figure 5).

Stop 4. Beacon Hill [SK 510 148]

Beacon Hill (Figure 6) is a local landmark and public viewpoint, with excellent exposures that serve as the type section for the Beacon Tuff Member of the Beacon Hill Formation. This member, about 740 m thick, occupies a significant stratigraphical position since it is in part contemporaneous with the Charnwood Lodge Volcanic Formation, which has just been visited in the north-west of Charnwood Forest (Figure 2), and which contains the principal record of primary pyroclastic activity in the Charnian Supergroup. At Beacon Hill the sequence is finer grained and the range of sedimentary structures suggests a considerable degree of secondary reworking. Accessibility of the exposures, and the occurrence of well-polished rock surfaces, are special features of Beacon Hill important for demonstrating the relative significance of pyroclastic and epiclastic sedimentation processes during a period of raised volcanic activity in the

Charnian arc.

Rock samples from Beacon Hill, when viewed in thin section, show acicular and y-shaped glass shards indicating that some of these beds have a significant juvenile pyroclastic content. Some of the youngest beds are exposed on the prominent crag by the footpath to the west of the Trig Point; ((Figure 6), Locality. 3). In this predominantly fine-grained sequence, the lowest bed, at least 2.8 m thick, consists of white-weathering, very fine-grained tuff or tuffaceous mudstone; it is devoid of bedding or lamination, but careful examination of favourable surfaces suggests that such features may have been obliterated by liquefaction (`slurrying') prior to consolidation. Extensive sedimentary load structures characterise a prominent undulating bedding plane in the middle part of these crags, and are continued a few metres to the south where completely detached, ball-shaped masses of sediment are enclosed within a lower bed. The overlying bed is 0.2 m thick and shows slight grading from tuffaceous siltstone at the base to a porcellanous, white-weathering mudstone at the top. The uppermost, laminated beds have highly lenticular geometries, due to a combination of large-stale slumping and intraformational scouring. The overlying strata are best seen around and to the east of the Trig Point; they are thinly bedded to laminated, with many small-scale examples of undulatory bedding, rafted or truncated lamination, normal grading and load structures.

Beacon Hill is not a recognised Charnian fossil locality; however, a possible disc-like fossil has been found on a bedding plane exposed to the south of the Trig Point.

Interpretation: The Beacon Hill exposures provide an opportunity to examine lithologies which are clearly of a distal facies with respect to the volcanic centres known to be active at that time in north-west Charnwood Forest. Contemporary volcanism is strongly suggested by the occurrence of juvenile pyroclastic material (glass shards) at Beacon Hill. In thin sections of such fine-grained lithologies it is commonly assumed that the unresovable matrix surrounding the shards, and constituting most of the rock, represents the highly comminuted, fine ash-grade equivalents of the shards, and that consequently the rock is a vitric tuff. Unfortunately, however, subsequent devitrification and silicification of the glassy material have masked the delicate textural details necessary to confirm such an origin. This process produced the extremely hard, porcellanous texture of these rocks and also perhaps their high silica content (79.81% in one sample).

The distinctive, very thick beds of fine-grained tuff in the sequence appear to be internally structureless, but it is possible that an earlier lamination may have been obliterated by liquefaction consequent upon large-scale movement within a water-saturated sequence. Such a complex pre-diagenetic history, in subaqueous environments, is suggested by soft-sediment deformation structures such as: undulatory and lenticular bedding, the extensive downward penetration of load structures, and incipient asymmetric slump folding of laminae. Normal grading suggests that at least some of the detrital material in these rocks was brought in by the action of low-density turbidity currents. Nevertheless, the abundance of fine-scale parallel lamination, as seen close to the Trig Point, may indicate a significant contribution of pyroclastic material in the form of fine-ash that settled through the water column after being carried in ash clouds from the north-west Charnwood volcanic source region(s).

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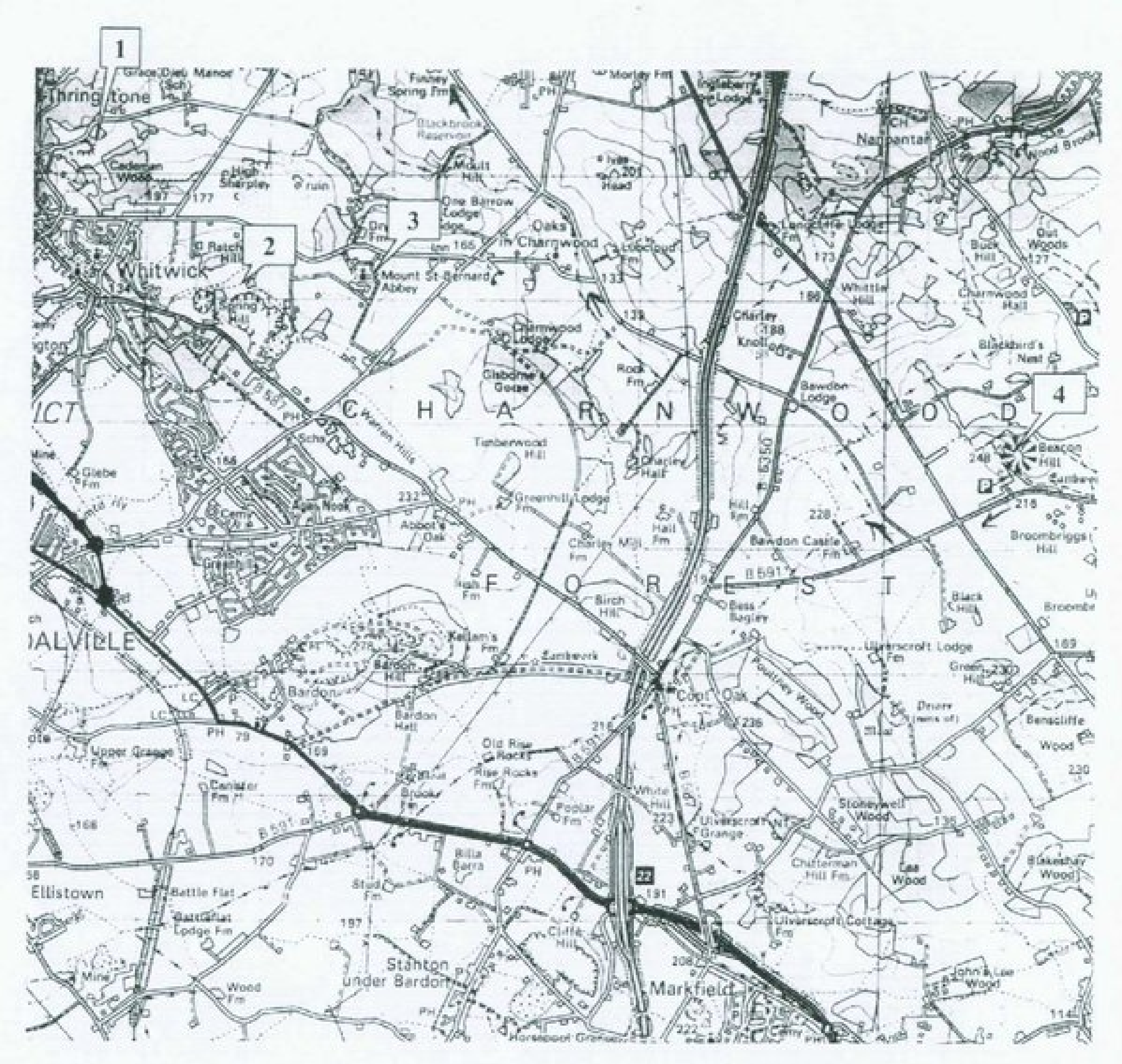
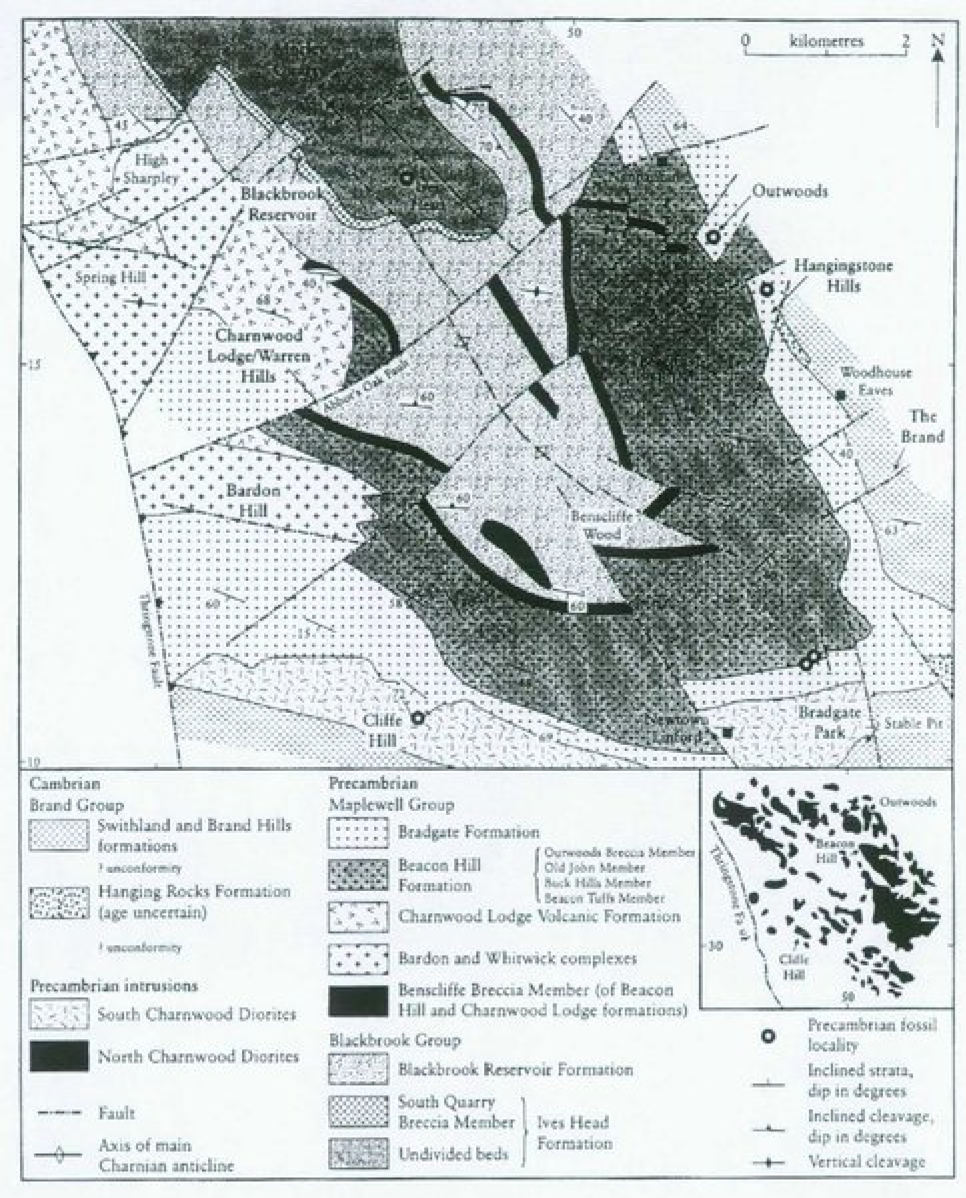
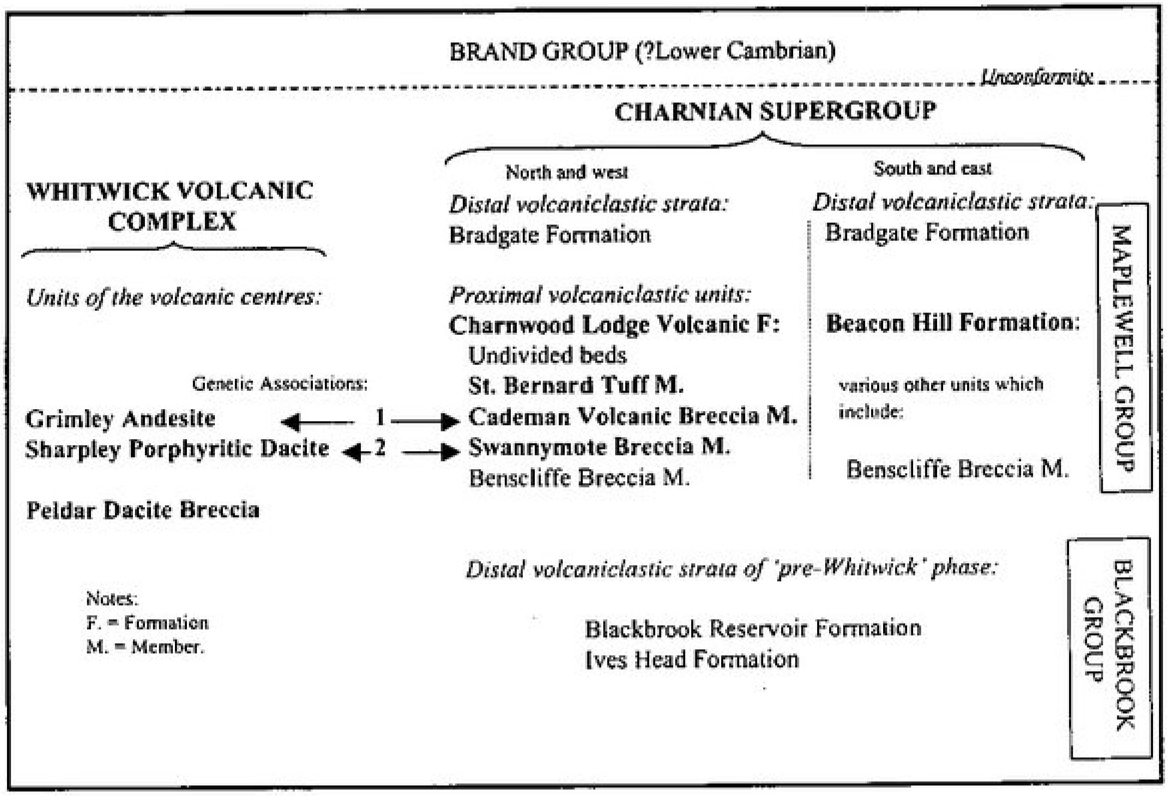


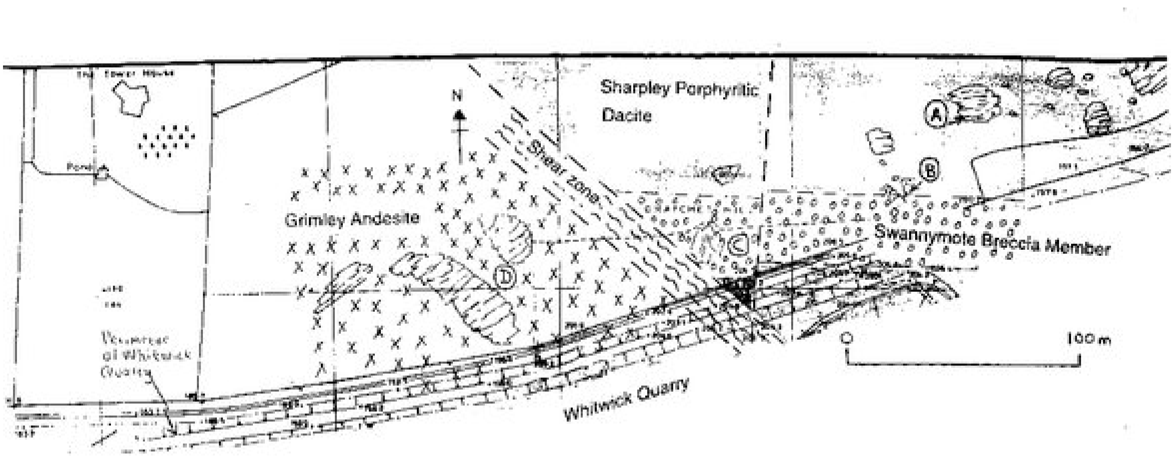
(Figure 1). Route map showing localities to be visited. This map is used with the permission of the Controller of Her Majesty's Stationery Office.



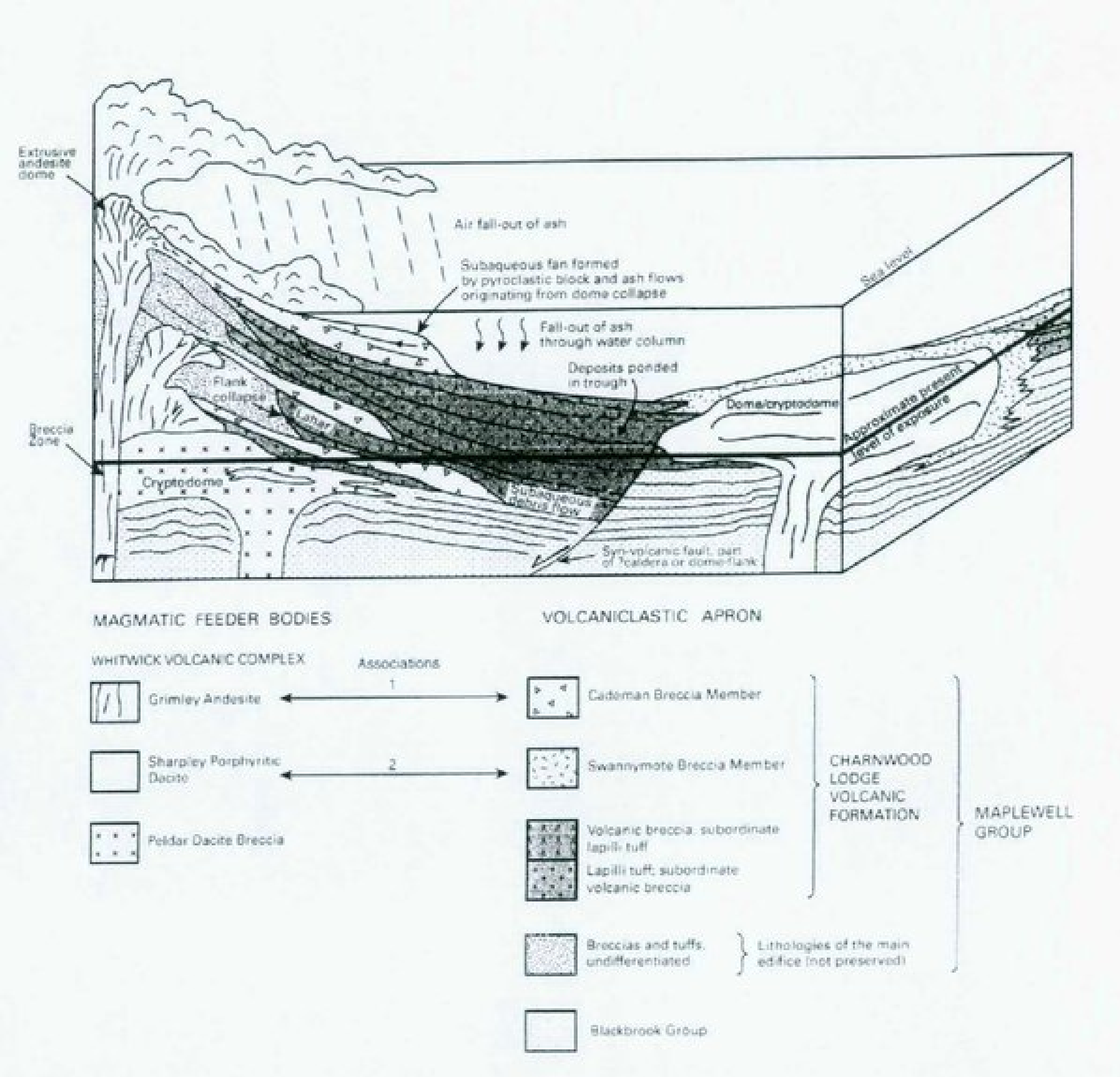
(Figure 2) Simplified geology of the Charnian Supergroup. The inset shows the actual Charnian outcrops (black shading), surrounded by Triassic strata. The extent of these outcrops is further reduced by a covering of Quaternary deposits (not shown).



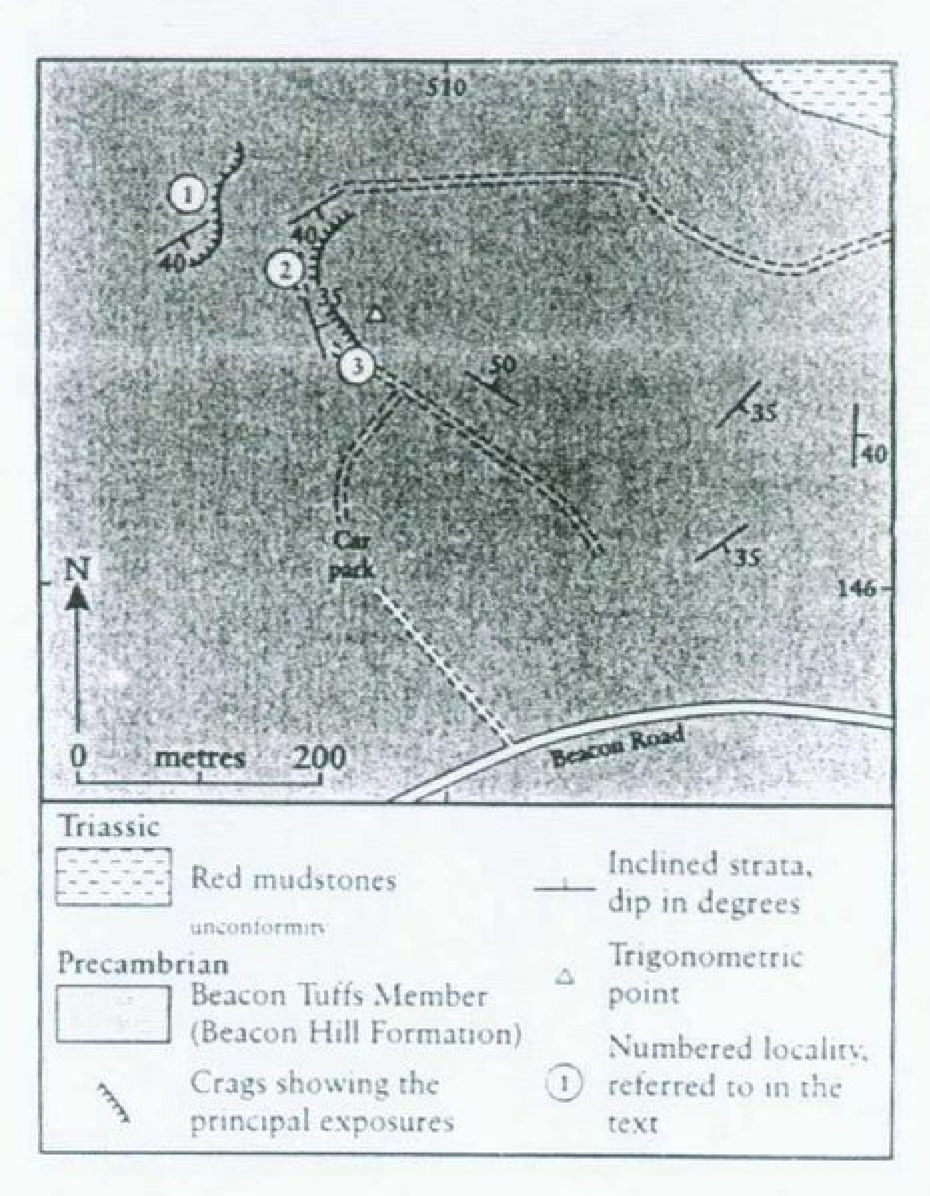
(Figure 3) Correlations and outline interpretations of selected Precambrian rocks. Those units of particular relevance to this excursion are highlighted in bold (from Carney, in press).



(Figure 4) Geology of Ratchet Hill, NW Charnwood Forest.



(Figure 5) Simplified model showing the range of volcanic and depositional processes occurring at a hypothetical point in time, during late Precambrian matImatism in north-western Charnwood Forest (from Carney. in press).



(Figure 6) Geological sketch map of Beacon Hill.