Bradgate Park

[SK 535 115]

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Introduction

Bradgate Park is a local conservation area consisting of rolling heathland studded with craggy knolls. Its size ((Figure 2.8), p. 34), and the fact that it contains palaeontological localities of international importance (Chapter 8), justify its selection as one of the principal Charnwood Forest GCR sites. In addition, many of its exposures serve as type sections for units within the Maplewell Group and overlying Brand Group. Intrusions belonging to the South Charnwood Diorites (see 'Introduction', this chapter) occur in the south of the site, but their contacts with the adjacent stratiform sequence are unexposed. The site occupies a structural position close to the hinge zone of the main Charnian anticline (Figure 2.1), and is one of the few areas of Charnwood Forest suitable for demonstrating geometrical relationships between folds mapped at outcrop scale and the regional Charnian cleavage.

The importance of this site is reflected by its frequent mention in the geological accounts of Charnwood Forest by Watts (1947), Moseley and Ford (1985, 1989) and Worssam and Old (1988). The principal reference works are the two guides to Bradgate Park by Sutherland *et al.* (1987, amended and reprinted in 1994), but there has since been a review of the stratigraphy and age of the Brand Group (Bland and Goldring, 1995; McIlroy *et al.,* 1998). Consequently, the strata of the Brand Hills Formation, exposed within the Stable Pit at Bradgate Park, are possibly referable to the Lower Cambrian. For this reason the Stable Pit is elevated to individual GCR site status and is described, together with other 'Charnian' strata of probable Cambrian age, later in this volume (Chapter 9).

Description

The oldest unit at the site is the *c.* 330 m-thick Old John Member of the Beacon Hill Formation. Its type section occurs on the crags (Locality 1, (Figure 2.8); [SK 525 113]) surmounting the hill crowned by the Old John Tower (Moseley and Ford, 1985). These exposures are in parallel-laminated to medium-bedded alternations of volcaniclastic mudstone, siltstone and sandstone. The commonest sedimentary structures are graded bedding and soft-sediment deformation, the latter seen as gently wavy bedding, rafted and truncated laminae, and spectacular load structures involving sand-grade material penetrating for up to 0.1 m into underlying mudstone or siltstone beds.

The junction between the Old John Member and overlying Bradgate Formation is defined by the base of the Sliding Stone Slump Breccia, whose middle to upper parts are exposed at the Memorial Crags (Locality 2;[SK 5237 1097]). This exposure also demonstrates the history of sedimentation of strata underlying the prominent bedding plane that contains the Precambrian fossils described in Chapter 8. The 5.5 m-thick bed forming the base of this sequence constitutes the breccia component; it consists of grey, very coarse-grained to granule-grade volcaniclastic sandstone with, near the exposed base, rafts of highly contorted mudstone or siltstone. The bed loses its sedimentary clasts and fines upwards to a 0.25 m-thick bed of massive sandstone. This is succeeded by *c.* 2.8 m of parallel-laminated to thinly bedded volcaniclastic mudstones and siltstones containing sporadic sharp-sided beds of massive sandstone. A further graded sedimentary cycle occupies the upper *c.* 1.6 m of the crag; it commences with graded, laminated volcaniclastic sandstone and culminates in exceptionally well-laminated siltstones and mudstones, with slight normal grading, capped by the fossiliferous bedding plane (Figure 2.9).

The most spectacular development of the Sliding Stone Slump Breccia occurs at the type locality (Locality 3; [SK 5309 1134]) and is described in some detail by Moseley and Ford (1989, fig. 6). It is composed of abundant contorted sedimentary rafts, some up to 0.6 m long (Figure 2.10), separated by irregular zones consisting of coarse-grained volcaniclastic sandstone devoid of such clasts. The sequence fines upwards, over 9 m, to a prominent bedding plane, but this is too fractured and cleaved to show whether fossils are present.

Intermittent exposures of the *c.* 500 m-thick Hallgate Member, basal to the Bradgate Formation, occur to the south of Locality 3. This unit is predominantly composed of fine-grained, parallel-laminated to medium-bedded, volcaniclastic lithologies, with further beds of sediment-raft breccia ('slump breccia') near the base.

Grading within this sequence is displayed at Locality 4 [SK 5315 1113], by repetitive normal grading in successive beds; each graded unit commences in very coarse-grained to granule-grade volcaniclastic sandstone that passes upwards into massive or poorly laminated fine-grained sandstone. In the same 1.5 m-thick sequence, the stratigraphically higher graded beds are thinner and commonly lack a coarse-grained basal layer.

Locality 5 [SK 5424 1100] exposes the Hanging Rocks Formation, defining the base of the Brand Group; better exposures of this unit occur at the Outwoods–Hangingstone Hills GCR site (this chapter). At Bradgate Park, the principal controversy revolves around the low topographical position of the Hanging Rocks Formation, relative to older strata of the Hallgate Member (Bradgate Formation), which occur on the hillside several metres above. The two alternative explanations for these field relationships, discussed in Sutherland *et al.* (1994), were that either this conglomerate lies within the Hallgate Member (and is therefore unique), or that it belongs to the Brand Group but occupies a channel cut into the member. A third explanation suggested here is that this limited exposure forms part of a faulted inlier of the Brand Group. The 3–4 m of exposed strata mainly consists of conglomerate with rounded to subangular clasts ranging from granules to pebbles of 20 mm size; the interstitial matrix is of coarse-grained, poorly sorted sandstone. Clasts of pale to dark grey mudstone occur near the top of the conglomerate. Particularly large pebbles, up to 80 mm across, are common in the lower 1.5 m of the conglomerate; they mainly consist of pink to cream, fine-grained tuff. The conglomerate shows a steeply dipping junction with grey, poorly sorted, medium- to coarse-grained, volcaniclastic sandstone containing thin pebbly lenticles. The roundness of these pebbles indicates that this sandstone is part of the Hanging Rocks Formation, rather than representing substrate of the Hallgate Member. This '2-D' exposure does not allow bedding dip to be estimated; however, a steep dip away from the observer (i.e. to the north-east) could be in keeping with the slope of the sandstone–conglomerate contact. A preferred orientation of spindle-shaped conglomerate pebbles defines a fabric dipping at about 75° to the NNW This is almost certainly not depositional but is due to stretching associated with development of the local cleavage.

At Locality 6 [SK 5405 1085] a gently folded sequence of volcaniclastic, turbidite-facies mudstones, siltstones and sandstones demonstrates refraction of the main Charnian cleavage (Sutherland *et al.,* 1994). At outcrop the cleavage trace appears to be broadly axial planar with the *c.* 90° trend of a minor synclinal axis. However, when bedding dips and cleavage orientations from this locality are plotted stereographically, it is apparent that the mean cleavage pole is offset in an anticlockwise sense from the fold-girdle representing the best-fit to bedding poles, the angle of offset being 8°. Moseley (1979) had earlier described transection of folds by cleavage throughout most of Charnwood Forest, inferring that the formation of cleavage post-dates the development of the folds.

Isolated exposures of intrusive rocks belonging to the South Charnwood Diorites ('markfieldite') occur near Bradgate House (Locality 7; [SK 5337 1013]). The smoother surfaces show the medium- to coarse-grained, inequigranular textures and mottled appearance that is typical of this lithology. The pale green rectangular crystals consist of partly albitized and epidotized plagioclase feldspars, and dark grey areas represent aggregates of mafic minerals (mainly secondary amphiboles and chlorite). They are enclosed within pale pink, fine-grained areas representing interstitial granophyric intergrowths of quartz and K-feldspar, described more fully in the section on the Cliffe Hill GCR site. The rocks are affected by systems of well-spaced, sub-horizontal joints but have resisted the cleavage formation defining the Acadian deformation (see 'Introduction' for the present chapter).

Interpretation

Bradgate Park, with its numerous accessible exposures, is an important area in which to study the sedimentology of the Beacon Hill and Bradgate formations (e.g. Sutherland *et al.,* 1994; Moseley and Ford, 1989). The fossils found at certain levels within this succession indicate deposition of these strata in a marine environment. Although these rocks are commonly referred to as 'tuffs', a high degree of secondary reworking is indicated by the numerous examples of graded bedding; this feature suggests rapid deposition of material by turbulent, sediment-laden currents, to produce typical

'Bouma' turbidite sequences (Bouma, 1962). In this setting the superposition of coarse, sand-rich material over the muddy or silty top of an underlying graded bed can result in a reverse density gradient and this may favour the formation of downward-penetrating load structures within the unconsolidated sediment pile. A pulsed sediment supply is further demonstrated, by sequences showing repetitive normal grading and coarse-tail grading (Middleton and Hampton, 1976), the latter seen at Locality 3 where only the coarse-grained fraction shows a vertical variation. Turbidite beds characterized by a thick, coarse-grained basal facies (Bouma division A) reflect proximity to the source region according to Walker (1967), the principal example being the Sliding Stone Slump Breccia Member. Sutherland *et al.* (1994) noted that although the matrix of this unit is composed almost exclusively of volcanic clasts, juvenile pyroclastic material (vitric constituents and some of the crystals) probably amounts to only half of the fragments. They concluded that the breccia did not originate as a pyroclastic flow but was more likely to have been a subaqueous sediment gravity flow, with a debris-flow component represented by the sediment rafts. The Hanging Rocks Formation is the first unit of the Charnwood Forest sequence to show rounded pebbles and is inferred to be unconformable or disconformable upon the Hallgate Member; its origin is discussed further in the section on the Outwoods–Hangingstone Hills GCR site.

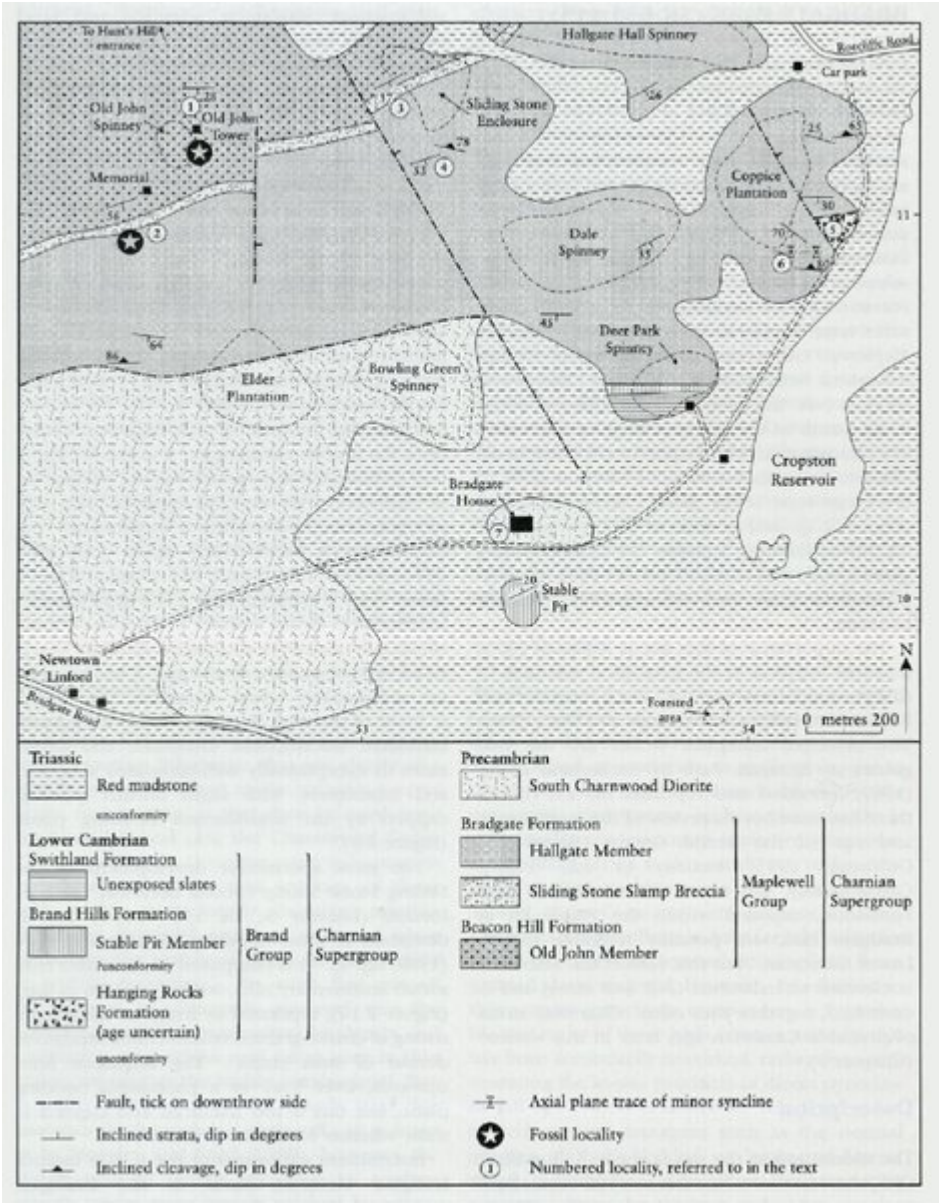
The relationship of the South Charnwood Diorites to the other lithologies of Bradgate Park cannot be conclusively demonstrated from the outcrops at this particular site (but see the section on Cliffe Hill). Sutherland *et al.* (1994) note that at a location close to the contact, south of the Memorial Crag (Locality 2), there is no evidence of hornfelsing of the sedimentary sequence, suggesting a faulted junction.

The Acadian age of the cleavage, and the regional tectonic implications of the anticlockwise cleavage–fold transection geometry seen at Bradgate Park, are discussed in the introductory section to this chapter.

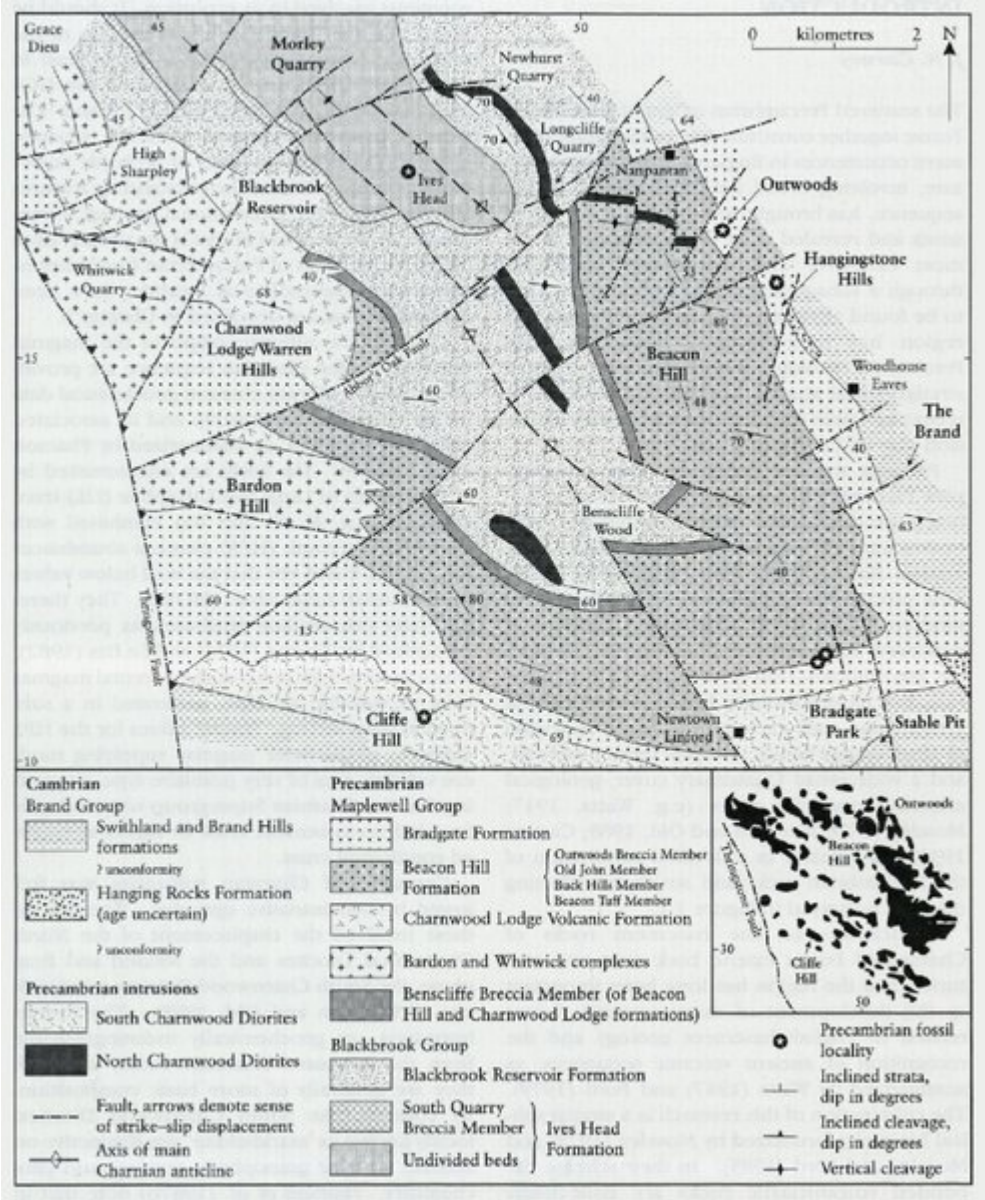
Conclusions

Bradgate Park contains unrivalled exposures demonstrating the high degree of 'reworking' of sedimentary material within the basin that accumulated the Beacon Hill and Bradgate formations. Deposition was entirely subaqueous and mainly involved the turbulent flow of unconsolidated sediment under the influence of gravity, with a relatively minor contribution by direct primary pyroclastic fall-out or pyroclastic flows. Turbidity currents were active throughout deposition of the sequence, but the Sliding Stone Slump Breccia represents a particularly important episode of instability that produced debris flows derived from the mobilization and subsequent collapse of previously deposited strata. Quiescent conditions prevailing at the end of this event were favourable to the preservation of the delicate, frondose fossils described in Chapter 8. The Bradgate Park succession records, at its very top, a dramatic sedimentary change to conglomerates with well-rounded pebbles in the Hanging Rocks Formation. The final phase of Charnian magmatic activity is represented by intrusions of the South Charnwood Diorites. A penetrative cleavage occurred much later, during the Acadian orogeny, in early Palaeozoic times. The cleavage transects local folds, rather than striking parallel to their axes, suggesting that the deformation was transpressive, with strike-slip and compressional components.

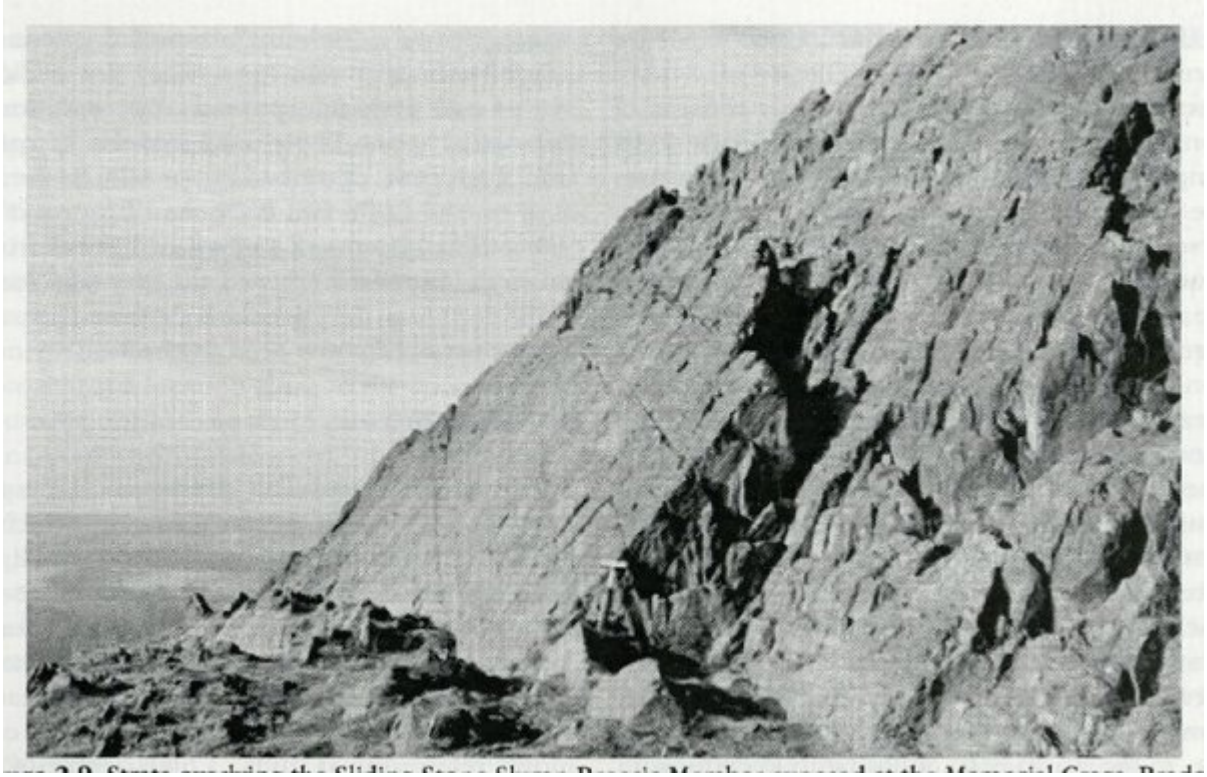
References



(Figure 2.8) Geological map of the Bradgate Park site, adapted from Sutherland et al., (1994) and Kelk and Old (1982).



(Figure 2.1) Geological map of Precambrian and Cambrian rocks in Charnwood Forest, showing the locations of the GCR sites (in bold lettering). Note that younger rocks are omitted for clarity. The inset shows the actual extent of the 'basement' inliers (dark shading) between this younger cover. The latter mainly consists of Triassic strata, with Coal Measures included to the west of the Thringstone Fault; extensive veneers of Quaternary drift are also present (modified from Worssam and Old, 1988).



(Figure 2.9) Strata overlying the Sliding Stone Slump Breccia Member exposed at the Memorial Crags, Bradgate Park, showing the prominent bedding plane (to left) on which occur fossil impressions (see also, Chapter 8). (Photo: J.N. Carney)

(Figure 2.10) Detail of the Sliding Stone Slump Breccia exposed near Sliding Stone Spinney, Bradgate Park, showing tight packing and chaotic orientation of laminated siltstone rafts. (Photo: J.N. Carney.)