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# Wetton to Beresford Dale, Staffordshire–Derbyshire

[SK 095 549]–[SK 095 561]–[SK 131 584]–[SK 127 592]

## Introduction

The complex Wetton to Beresford Dale GCR site on the north Staffordshire–Derbyshire border offers a unique opportunity to examine the relationships between Lower Carboniferous rock formations deposited in a wide range of sedimentary environments both within the North Staffordshire Basin and in close proximity to its north-eastern margin. It includes both a deep-water 'knoll reef' (carbonate mud-mound) facies and an 'inter-reef' ('bedded') facies in the Milldale Limestones (Chadian), a deep-water turbidite facies in the Ecton Limestones (mainly post-Chadian) and a shallow-water 'knoll reef' facies of the Hopedale Limestones which extends into an 'apron-reef' facies of the Bee Low Limestones (both Asbian), the post-Chadian turbidite facies and reef facies developing respectively some distance from and close to the margin of the North Staffordshire Basin as the Derbyshire shelf area became established to the north-east of the basin in later Dinantian times.

The site (formerly referred to as the 'Wetton–Grafton' GCR site) extends for approximately 6 km from the cliffs and caves of the Manifold Valley [SK 095 549]–[SK 095 561] near Wetton in the south-west, to the valley-side crags of Beresford Dale [SK 127 592]–[SK 131 584] in the Dove Valley and Pennilow [SK 1289 5950], near Hartington, in the north-east (Figure 7.26). It also includes the scattered hillside exposures that extend eastwards from Wetton Hill, recognized here as two separate hill features, namely Wetton Hill East [SK 1130 5658] and Wetton Hill West [SK 1049 5627] following the terminology of Aitkenhead *et al.* (1979), to Gratton Hill [SK 1320 5715] and the outlying outcrops at Swainsley [SK 0937 5763], Ecton Bridge [SK 0950 5818]–[SK 0910 5794] and Apes Tor [SK 0999 5868].

Although significant contributions to our understanding of the site geology were made by Parkinson (1950a), Prentice (1951) and Parkinson and Ludford (1964), these works have largely been superseded by the more comprehensive and modern accounts of Aitkenhead *et al.* (1985) and Chisholm *et al.* (1988) in the Buxton and Ashbourne [British] Geological Survey memoirs. In addition, areas of the site, and in particular the Chadian–Asbian 'knoll reef' limestones, have proved a rich hunting ground for palaeontologists, and records of their findings appear in numerous publications (e.g. Davidson, 1851–1886; Carrington, 1865; Brunton and Champion, 1974; Brunton and Mundy, 1986, 1988a, 1993, 1994, 1997; Tilsley, 1988; Riley, 1991). A further work of significance is the detailed sedimentological and palaeoecological study of the Chadian 'knoll reef' facies by Morgan (1980).

## Description

At this locality, as at Dovedale (see GCR site report, this chapter), the Milldale Limestones are represented by a 'knoll reef' facies and an 'inter-reef' or 'bedded' facies (Aitkenhead *et al.*, 1985; Chisholm *et al.*, 1988). Detailed sedimentological work by Lees *et al.* (1985), Lees and Miller (1985) and Bridges and Chapman (1988) considered the 'knoll reefs' of the Milldale Limestones as representing deep-water carbonate 'mud-mounds' rather than reefs and this terminology is adopted in the following account.

Chisholm *et al.* (1988) estimated that the Milldale Limestones are around 218 m thick in the Manifold Valley area, with much of this thickness (c. 75%) being represented by the 'mud-mound' facies. The principal outcrops of this facies occur as composite developments in the core and flanks of the Ecton Anticline (Figure 7.26). The larger of these developments to the west, extends from the southern slopes of Ecton Hill in the north, via Sugar Loaf [SK 0980 5680], Wettonmill [SK 0957 5611] and the eastern slopes of Ossoms Hill to Thors Cave [SK 0982 5496] and Ladyside Wood [SK 0950 5496] in the south. A smaller and slightly younger complex to the east encompassing Wetton Hill West (Aitkenhead *et al.*, 1979, 1985) is partly disrupted by faults that form part of the Manifold Valley Fault plexus (Chisholm *et al.*, 1988). The discovery of a late-Chadian macrofauna from an isolated outcrop on Wetton Hill East by Tilsley (1988) and Riley (1991) indicates that the Chadian mud-mound facies extends farther to the east than is indicated on [British] Geological Survey maps of the area (Institute of Geological Sciences, 1978).

The mud-mound facies comprises massive and poorly bedded micrites with stromatactoid cavities and a macrofauna of brachiopods, fenestrate bryozoans, crinoids, trilobites and ammonoids together with a few corals and nautiloids. Typically these occur either scattered throughout the mud-mound structures or concentrated in isolated pockets within their fabric. Sponge remains, foraminifera and ostracodes also occur in this facies (Ludford, 1970; Bridges and Chapman, 1988).

A Chadian age for the bulk of the mud-mound facies is indicated by the presence of trilobite and ammonoid assemblages that include *Namuropyge decora*, *N. glaphra*, *Bollandia columba*, *Phillibole* cf. *nitidus*, *Phillibolina worsawensis*, *Reediella reedi*, *Weania feltrimensis*, *Winterbergia hahnorum*, *Dzhaprakoceras*, *Rotopericyclus*, *Ammonellipsites* and *Helicocyclus* (Tilsley, 1988; Riley, 1991). Courceyan conodonts and Arundian corals are also reported from this facies (Aitkenhead *et al.*, 1985) but later work by Chisholm *et al.* (1988) has cast doubt on the significance of some of this conodont evidence.

The 'bedded' facies of the Milldale Limestones comprise crinoidal calcarenites and calcisiltites with shaly interbeds and minor developments of dark cherry micritic limestone (Aitkenhead and Chisholm, 1982). This facies is particularly well developed in the core of the Ecton Anticline east of Wettonmill [SK 0984 5607] and either side of the mud-mound at Thors Cave — i.e. both below it, in the bed of the Manifold River, and above it in the cutting of the disused railway line at Ladyside Wood (Prentice, 1951; Chisholm *et al.*, 1988) (Figure 7.27). Although macrofossil and microfossil evidence indicates a Chadian age for the 'bedded' facies at this site, elsewhere the facies is reported to range up into the Asbian (Aitkenhead *et al.*, 1985; Chisholm *et al.*, 1988). The occurrence of *Lamdarina manifoldensis* in a rare and silicified brachiopod assemblage found locally (Brunton and Champion, 1974) confirms the Chadian age suggested for parts of this facies.

Formations lying stratigraphically above the Milldale Limestones include the Ecton Limestones to the north and west, and the Hopedale Limestones to the south and east. Although across much of their outcrop area these younger formations appear to be of Asbian age, faunas as old as the Chadian (some possibly reworked) have been recorded from both of them (Chisholm *et al.*, 1988), and their precise stratigraphical relationship to the underlying Milldale Limestones remains uncertain. Whereas an unconformity between the Milldale Limestones and these younger formations is either present or suspected in certain areas, the boundary between the Milldale Limestones and the Ecton Limestones is at least partly diachronous (Chisholm *et al.*, 1988).

The Ecton Limestones (c. 225 m thick) comprise a turbiditic sequence of sharp-based, graded and locally conglomeratic, peloidal bioclastic limestones (some cherry) with sparse developments of dark, laminated and locally bioturbated micritic limestones with shaly interbeds. At Swainsley, a 45 m section near the middle of the formation showing both these lithofacies includes, in the lower and coarser part of the succession, both an Arundian micro-fauna and a detached limestone block approximately 4 m across containing attached productoids, pseudomonotids and large cavity-dwelling myodocopid ostracodes — an assemblage typical of the shallow-water microbial framework facies of Asbian reefs (Mundy in Aitkenhead *et al.*, 1985; and see Chapter 5). The contact between the Milldale Limestones and Ecton Limestones is exposed at Ladyside Wood where a prominent (1.75 m) and erosively based graded bioclastic limestone occurs at the base of the formation (Figure 7.27). A late Chadian age for the Ecton Limestones here is supported by foraminiferal and trilobite evidence (Chisholm *et al.*, 1988). The same formation boundary is also exposed in the disused railway cutting close to Ecton Bridge (SK 0950 5818–SK 0910 5794; the type section of the Ecton Limestones) where foraminiferal evidence indicates the lower part of the Ecton Limestones to be of Arundian age, despite the presence of a coral assemblage of Asbian aspect (Aitkenhead *et al.*, 1985). A further exposure of the Ecton Limestones is at Apes Tor where the turbiditic sequence is strongly folded in the hinge zone of the Ecton Anticline.

The Hopedale Limestones (the lateral facies equivalent of the Ecton Limestones) comprise a well-bedded, coarsely crinoidal and peloidal calcarenite sequence with some sharp-based limestone conglomerate units. The only significant section is in a disused quarry [SK 1070 5568] 250 m north-west of Wetton; one of four 'type sections' designated for the Hopedale Limestones by Aitkenhead and Chisholm (1982). The sequence here contains an Asbian–early Brigantian coral fauna and is approximately 11 m thick (Aitkenhead *et al.*, 1985).

To the north-east, between Pennilow and Gratton Hill, an 'apron-reef' complex of Asbian age marks the position of the North Staffordshire Basin-Derbyshire Platform margin. The lateral transition across the platform margin can be examined in Beresford Dale. Here the 'platform' facies (Bee Low Limestones), represented by massively bedded crinoidal

biosparites containing possible gigantoproductids, is seen to pass westwards into a 'fore-reef' facies of obscurely bedded biomicrites (Aitkenhead *et al.*, 1985).

An extension of this reef complex to the west, away from the platform margin, is represented by a 'knoll reef' facies in the Hopedale Limestones at Gratton Hill, Narrowdale Hill [SK 1233 5723], Gateham Hill [SK 1152 5704] and parts of Wetton Hill East. A rich macrofauna reported from this facies is dominated by brachiopods (Prentice, 1951; Brunton and Mundy, 1986, 1988a, 1993, 1994, 1997) but also include trilobites (Tilsley, 1988), bivalves, corals, bryozoans, ostracodes and sparse goniatites (Prentice, 1951; Aitkenhead *et al.*, 1985). An upper B<sub>2</sub> or late Asbian age for the bulk of this facies is supported by the presence of beyricho-ceratid goniatites, *Bollandoceras cf. micronotum* and the trilobites *Bollandia obseleta*, *Piltonia bumilis* and *Reediella granifera* (Bisat, 1934; Aitkenhead *et al.*, 1985; Tilsley, 1988).

The occurrence of both Chadian and Asbian faunas at Wetton Hill East together with field evidence provided on [British] Geological Survey maps of the area (Institute of Geological Sciences, 1978) indicates the presence of an unconformity between the Chadian mud-mound facies and the Asbian 'knoll reef' facies, and that the younger 'knolls' may have been rooted (at least in part) on the upstanding remnants of the older Chadian mud-mounds.

## Interpretation

Regional stratigraphical and geophysical studies suggest that the Milldale Limestones (mainly Chadian) of the North Staffordshire Basin and Widmerpool Gulf areas were deposited on a gently sloping carbonate ramp above a basement 'tilt-block' that dipped to the south or southwest (Smith *et al.*, 1985; Chisholm *et al.*, 1988). Detailed sedimentological work by Lees and Miller (1985) indicated that the deep-water carbonate mud-mounds formed principally as a result of microbial activity and that the 'buildups' of the Manifold Valley area, including the Thors Cave development, were deposited in water depths of 220–280 m. For further details on the origin and development of these 'Waulsortian' carbonate mud-mounds, see the Dovedale GCR site report (this chapter).

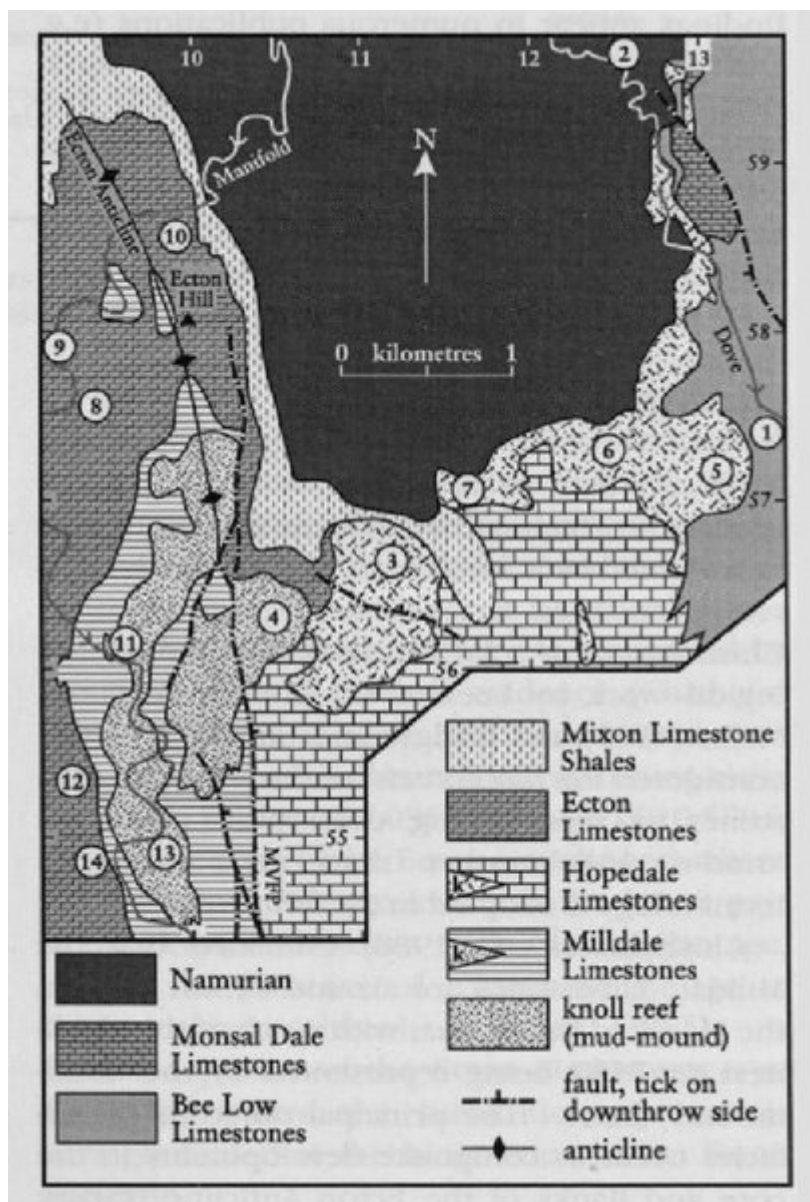
Towards the end of Chadian times, a period of crustal instability; possibly associated with movements of the underlying 'tilt-block', or a sea-level change, triggered gravity flows within the basin — an event that marked the onset of turbidite deposition at the base of the Ecton Limestones and Hopedale Limestones. This pattern of sedimentation continued into Asbian times (Chisholm *et al.*, 1988). By this time, the North Staffordshire Basin had become clearly differentiated from the Staffordshire Shelf and Derbyshire Platform areas, the margins of which are defined by the development of an apron-reef facies seen to the south-west in the Weaver Hills district (bordering the Staffordshire Shelf) and to the north-east (at this site) in Beresford Dale (bordering the Derbyshire Platform). The latter forms part of a discontinuous apron-reef development that extends around the western and northern margins of the Derbyshire Platform. The significance of this facies is discussed more fully in connection with Castleton (see GCR site report, this chapter) where it is better developed.

The Asbian 'knoll reef' extension to the Beresford Dale apron reef developed in an area of mixed water depth where the narrow seaway separating the Derbyshire Platform and Staffordshire Shelf is at its narrowest. In the current-swept 'channels' between the knoll reefs, the Hopedale Limestones were deposited as an 'inter-reef' facies (Aitkenhead *et al.*, 1985) possibly by occasional storm-generated gravity flows. In deeper-water areas to the west, the turbiditic Ecton Limestones continued to be deposited. Sequence thickness trends in the Manifold Valley area and the presence of a detached block of ?Asbian reef limestone in the Ecton Limestones at Swainsley are cited by Chisholm *et al.* (1988) as possible evidence of syn-sedimentary growth faulting along the line of the N–S-orientated 'Manifold Valley Fault plexus'. In this context it is perhaps significant that the line of this fault plexus appears to separate the entire outcrop area of the deep-water Ecton Limestones in the west, from that of the relatively shallow-water Hopedale Limestones and Asbian 'knoll reefs' developed to the east, and where an unconformity exists between the Asbian 'knoll reefs' and the underlying (older) Chadian mud-mound complex. Together these features are attributed to a period (or possibly several periods) of uplift and faulting centred upon the Manifold Valley Fault plexus during the Chadian–Asbian time interval. The faulting in this region most probably occurred as an antithetic response to similar displacements occurring along the line of the Lask Edge Fault (Lee, 1988a; and see (Figure 7.2)) at the western margin of the North Staffordshire Basin, as crustal extension led to rifting and subsidence of the basin at this time.

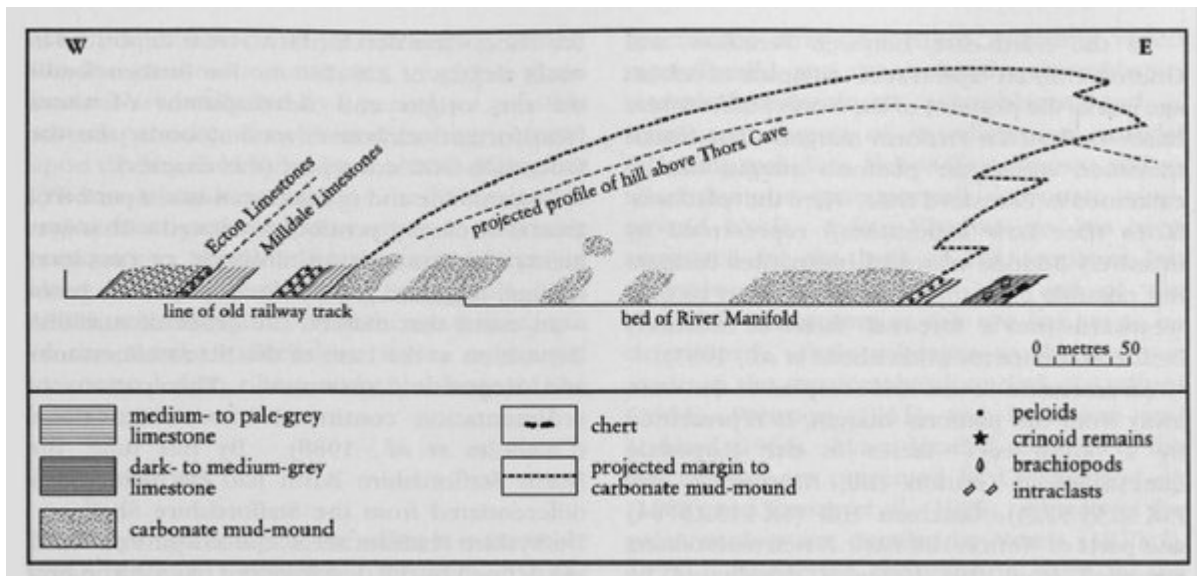
## Conclusions

This large and complex site offers a remarkable and unique transect through Lower Carboniferous strata formed in a variety of sedimentary environments close to and across the North Staffordshire Basin-Derbyshire Platform margin during the Chadian to Asbian time period. The vertical transition from deep-water carbonate mud-mound facies (Milldale Limestones) into shelf apron-reef, knoll reef and inter-reef facies (Bee Low Limestones–Hopedale Limestones) and deep-water basinal facies (Ecton Limestones) marks a significant change in depositional setting from gently inclined ramp to rimmed shelf as the Derbyshire shelf area became clearly differentiated from the North Staffordshire Basin and Widmerpool Gulf during Asbian times. The site includes a fascinating mix of many different sedimentary rock types (some extremely fossiliferous) in an area of considerable structural complexity and where the age of certain parts of the succession remains contentious. For these reasons the site will remain invaluable to future biostratigraphical and sedi-mentological research work for many years.

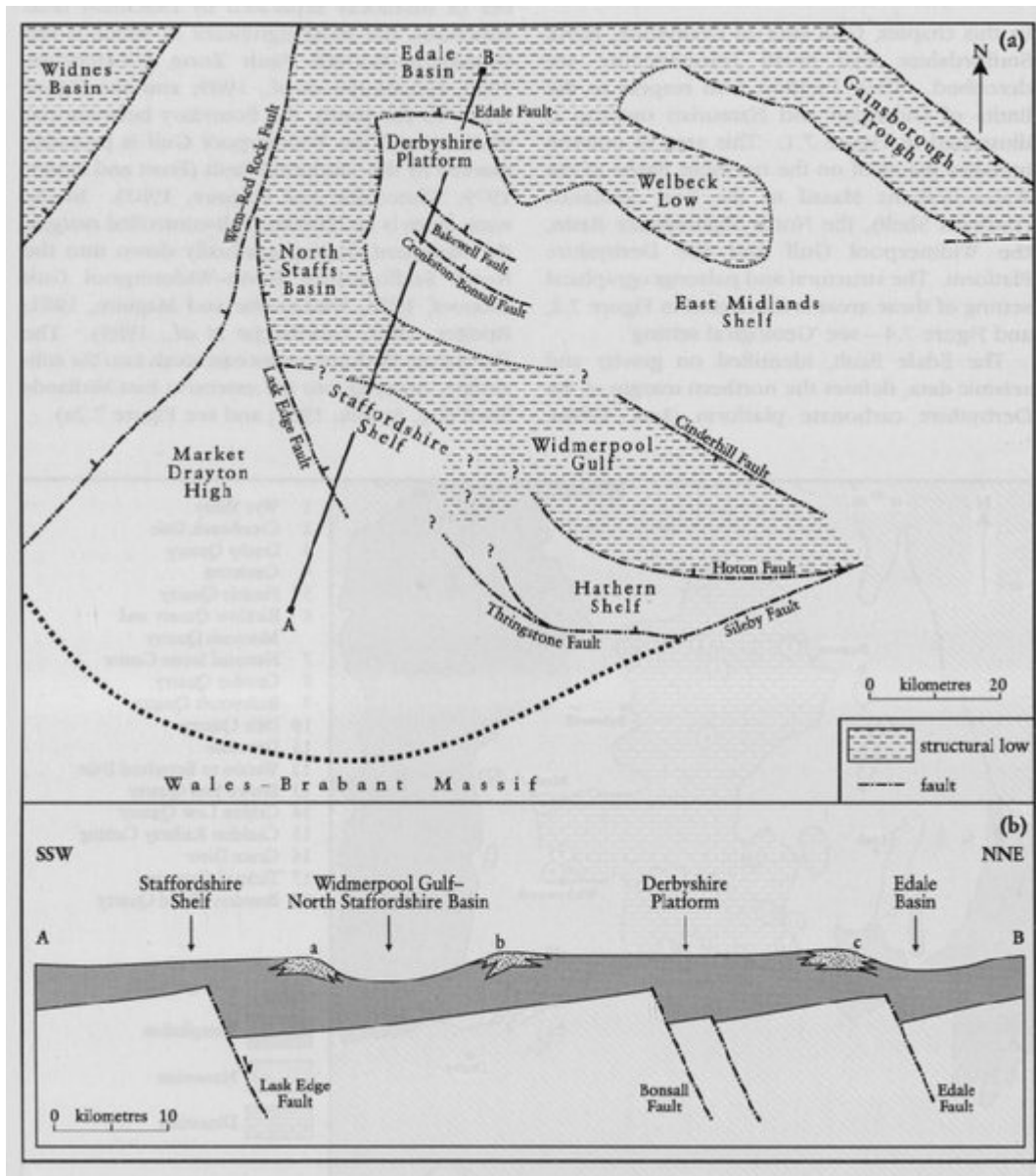
## References



(Figure 7.26) Simplified geological map of the Wetton to Beresford Dale GCR site, showing the distribution of 'knoll reef' facies (k) both in the Milldale Limestones (carbonate mud-mound facies) and in the Hopedale Limestones. Also shown are the positions of localities referred to in the text: 1- Wolfscote Dale; 2 — Beresford Dale; 3 — Wetton Hill East; 4 — Wetton Hill West; 5 — Gratton Hill; 6 — Narrowdale Hill; 7 — Gateham Hill; 8 — Swainsley; 9 — Ecton Bridge; 10 — Apes Tor; 11 — Wettonmill; 12 — Ossoms Hill; 13 — Thors Cave; 14 — Ladyside Wood; MVFP — Manifold Valley Fault Plexus. After the [British] Geological Survey map of the Buxton district (Institute of Geological Sciences, 1978).



(Figure 7.27) Sketch cross-section through the Thors Cave carbonate mud-mound from Ladyside Wood [SK 0947 5487] to the bed of the River Manifold [SK 0988 5509]. After Chisholm et al. (1988).



(Figure 7.2) (a) Structural setting and palaeogeography of central England during Early Carboniferous times. (b) Schematic section of the line A-B marked in (a) illustrating the possible basement structure to the Derbyshire Platform, North Staffordshire Basin-Widmerpool Gulf and Staffordshire Shelf during late Dinantian times. Above this basement

*structure the approximate locations of Asbian reef developments are shown: a — Weaver Hills; b — Earl Sterndale-Wirksworth margin; c — Castleton. Vertical scale schematic. Based on information in Smith et al. (1985), Gutteridge (1987), Chisholm et al. (1988), Lee (1988a), Gawthorpe et al. (1989), Ebdon et al. (1990), Fraser and Gawthorpe (1990), Corfield (1991), Corfield et al. (1996) and Rees and Wilson (1998).*