Castleton, Derbyshire

[SK 132 832]–[SK 149 824] and [SK 126 830]

Introduction

The Castleton GCR site is a classic Lower Carboniferous site in north Derbyshire. It provides a unique opportunity for the examination of highly fossiliferous apron-reef limestones formed at the northern margin of the Derbyshire Platform during late Dinantian (Asbian) times; arguably the finest and most intensively studied apron-reef complex of Early Carboniferous age in Britain. Important accounts of the stratigraphy of the area are by Shirley and Horsfield (1940), Ford (1952) and Parkinson (1943, 1947, 1953, 1965) and Stevenson and Gaunt (1971). The anatomy, development and palaeoecology of the reef complex has been described by Wolfenden (1958), Broadhurst and Simpson (1973) and Timms (1978). Aspects of the limestone diagenesis are detailed by Bingham (1992). An excellent overview of the site geology has recently been presented by Ford (1996).

Additional features of interest that make this one of the most popular destinations for educational field parties and tourists include the spectacular development of Pleistocene cave systems, some unusual mineral deposits, both disused and fully operational mineral workings (the latter most notably for the extraction of 'blue john' — a variety of the mineral fluorite) and the famous Mam Tor Landslip (Ford, 1996).

Description

The site, which occupies a 2.5 km strip of land west of Castleton village, extends from Cave Dale [SK 149 824] in the east, via Long Cliff [SK 140 825], Winnats Pass [SK 135 826], Treak Cliff [SK 135 830] and the Blue John Mine [SK 132 832] to Windy Knoll Quarry [SK 126 830] in the west (Figure 7.10). Enclosed within it are a range of sedimentary facies that illustrate the shelf-apron-reef-basin transition across the northern margin of the Derbyshire Platform during Asbian times.

Occupying the higher ground around Cave Dale and Winnats Pass, and forming an Integral part of the Deryshire Platform as far south as Hartington, are the massive and generally flat-lying beds of the Bee Low Limestones (shelf facies). This formation is of D_1 age (Stevenson and Gaunt, 1971). To the north-east, an apron-reef complex of B_2 age defines the position of the shelf margin separating the Derbyshire Platform from the Edale Basin (Stevenson and Gaunt, 1971; Gutteridge, 1991a, 1996). Although Shirley and Horsfield (1940) originally regarded the B_2 reef limestones as post-dating the D_1 shelf facies, and separated from them by an unconformity, later workers demonstrated the lateral continuity and equivalence of these two facies (Parkinson, 1943, 1947, 1953, 1965; Ford, 1952). Similarly, the relatively steep outward dip (up to 35°) to beds of the reef complex, once thought to be tectonic in origin (Green *et al.,* 1887; Fearnsides and Templeman, 1932), is now considered to be a depositional feature and the manifestation of an original reef palaeoslope at the platform margin flanking the Edale Basin to the north (Wolfenden, 1958; Broadhurst and Simpson, 1967). Remarkably, the original form of this Lower Carboniferous palaeoslope has been exhumed by recent erosion and is beautifully preserved in the hillside slopes of Treak Cliff and Long Cliff, which border the high ground shelf area between Main Tor and Castleton village (Figure 7.11).

The shelf facies (Bee Low Limestones) is characterized mainly by thickly bedded, pale-coloured, crinoidal grainstones, some with superficial ooids, marine cements and hydrocarbon residues, while others contain *Koninckopora,* locally in abundance. In Cave Dale, a prominent (7.5 m thick) olivine basalt (the Cave Dale Lava) occurs in the sequence. Macrofossils, mainly corals and thick-shelled brachiopods, are generally sparse with concentrations of fossils occurring in discrete bands. Two notable developments include, the Upper Davidsonina septosa Band recorded by Wolfenden (1958) from the Winnats Pass area approximately 50 m below the Cave Dale Lava, and the Lithostrotion aff maccoyanum Band of Shirley and Horsfield (1940), identified with some uncertainty by Stevenson and Gaunt (1971) in Cave Dale approximately 12 m above the Cave Dale Lava.

The terminology used here to describe the various apron-reef facies (i.e. back-reef, algal-reef and fore-reef) derives mainly from the work of Wolfenden (1958), with minor modifications by Stevenson and Gaunt (1971). The distribution of these facies and their three-dimensional relationship to each other are illustrated in (Figure 7.10) and (Figure 7.12).

The back-reef deposits comprise a variable facies with characteristics intermediate between those of the shelf and those of the algal-reef. A notable feature in this respect is the association of both thick-shelled brachiopods (typical of the shelf) and thin-shelled brachiopods (typical of the reef). Generally, the macrofossils here appear to be more common, larger and less fragmented than they are on the shelf. The occurrence of foraminifera, cyanobacteria and algae (*Koninckopora*) in abundance indicates formation in shallow water (Ford, 1996). The back-reef beds are gently inclined towards the shelf area.

The algal-reef comprises two discontinuous wall-like masses of pale micritic limestone with an organic framework composed of microbial stromatolites (of the '*Collenia–Cryptozoon*' type) with associations of *Girvanella, Ortonella* and *Aphrylasia* (Wolfenden, 1958). Additional elements of framework include the encrusting bryozoans *Fistulipora* and *Tabulipora* and the lithistid sponges *Haplistion* '*Radiatospongia*' *carbonaria* and *Scheiia 'Microspongia*' *castletonense* (Wolfenden, 1959; Mundy, 1994; Rigby and Mundy, 2000). Also present are large but isolated colonies of the lithostrotionid corals *Siphonodendron martini* and *S. pauciradiale* (Stevenson and Gaunt, 1971), the heterocorals *Hexaphyllia marginata* and *Heterophyllia ornata* (Cossey, 1997) and scattered concentrations of brachiopods, bivalves, gastropods and ostracodes. The abundance of *Girvanella* and microbial structures (Wolfenden, 1958) supports the view of this being the shallowest facies of the reef-belt and of deposition in the upper levels of the photic zone. The algal-reefs effectively separated the shallow-water shelf and back-reef areas to the west and south from the more open and deeper-water areas of the fore-reef and basin to the north-east. The facies is particularly well exposed in the prominent ridge at the top of the fore-reef slope above Treak Cliff Cavern (Figure 7.10).

The fore-reef constitutes a zone of poorly bedded but locally highly fossiliferous limestones (mainly wackestones, floatstones and rudstones) with moderate, outward-facing dips of up to 35° towards the Edale Basin. Evidence provided by geopetal infillings has indicated that these dips are mainly depositional in origin (Broadhurst and Simpson, 1967). In a later paper, these same authors (Broadhurst and Simpson, 1973) recognized a bathymetric zonation of the faunas in the fore-reef. Moving successively down the fore-reef 'palaeoslope' into areas of deeper water away from the algal-reef these zones are characterized by (a) the tabulate coral *Michelinia*;(b) an association in which the small brachiopods '*Dielasma*', *Pleuropugnoides, Pugnax* and *Schizophoria* are particularly common but in which numerous other groups such as bivalves, goniatites, orthoconic nautiloids, gastropods and trilobites also occur; and (c) bivalves (especially Streblochondria = *'Pseudamussium*' of Shaw, 1970) and bryozoans. Palaeoslope depths of around 122 m for the reefs at Castleton have been suggested by Wolfenden (1958).

Extensive faunal lists from the various reef facies are provided by Wolfenden (1958) and Mitchell (in Stevenson and Gaunt, 1971). Additional palaeontological works on foraminifera (Cossey and Mundy, 1990), bryozoans (Owen, 1966; Wyse Jackson *et al.,* 1999), heterocorals (Cossey, 1983, 1997), brachiopods (Parkinson, 1952b, 1954a,b,c, 1960, 1961, 1969; Timms, 1973, 1978; Brunton and Tilsley, 1991), bivalves (Shaw, 1970), trilobites (Tilsley, 1977, 1988) and goniatites (Ford, 1965) bear witness to the rich diversity of the faunas in the apron reef.

Marginal to the apron reef and occupying low-flanking ground either side of Winnats Pass are the Beach Beds — a coarsely bioclastic grainstone unit containing large mechanically worn and bioeroded brachiopod shell fragments of shelf aspect set in a finer-grained matrix of brachiopod and crinoid debris (Sadler, 1964b, 1970). Formerly regarded as the littoral deposits of an ancient shoreline (Barnes and Holroyd, 1897; Shirley and Horsfield, 1940), the Beach Beds are now regarded as re-sedimented beds (see Sadler 1964b; Gutteridge, 1991a) derived from earlier formed deposits at the platform margin (e.g. grainstone shoals, seen at Pindale Quarry) that were subsequently washed down the reef slope (Sadler, 1964b; Ford, 1987, 1996; Gutteridge, 1991a, 1996). Although many considered the Beach Beds to be contemporaneous with the apron reef and of either B_2 or P_{1a} age (Sadler, 1964b; Parkinson, 1974b; Timms, 1978), the interdigitation of these beds with basinal strata of P_2 age in the Castleton Borehole (Stevenson and Gaunt, 1971) indicates that they are most probably a Brigantian facies that post-dates and onlaps the currently exposed beds of the reef complex (Gutteridge, 1991a). Further post-reef developments of basinal facies include the dark limestones and shales of P_1–P_2 age that occur in discontinuous outcrops marginal to the Beach Beds between Castleton and Treak Cliff

(Figure 7.10).

Occupying hummocky ground close to the foot of Long Cliff an isolated area of carbonated basalt and palagonitized hyaloclastite once regarded as a vent agglomerate (the so-called 'Speedwell Vent' of Arnold-Bemrose, 1907; and see Wilkinson in Neves and Downie, 1967) has also been considered as a subaqueous littoral cone, formed by the rapid chilling and brecciation of a lava tongue extension of the Cave Dale Lava as it flowed subaerially over the exposed top to the apron reef into shallow seas lapping against the fore-reef during a period of sea-level lowstand (Broadhurst and Simpson, 1973; Cheshire and Bell, 1977).

An angular unconformity separates the late Viséan (Asbian) apron reef from the overlying Namurian (Pendleian–Kinderscoutian) Edale Shales (Barnes and Holroyd, 1897; Jackson, 1925a, 1927). The latter comprise a succession of dark pyritic shales with marine bands containing pelagic goniatites and bivalves. Outcrops are confined to a few small exposures at the northern end of the site (north of Odin Fissure) and at the foot of Treak Cliff. Locally developed at the base of the formation and overlying a fissured palaeokarst surface in the underlying apron reef is a prominent boulder bed consisting of limestone blocks up to several metres in diameter set in a calcareous or shale matrix (Simpson and Broadhurst, 1969). The boulder bed is seen particularly well at Treak Cliff Cavern in association with fluorite (blue john') deposits (Ford, 1969) and at Windy Knoll Quarry infilling deep palaeokarstic pits in limestones of the back-reef facies as 'Neptunean dykes' where they are associated with some rare hydrocarbon deposits (Ford, 1996). It also occurs near Odin Fissure and at Winnats Pass. Although the age of the boulder bed remains uncertain, it most probably formed during late Brigantian and early Namurian times following a period of sub-aerial weathering at the platform margin which eventually led to its collapse (Ford, 1987; Gutteridge, 1996).

Interpretation

The Castleton Reef-Belt forms a significant part of an extensive apron-reef complex that developed at the margin of the Derbyshire Platform during Asbian times (Figure 7.4)a. Its location here appears to have been controlled by the Edale Fault, which defines the northern limit of an underlying basement 'tilt-block' (Lee, 1988a; Gutteridge, 1991a; and see (Figure 7.2)b. Although similar developments define the southern and western limits of the platform from Wirksworth to Parwich and Beresford Dale to Chrome Hill respectively (see Wetton to Beresford Dale GCR site report, this chapter), these are generally either less well exposed or less accessible.

Although various episodes of reef development have been recognized, the stratigraphy of the apron reef is complex and a clear understanding of its development has been hampered by uncertainties relating to the distribution of stratigraphically useful goniatites and the relationships between certain critical lithostratigraphical units. A lower B_2 (B_{2a} and upper B_2 (B_{2b}) phase of reef development was recognized by Wolfenden (1958), but Parkinson (1947, 1965) and Timms (1978) also recognized the presence of reef limestones of P_{1a} age (Figure 7.13). Records of goniatites including *Bollandites castletonensis, B. umbilicatum, Bollandoceras micronotum, Beyrichoceras delicatum, B. rectangularum, B. vesiculiferum, Dimorphoceras gilbertsoni, Nomismoceras vittiger, Prolecanites discoides, Goniatites* '*maximus*' (= *G globostriatus*), *G.* cf. *hudsoni* (Bisat, 1934; Shirley and Horsfleld, 1940; Parkinson, 1947, 1965; Ford, 1952, 1965; Brunton and Tilsley, 1991) confirm the B_2 age assigned to the apron reef by most authors (e.g. Stevenson and Gaunt, 1971), as well as its placement largely in the B_{2b} Subzone of Riley (1990b). However, although goniatites diagnostic of the B_{2a} Subzone appear to be absent from the reef complex, the occurrence of forms resembling *Goniatites crenistria* and *Beyricboceratoides truncatum* from the northern slopes of Treak Cliff indicates that a P_{la} phase of reef development is most probably also present (Parkinson, 1947, 1953).

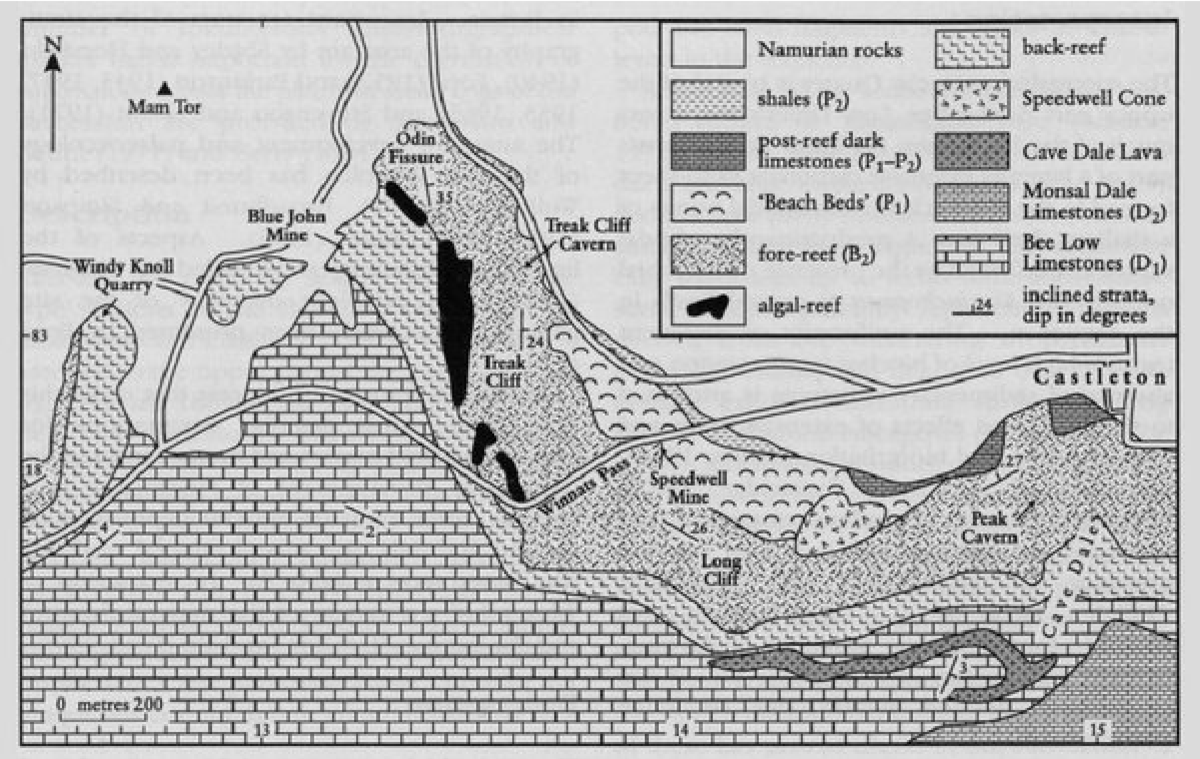
The occurrence of P_{1a} reef limestones at Castleton was later supported by the unpublished work of Timms (1978) who recognized four reef phases (of 'lower B_2, upper B_2, high upper B_2 and P_{1a} age') developed during periods of sea-level highstand (transgressive episodes), each being separated by an erosional unconformity formed during a lowstand (regressive) episode when the shelf margin was exposed above sea level (Figure 7.13).

The unconformity between Asbian reef limestones and the Namurian Edale Shales marks a further but late Dinantian-early Namurian regressive episode which resulted in emergence, erosion and karstification of the platform margin, which led to the removal of earlier-deposited Brigantian strata from the shelf area and the deposition of the boulder bed down the apron-reef flanks (Ford, 1996; Gutteridge, 1996). A similar process is envisaged for the formation of the Beach Beds formed earlier in Brigantian times (Gutteridge, 1991a, 1996).

Conclusions

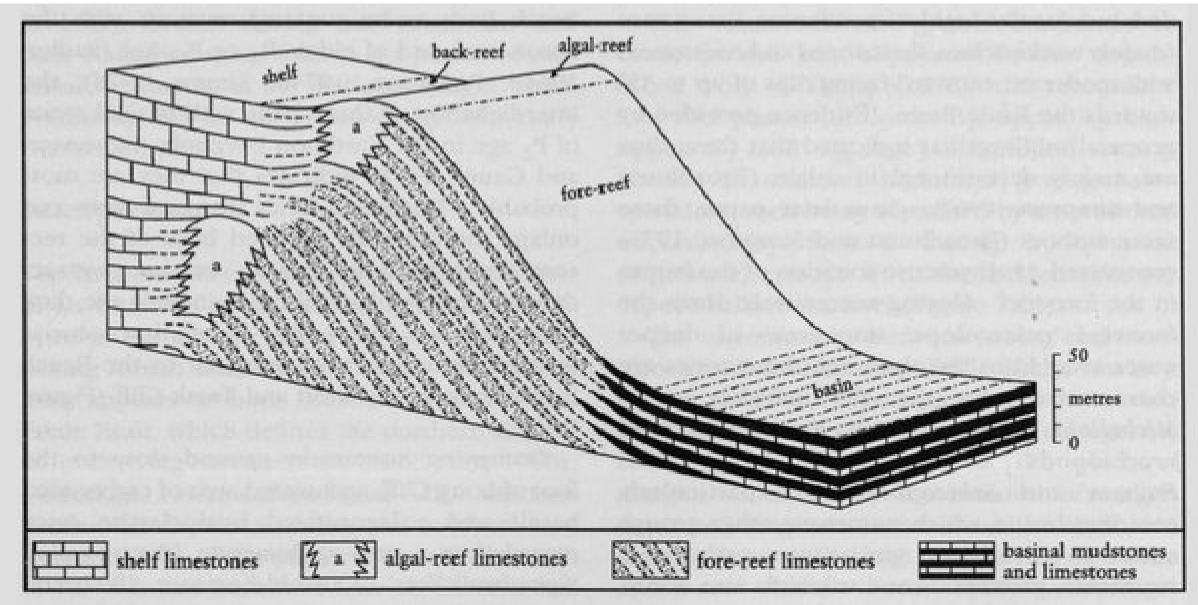
This site offers visitors a spectacular insight into the nature and origin of arguably the finest and best preserved Lower Carboniferous apron reef in England. With its rich macrofossil assemblages and its diverse suite of sedimentary rocks, the site is vital in the reconstruction of ancient reef environments and in understanding the progressive evolution of the margin of the Derbyshire Platform during late Dinantian times. The site is particularly important for illustrating the relationship between strata of shelf; shelf-margin and basin facies and for establishing correlations between the coral–brachiopod zonal scheme of the shelf area and the goniatite–bivalve scheme of the basin. Considered together, these features combine to make this one of the most important educational sites in Britain.

References

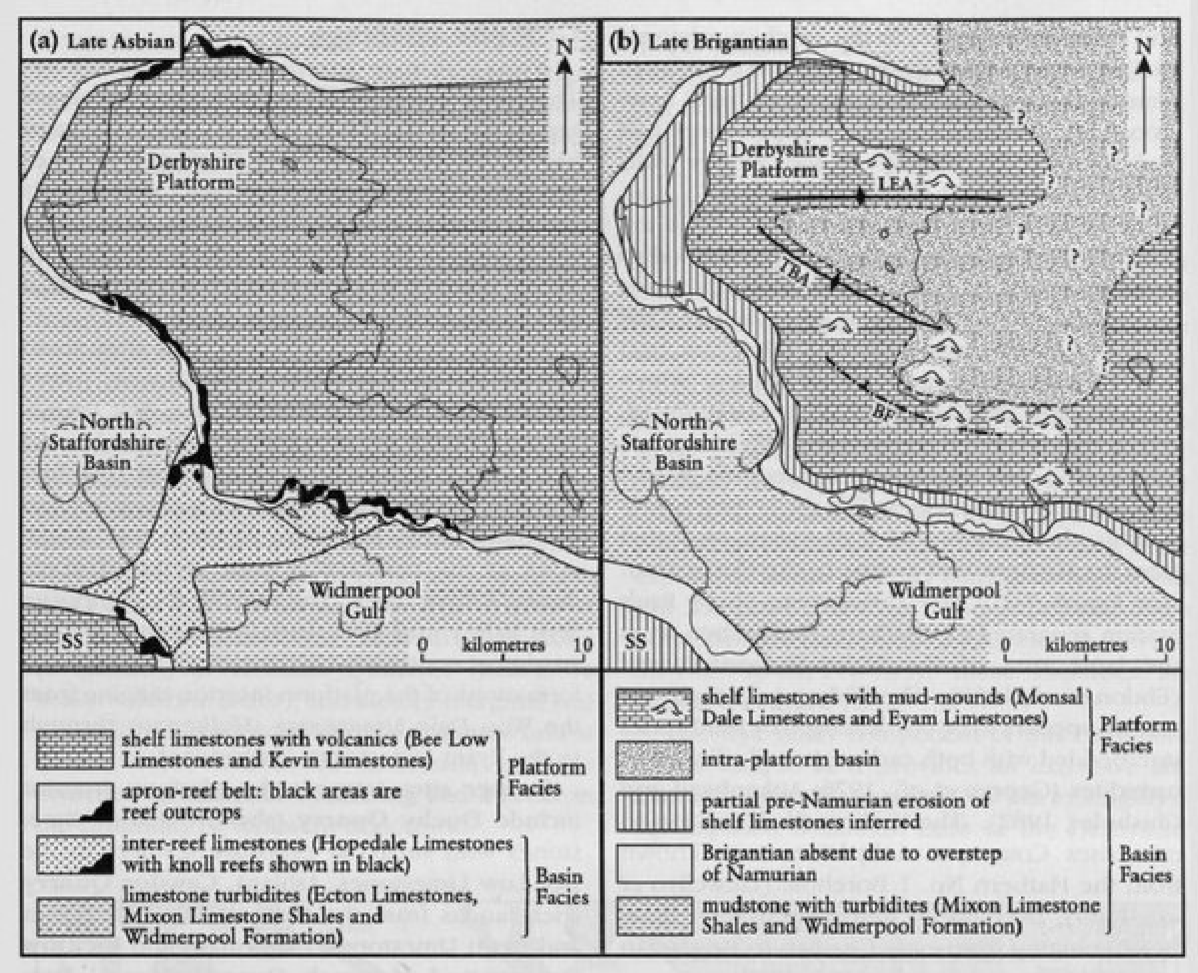


(Figure 7.10) Geological map of the Castleton Reef-Belt (Asbian). After Stevenson and Gaunt (1971).

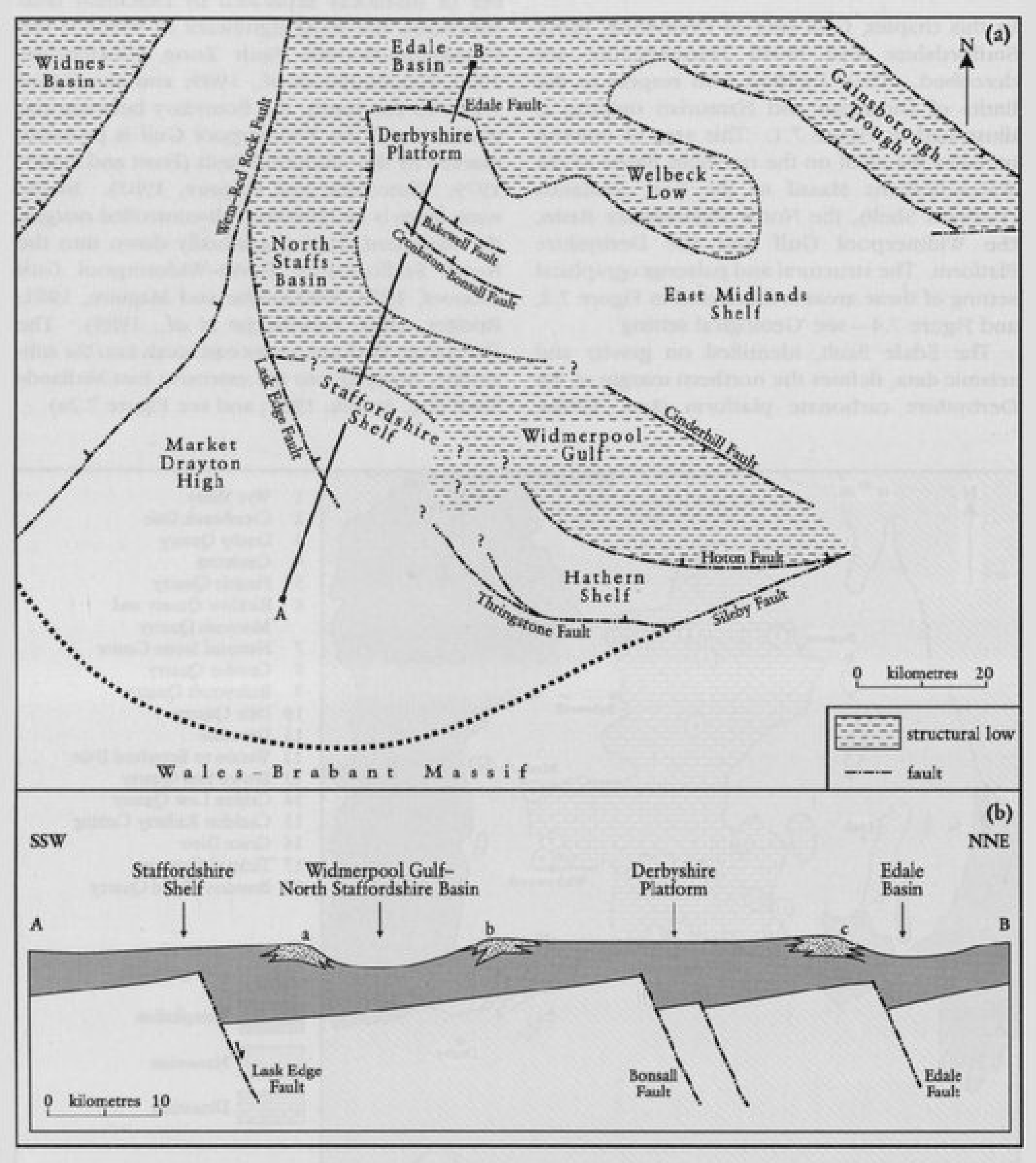
(Figure 7.11) General view across the Castleton Reef-Belt at the northern margin of the Derbyshire Platform. The steeply sloping ground of the fore-reef is clearly seen to the right of Castleton village (left), separating the high plateau shelf area (right) from the basin (lower left). (Photo: P.J. Cossey.)



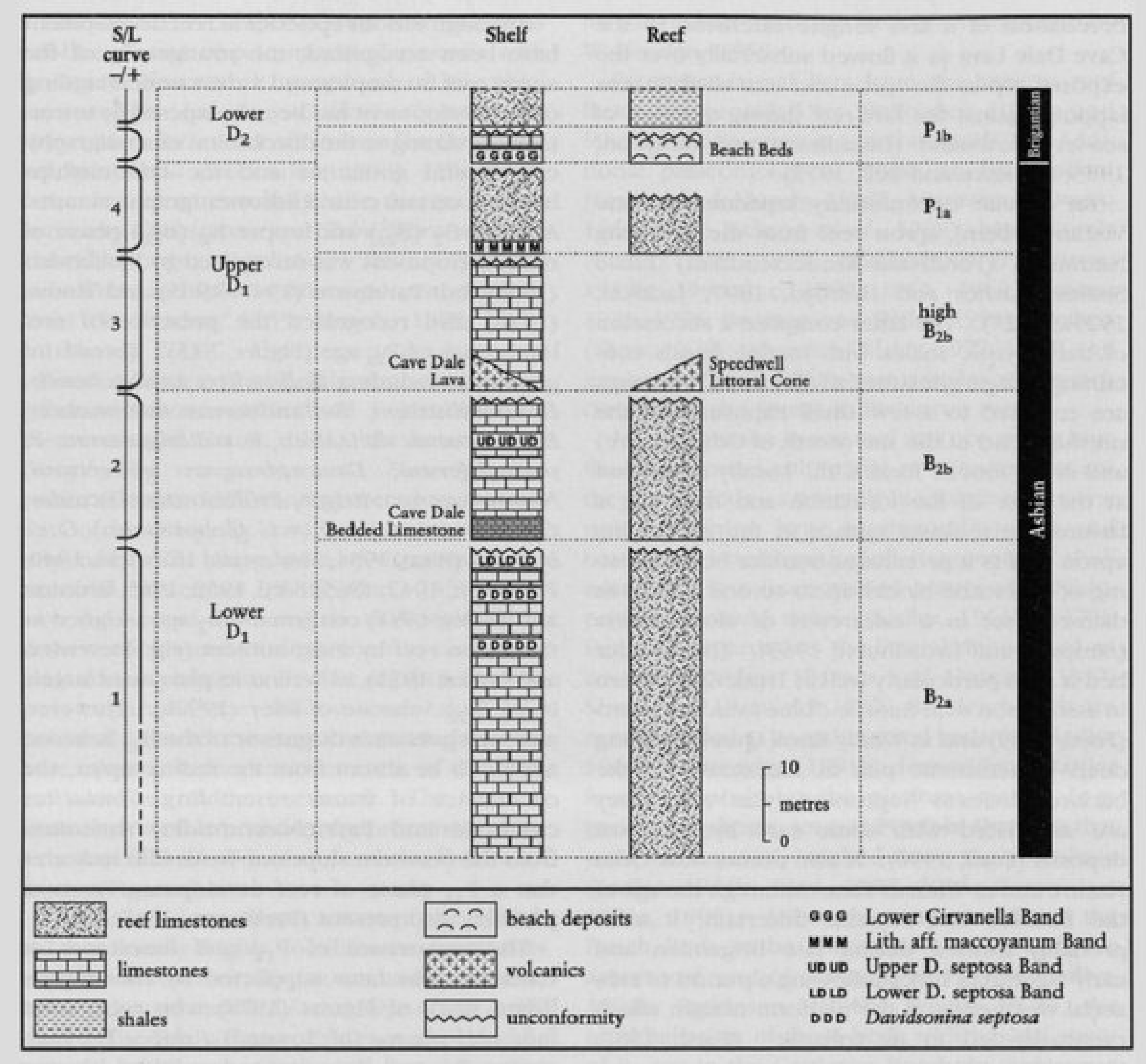
(Figure 7.12) Block diagram illustrating the distribution of sedimentary facies in the Castleton Reef-Belt. Based on Wolfenden (1958), Timms (1973) and Ford (1996).



(Figure 7.4) Palaeogeographies of the Derbyshire and north Staffordshire areas for (a) late Asbian times and (b) late Brigantian times. A faint dotted line marks the position of the Dinantian–Namurian boundary. SS — Staffordshire Shelf; LEA — Longstone Edge Anticline; TBA — Taddington-Bakewell Anticline; BF — Bonsall Fault. After Aitkenhead and Chisholm (1982), with additional information from Gutteridge (1987, 1995).



(Figure 7.2) (a) Stuctural 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).



(Figure 7.13) Interpretation of the stratigraphy at the Castleton GCR site showing the four principal transgressive–regressive cycles responsible for reef development. Whereas transgressive episodes influenced periods of reef growth as the platform margin was flooded, erosion took place during regressive episodes when parts of the reef complex became subaerially exposed. Although Timms (1978) regarded the Beach Beds as a P $_{la}$ erosional by-product of a high B_{2b} reef which is no longer preserved, their placement at a higher stratigraphical level here (P_{1b}) is based on evidence provided by Gutteridge (1991a, 1996); see text for further details. After Timms (1978).