Chapter 7 Derbyshire Platform, North Staffordshire Basin and Hathern Shelf

P.J. Cossey, P Gutteridge, M.A. Purnell, A.E. Adams and G.M. Walkden

Introduction

In this chapter, GCR sites in Derbyshire, north Staffordshire and north Leicestershire are described. Their location with respect to the limits of Dinantian and Namurian outcrop is illustrated in (Figure 7.1). This area of outcrop includes the shelf on the northern flanks of the Wales–Brabant Massif in the East Midlands (Hathern Shelf), the North Staffordshire Basin, the Widmerpool Gulf and the Derbyshire Platform. The structural and palaeogeographical setting of these areas is illustrated in (Figure 7.2), and (Figure 7.4) — see 'Geological setting'.

The Edale Fault, identified on gravity and seismic data, defines the northern margin of the Derbyshire carbonate platform (Lee, 1988a; Gutteridge, 1991a) which is divided into a number of tilt-blocks separated by basement fault structures, the most significant of which is the Cronkston–Bonsall Fault Zone (Gutteridge, 1987; Gawthorpe *et al.,* 1989; and see (Figure 7.2)). To the south, the boundary between the platform and the Widmerpool Gulf is probably marked by the Cinderhill Fault (Frost and Smart, 1979; Whitcombe and Maguire, 1981). In the west, there is no obvious fault-controlled margin, the basement sloping gradually down into the North Staffordshire Basin–Widmerpool Gulf (Maroot 1976; Whitcombe and Maguire, 1981; Bridges, 1984; Gawthorpe *et al.,* 1989). The Derbyshire Platform passes eastwards into the subsurface, merging into the extensive East Midlands Shelf (e.g. Strank, 1987; and see (Figure 7.2)a).

The North Staffordshire Basin west and southwest of the Derbyshire Platform is a narrow gulf whose western margin is controlled by the Lask Edge Fault (Lee, 1988a). The easterly extension of the North Staffordshire Basin, the Widmerpool Gulf is probably bounded on the south side by a suite of NNW–SSE-trending faults of which the Hoton and Thringstone fault systems are a part (Gawthorpe *et al.,* 1989). The shelf area between this and the Wales-Brabant Massif is variously referred to as either the West Midlands Shelf (Swank, 1987) or the Staffordshire Shelf (Chisholm *et al.,* 1988) in the west, and the Hathern Shelf in the east (Ebdon *et al.,* 1990).

Whereas the existence of some of those faults illustrated in (Figure 7.2) has been confirmed by surface mapping (e.g. Cronkston-Bonsall Fault Zone), others (e.g. Edale, Bakewell and Lask Edge faults) are recognized mainly on the evidence of subsurface gravity and seismic data.

The maximum known thickness of Dinantian strata is about 1900 m in the Eyam area (Dunham, 1973; Aitkenhead *et al.,* 1985), and about a third of this in the Buxton area, thickening to about 1000 m in the North Staffordshire Basin (Aikenhead *et al.,* 1985). Up to about 500 m of Pendleian and Arnsbergian strata occur in the basins adjacent to the north, west and south sides of the Derbyshire Platform, but the equivalent succession overlying the platform to the east is highly condensed, with only 27 m being recorded at Ashover for example (Frost and Smart, 1979).

The Dinantian limestones of the Derbyshire Platform and North Staffordshire Basin are well exposed in dale sides and in numerous working and disused quarries, although on the platform only late Holkerian, Asbian and Brigantian strata occur at the surface. Older rocks are known solely from boreholes. Exposures of Dinantian strata on the Staffordshire Shelf are generally confined to a few working quarries. Dinantian successions in the Widmerpool Gulf are mostly covered by Upper Carboniferous and Triassic strata, with outcrop restricted to some inliers of Dinantian basinal rocks; while on the Hathern Shelf to the south, the Dinantian succession is represented by a few small Dinantian inliers (Figure 7.1). Pendleian and Arnsbergian successions are dominated by shales and are best known from railway cuttings and stream sections at the surface, and from boreholes.

History of research

The earliest observations on the geology of Derbyshire are to be found in the publications of Whitehurst (1778), Mawe (1802), Farey (1811) and Watson (1811). Although these authors went some way to establishing the broad succession, it

was the work of the [British] Geological Survey in the mid-19th century, leading to the publication of the first one-inch maps and accompanying memoirs (Hull and Green, 1866; Green *et al.,* 1869, 1887), that first dealt in any detail with Lower Carboniferous stratigraphy. Other work from the late 19th and early 20th centuries includes Barnes and Holroyd (1897) on shell beds in the Castleton area; Hind and Howe (1901) who drew a comparison between the faunas of the Castleton area and those of the Craven Reef-Belt; and Sibly (1908) who first applied the coral–brachiopod zonation of Vaughan (1905) to the Derbyshire area. Aspects of the geology along the railway line between Ashbourne and Buxton were described by Hind (1897) and Arnold-Bemrose (1899, 1903). Sargent (1912) discussed the clays in the limestone succession at Crich. TWo further memoirs containing detailed descriptions of Lower Carboniferous rocks also appeared at this time: Fox-Strangways (1905) included the outcrops in north Leicestershire, and Gibson and Wedd (1913) covered the north-eastern part of the area.

Important contributions to our knowledge of the palaeontology and stratigraphy of both the Dinantian and Namurian sequences of Derbyshire and Staffordshire were made by Jackson (1908, 1919, 1922, 1923, 1925a, 1926, 1927, 1941a,b). Jackson and Alkins (1919), Jackson and Charlesworth (1920) and Barke *et al.* (1920) discussed the origin of a conglomerate containing quartz pebbles at Caldon Low. Other work between the wars included Alkins (1921) on brachiopod faunas from Caldon, Sargent (1921) on cherts, Parsons (1918a,b, 1922) on the stratigraphy and dolomitization of the Carboniferous Limestone in the south-east of the area, Morris (1929) on the geology of the area around Middleton Dale, Hudson (1932) on the knoll topography, Pulfrey (1932) on radiolarians from the base of the Edale Shales, Fearnsides (1932) on the geology of the Derwent Valley, and Fearnsides and Templeman (1932) on a borehole at Hope. Aspects of the stratigraphy of the Carboniferous Limestone in the Buxton area and in north Derbyshire were reported by Cope (1933, 1936, 1937, 1939, 1949, 1972, 1973).

Studies published during and in the years immediately after the Second World War include Ludford (1940, 1951) on the geology of the Weaver Hills, Shirley and Horsfield (1940, 1945) on the outcrop at the northern edge of the Derbyshire Platform, Shirley (1959) on the Monyash to Wirksworth area, Mitchell and Stubblefield (1941) on the inlier of Lower Carboniferous strata at Breedon Cloud, north Leicestershire, Hudson and Cotton (1943, 1945a,b) on the Lower Carboniferous rocks of the Alport Borehole and the Namurian of the Alport and Edale areas, Parkinson (1943, 1947, 1950a, 1953, 1964, 1965) on the 'reef' limestones and their contained fauna both from north Derbyshire and Dovedale, Sweeting (1946) and Sweeting and Himus (1946) on the Ashover Anticline, Prentice (1951, 1952) on the geology of the Manifold Valley, Ford (1952, 1965) on aspects of the Castleton Reef-Belt, including goniatite faunas, Bisat (1957) on goniatites from the Manifold Valley, Wolfenden (1958, 1959) on the palaeoecology and sponge faunas of limestones in the Castleton area, and Robinson (1959) on ostracode faunas from shales near Matlock.

With the expansion in scientific research since 1960, the Lower Carboniferous successions in this area have perhaps received more attention than those of any other region. This is probably partly because of the quality of exposure, but also because of the central location and easy access. Five [British] Geological Survey memoirs cover the Derbyshire and Staffordshire area: Smith *et al.* (1967) on the eastern area around Chesterfield and Matlock; Stevenson and Gaunt (1971) on the northern part of the area; Frost and Smart (1979) on the south-eastern area; Aitkenhead *et al.* (1985) on the area around Buxton, Leek and Bakewell; and Chisholm *et al.* (1988) on the southern part of the area, including Dovedale, Caldon and the Weaver Hills. Important contributions on palaeontology and/or biostratigraphy from Mitchell, Mundy, Ramsbottom, Reynolds, Riley and Strank are included in these memoirs. Useful bibliographies of the geology of the Peak District have been compiled by Ford and Mason (1967) and Ford (1972, 1999).

Ramsbottom *et al.* (1962) described sections from boreholes in the Ashover area, and Holdsworth (1963a,b, 1966), Holdsworth and Trewin (1968), Trewin (1968) and Trewin and Holdsworth (1972, 1973) considered aspects of Namurian stratigraphy and sedimentation in the North Staffordshire Basin. Eden *et al.* (1964) reported a detailed study of the northern margin of the Dinantian outcrop around Pin Dale; sedi-mentological studies of limestones from near Sparrowpit, Castleton and the Hartington area were reported by Sadler (1964a,b, 1966, 1969, 1970) and Sadler and Wyatt (1966); while the PhD thesis of Thach (1964) dealt with limestones of the south-western part of the area. Parkinson and Ludford (1964, 1973), Ludford (1970) and Ludford *et al.* (1973) discussed the geology of the south-western Dinantian outcrops; Morris (1967a,b, 1969, 1970a,b) described stratigraphy and faunas from the Dinantian and Namurian outcrops of south-west Derbyshire and Staffordshire; and Llewellyn *et al.* (1969) and Llewellyn and Stabbins (1970) described the Hathern Anhydrite Series. Two PhD theses of this period were by Biggins (1969) who described a Carboniferous knoll

reef at High Tor, Matlock, and Coffey (1969) who discussed the geology of the Mixon and Ecton area, north Staffordshire.

Aspects of sedimentology, stratigraphy and faunas of the Castleton Reef-Belt have been described by Broadhurst and Simpson (1967, 1973), Simpson and Broadhurst (1969), Shaw (1970), Timms (1973, 1978), Parkinson (1974b), Tilsley (1977), Brunton and Tilsley (1991), Cossey (1997) and Wyse Jackson *et al.* (1999). Other 'reef' or carbonate buildups and their associated facies and faunas have also continued to attract the interest of palaeontologists and sedimentologists, and contributions include those of Orme (1970), Brunton and Champion (1974), Morgan (1980), Chapman (1984), Bridges and Chapman (1988), and Gutteridge (1990a, 1991b, 1995). Other largely sedimentological studies on the Lower Carboniferous rocks include those of Walkden (1970, 1972a,b, 1974, 1977, 1982) on volcanic, erosive and early diagenetic events in the limestone succession of the platform and on the geology of the area around Wirksworth; Butcher and Ford (1973) on the Monsal Dale area; Brown (1973) on the eastern Derbyshire outcrops; Bolton (1978) on part of the Namurian succession in the North Staffordshire Basin; Adams and Cossey (1978) on a slumped unit in the Monsal Dale Limestones; Bridges (1982) on cyclicity in the Crich outcrop; Pazdzierski (1982) on the Monsal Dale Limestones; Schofield (1982) and Schofield and Adams (1985) on the Woo Dale Limestones; Gutteridge (1983, 1987, 1989a, 1990b, 199 la,b) on Brigantian sedimentation; Oakman (1984) on the Asbian and Brigantian limestones of the south-eastern part of the platform; Gawthorpe and Gutteridge (1990) on carbonate shoals at the northern margin of the platform; and Vanstone (1996) on late Dinantian climates.

Further contributions to our understanding of the palaeontology and stratigraphy of the Lower Carboniferous rocks of the area include those of Mortimer *et al.* (1970) on miospores from Breedon Cloud, Dunham (1973) on the Eyam Borehole, Chisholm and Butcher (1981) on a borehole near Matlock, Strank (1981, 1982b, 1985, 1986, 1987) who described foraminiferal faunas from key sections and boreholes in the area and also discussed the structure and stratigraphy of the Dinantian succession in the concealed area of the East Midlands Shelf to the east of the Peak District, Aitkenhead and Chisholm (1982) who standardized the nomenclature for the Dinantian formations of the area, Chisholm *et al.* (1983) on revisions to the stratigraphy in the area west of Matlock, Welsh and Owens (1983) on miospores from the Caldon Low Borehole, Cossey (1983, 1997) on corals (especially heterocorals), Tilsley (1988) on trilobites, and Cossey *et al.* (1995) on Brown End Quarry, Staffordshire.

A number of studies in recent years have focused on the diagenesis of the limestone succession. These include Orme and Brown (1963) on diagenetic fabrics, Orme and Ford (1970) and Orme (1973) on aspects of chert formation, Adams (1980) on calcretes, Munn and Jackson (1980) on de-dolomitization in the Wirksworth area, Berry (1984) and Walkden and Berry (1984) on cementation, Schofield and Adams (1986) on the origin of the Woo Dale Dolomite, Walkden (1987) on diagenesis and depositional cyclicity, Fowles (1989) on dolomitization, and Currie (1988) on the relationship between diagenesis in the Monsal Dale Limestones and the occurrence of igneous rocks. Williams (1988), Walkden and Williams (1991), Bingham (1992), Hollis (1995) and Hollis and Walkden (1996) all deal with aspects of the diagenetic history of the succession on a regional scale.

Large-scale structural and stratigraphical studies that embrace the area include those of Maroof (1976), Whitcombe and Maguire (1981), Smith *et al.* (1985), Gutteridge (1987), Lee (1988a), Gawthorpe *et al.* (1989), Ebdon *et al.* (1990), Fraser and Gawthorpe (1990) and Rogers and Stuart (1991). Reviews of the limestone resources have been compiled by Cox and Bridge (1977), Cox and Harrison (1980), Bridge and Gozzard (1981), Harrison (1981), Gatliff (1982), Bridge and Kneebone (1983) and summarized for the whole of the Peak District by Harrison and Adlam (1985).

Stratigraphy

Early accounts of the stratigraphy refer to the 'Carboniferous Limestone' or 'Mountain Limestone', together with various igneous rocks, overlain by shales termed 'Yoredale Beds' and the sandstones of the 'Millstone Grit', although the term 'Yoredale Beds' was soon dropped in this area. Barnes and Holroyd (1897) recognized that in north Derbyshire later strata are unconformable on the Carboniferous Limestone.

During the latter part of the 19th and most of the 20th century a plethora of lithostratigraphical names was introduced, ranging from names for major units, recognizable over a wide area, to local marker beds often named after a characteristic fossil. According to Aitkenhead and Chisholm (1982), at least 60 different lithostratigraphical names for

parts of the Carboniferous Limestone of the Peak District had appeared in the literature during the previous 30 years. Accordingly, Aitkenhead and Chisholm (1982) provided a standard nomenclature for the Derbyshire and Staffordshire outcrops, dividing the region into four areas. Their scheme appears in (Figure 7.3), together with the nomenclature of the succession seen on the Hathern Shelf, adapted from Ambrose and Carney (1997, 1999). The nomenclature of the Namurian Series is based on that of the relevant memoir.

Geological setting

On the Derbyshire Platform, the earliest exposed rocks are of late Holkerian age. Earlier Dinantian strata and basement rocks are only certainly known from two boreholes, at Woo Dale (Cope, 1949, 1973, 1979; Strank, 1986) and Eyam (Dunham, 1973; Strank, 1985). Pre-Holkerian marginal marine evaporites and shallow-marine carbonates onlapped an irregular Charnian and Lower Palaeozoic basement surface, which in the northern part of the area was broadly a southeasterly dipping tilt-block (Gutteridge, 1987; Gawthorpe *et al.,* 1989). By late Arundian or Holkerian times, a shallow carbonate platform had been established over the whole area. Uplift at the end of Holkerian times led to Asbian limestones resting unconformably on Holkerian strata in the central and southern parts of the platform. During Asbian times a rimmed shelf margin characterized by apron reefs developed around the north, west and south of the platform while cyclic shelf limestones separated by episodes of subaerial exposure and karstification developed in the interior (Figure 7.4)a. Occasional footwall uplift along the Edale Fault led to local unconformities along its northern margin. At the beginning of Brigantian times, the platform margin became dominated by crinoidal grainstone shoals (Walkden, 1982; Gawthorpe *et al.,* 1989; Gawthorpe and Gutteridge, 1990). An intra-platform basin also developed at this time as a result of re-activation of basement faults (Gutteridge, 1987, 1989a) (Figure 7.4)b. Towards the close of the Brigantian Age, an eastwards-dipping carbonate ramp developed on the central part of the platform (Gutteridge, 1984, 1987, 1995) (Figure 7.4)b.

The North Staffordshire Basin occurs to the west and south-west of the Derbyshire Platform ((Figure 7.4)a). During the early to mid part of Dinantian times there was probably a W- or SW-dipping carbonate ramp (Bridges, 1984) between the two areas rather than a distinct shelf margin, although by Asbian times a reef-rimmed margin separated platform from basin. The Caldon Low Borehole records late Devonian–early Dinantian fluvial terrigenous clastics of the Redhouse Sandstones, overlain by interbedded dolomi-tized shaly limestones and brecciated dolomites (Rue Hill Dolomites) of Courceyan age, interpreted as marginal marine deposits (Chisholm *et al.,* 1988). For the remainder of Dinantian times the area was one of deep-water, largely turbidite deposition. On the ramp, carbonate buildups of Chadian age are found in the Milldale Limestones (although some authors prefer to describe these structures as carbonate 'mud-banks' (see Chapter 6) the term 'mud-mound' is preferred here in keeping with current usage). Local non-sequences and unconformities are also recorded from within the Milldale Limestones (Aitkenhead and Chisholm, 1982). To the south, a relatively shallow-water Asbian carbonate facies (the Kevin Limestones) and associated marginal 'reef' limestones are developed on the Staffordshire Shelf and these beds outcrop In the Weaver Hills district (Chisholm *et al.,* 1988).

The Widmerpool Gulf and Hathern Shelf are poorly represented at outcrop, being limited to localities south and west of Wirksworth (Frost and Smart, 1979; Chisholm *et al.,* 1988) and the inliers in north Leicestershire. They are best known from subsurface Investigations, which include the Duffield Borehole (Aitkenhead, 1977) and seismic interpretation (Ebdon *et al.,* 1990). The area appears to be occupied by two half-graben, with sediment fills thickening southwards — the Widmerpool Half-graben separated from the Hathern Half-graben by the Hoton Fault (see (Figure 7.2)). The Thringstone-Sileby Fault System separates the Hathern Half-graben from the land area of the Wales-Brabant Massif (Ebdon *et al.,* 1990). The Widmerpool Gulf succession appears to be characterized by mudstones interbedded with both carbonate and siliciclastic turbidites (George *et al.,* 1976; Aitkenhead and Chisholm, 1982). The Hathern Shelf succession comprises Courceyan anhydritic strata known from the Hathern No. 1 Borehole (Llewellyn *et al.,* 1969), overlain by dolomitized shelf limestones ranging from early Chadian to Brigantian age (Ambrose and Carney, 1997, 1999).

Carbonate sedimentation ceased during mid-Brigantian times. Late Brigantian and early Namurian strata are mostly marine shales with turbiditic sandstones. In the basinal areas these rest conformably on the Dinantian strata, but where they overlie Dinantian shelf or shelf-margin facies, the relationship is unconformable, with some or all of the Brigantian carbonates missing and an incomplete or condensed early Namurian succession is present (Aitkenhead *et al.,* 1985;

Chisholm *et al.,* 1988).

Locally, and especially during later Dinantian times, the continuity of carbonate sedimentation across the Derbyshire Platform was interrupted by episodes of volcanic activity, the most common by-product of which was the formation of basaltic lavas and tuffs. These and other igneous rocks in the area are described in detail by Aitkenhead *et al.* (1985) and Chisholm *et al.* (1988); the more important igneous exposures in the area are described in a companion GCR volume, *Carboniferous* and *Permian Igneous Rocks of Great Britain,* by Stephenson *et al.* (2003).

GCR site coverage

The sites considered in this chapter reveal important evidence relating to the geological history of the Derbyshire Platform, Hathem Shelf and North Staffordshire Basin during early Carboniferous times. In keeping with other areas, most of the sites were selected because of their combined stratigraphical, sedimentological and palaeontological interest.

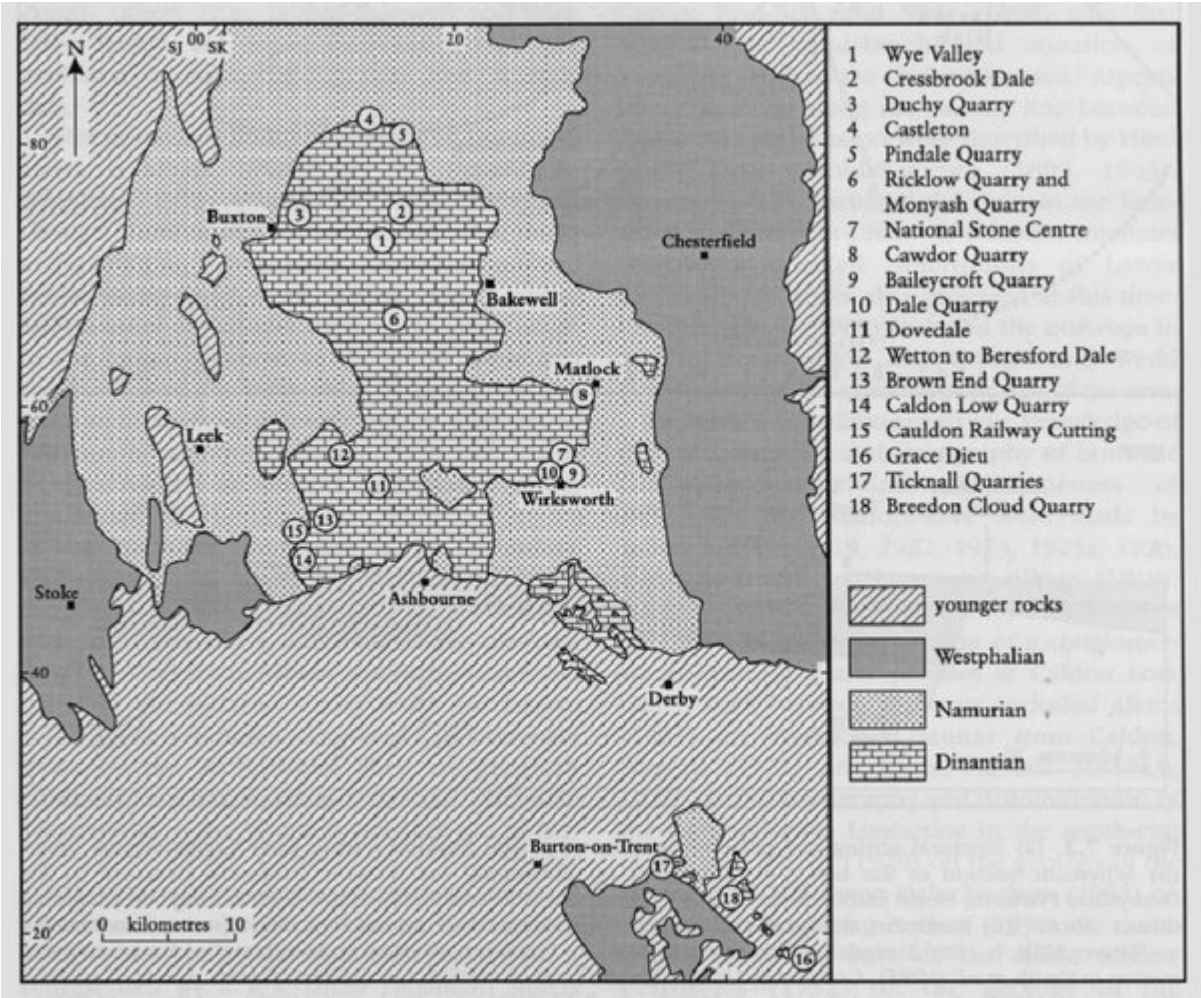
On the Derbyshire Platform, two sites stand out as being particularly significant, partly because of their considerable size, but mainly because of the great range of stratigraphy and facies that is represented within them. The first of these, at Castleton, provides a classic section through a highly fossiliferous 'apron reef' developed at the northern margin of the platform during Asbian times. The second, the composite Wye Valley and Cressbrook Dale site, records an almost continuous section of all the exposed formations of the platform interior, ranging from the Woo Dale Limestones (Holkerian) through to the Eyam Limestones (Brigantian).

Further sites towards the platform interior include Duchy Quarry (shallow marine limestones with subaerial exposure features in the Bee Low Limestones, Asbian), Cawdor Quarry (rich faunas from the Monsal Dale Limestones and Eyam Limestones, Brigantian) and Ricklow Quarry and Monyash Quarry (Monsal Dale Limestones and Eyam Limestones, Brigantian including faunas and carbonate mud-mounds). Other sites either close to or at the platform margin include Pindale Quarry (carbonate sand shoal, Bee Low Limestones, Asbian), both Dale Quarry and Baileycroft Quarry (shelf and slope deposits including slumps, slides and re-sedimented beds, Bee Low Limestones-Eyam Limestones, Asbian–Brigantian) and the National Stone Centre (carbonate mud-mounds, Monsal Dale Limestones and Eyam Limestones, Brigantian).

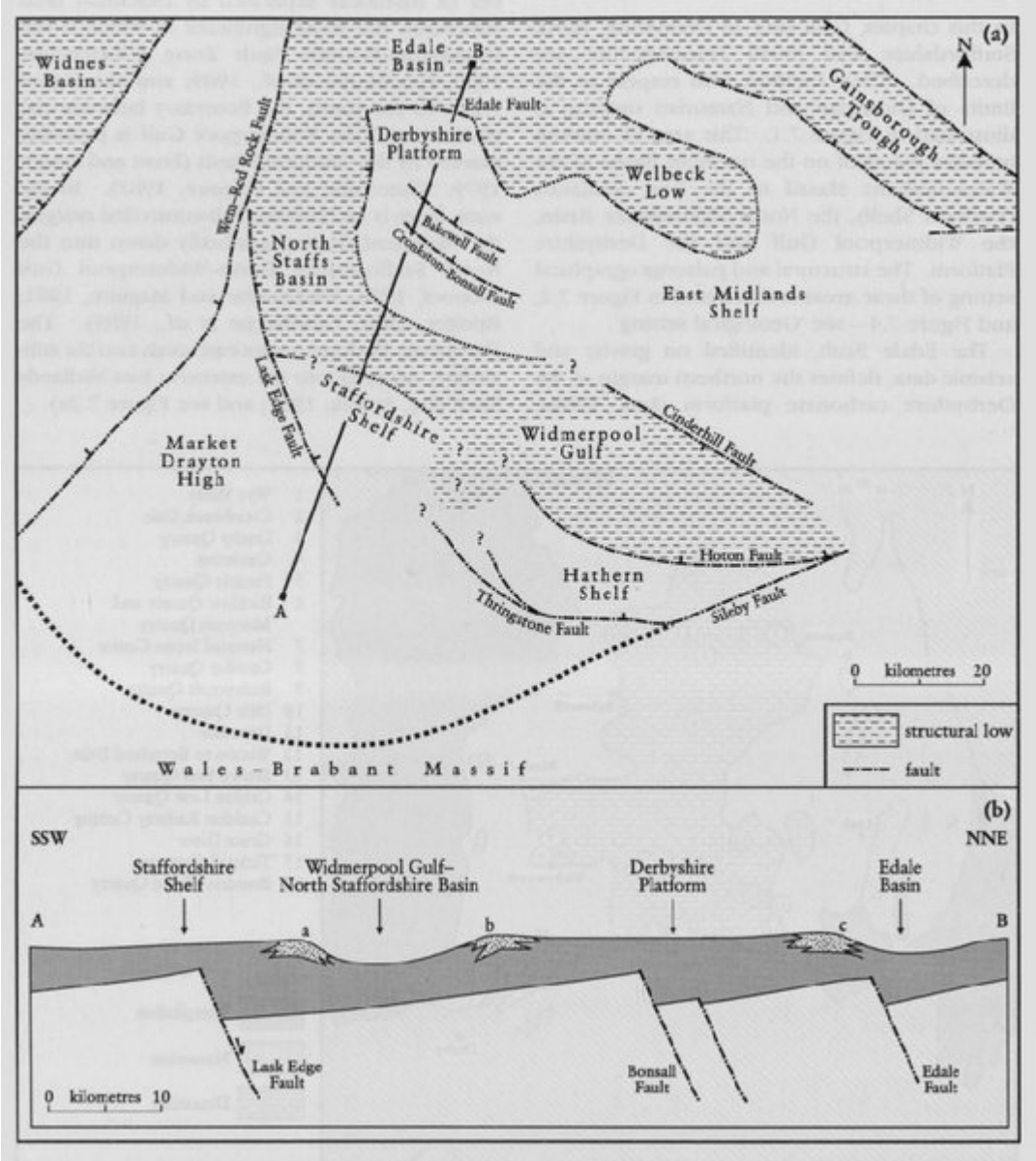
In the North Staffordshire Basin, two large sites are of particular importance. The first of these, at Dovedale, offers spectacular sections through the largest and best exposed deep-water carbonate mud-mound complex of Early Carboniferous age in Britain (Milldale Limestones, Chadian). The second, the Wetton to Beresford Dale site, includes similar facies together with a younger (Asbian) reef complex developed across the basin margin in the Hopedale Limestones and Bee Low Limestones, and the turbiditic Ecton Limestones (Chadian–Asbian). Other sites in the area include Brown End Quarry (type sections, in part, of both the Milldale Limestones and Hopedale Limestones and re-sedimented beds), Caldon Low Quarry (unconformity between the Milldale Limestones and Hopedale Limestones at the basin margin and the ?Holkerian or Asbian Caldon Low Conglomerate) and Cauldon Railway Cutting (fossiliferous Namurian shales, Pendleian).

Sites from the Hathern Shelf illustrate a range of sedimentary facies developed between the Widmerpool Gulf and the Wales–Brabant Massif during Dinantian times. These include the extensive Chadian–Asbian sections of dolomitized ramp successions containing storm deposits, carbonate mud-mounds and stratigraphical discontinuities at Breedon Cloud Quarry (Milldale Limestones and Cloud Hill Dolostone), the type section of the highly fossiliferous Ticknall Limestone (Brigantian) at Ticknall Quarries (nearshore shallow marine facies), and a more marginal and dolomitized facies equivalent of this same unit at Grace Dieu, where the succession contains evidence of subaerial weathering and a break in the continuity of sediment deposition.

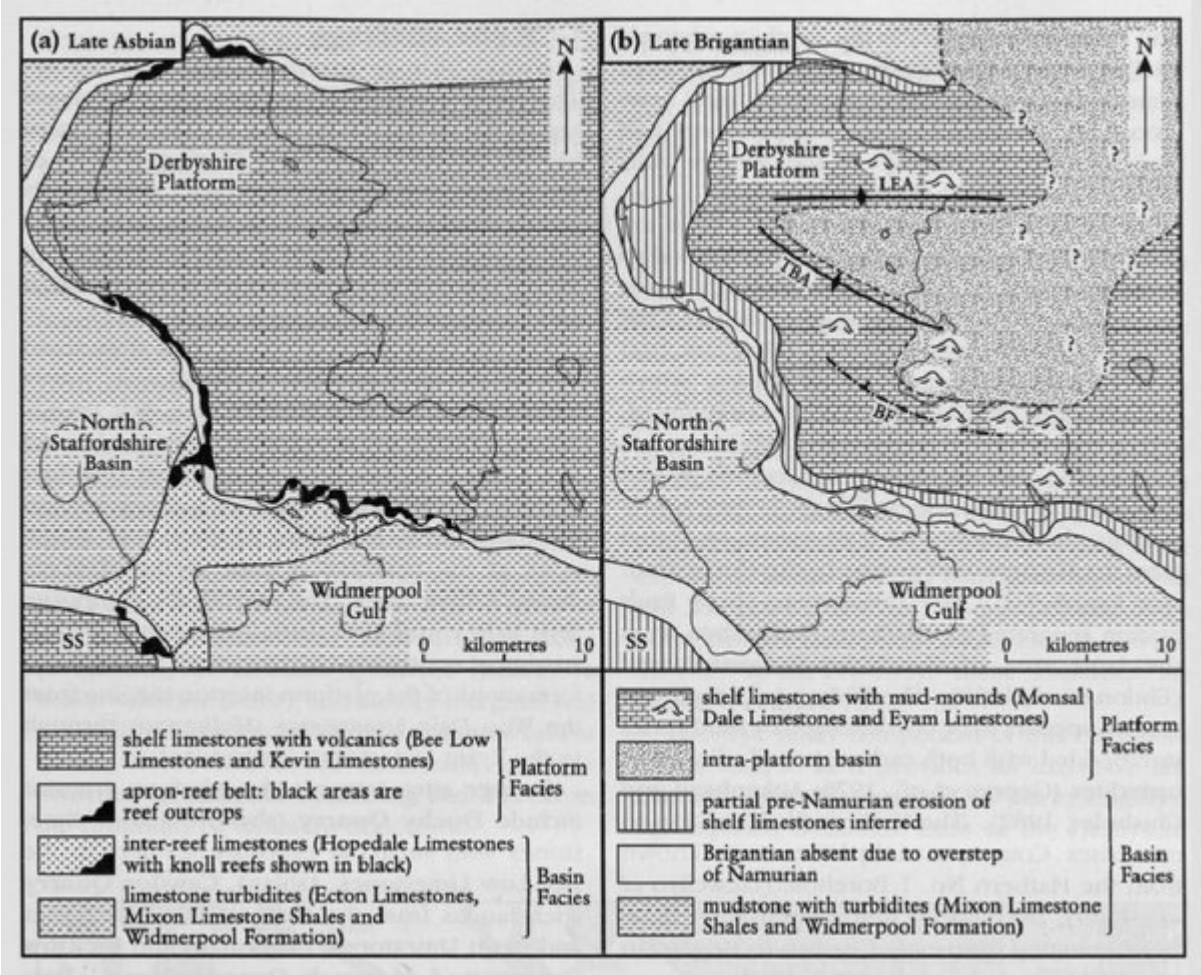
References



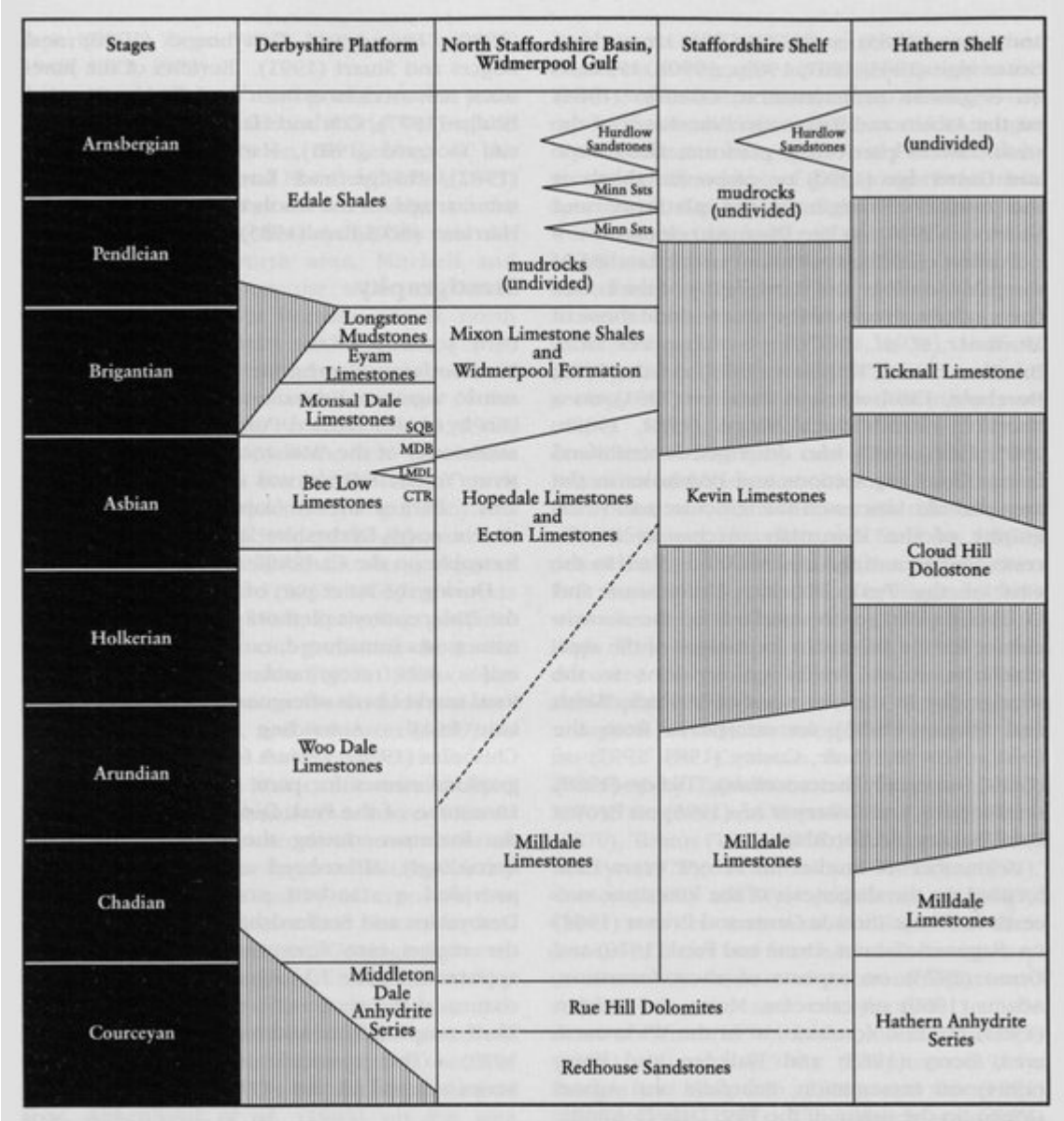
(Figure 7.1) Geological map illustrating the distribution of Carboniferous rocks in Derbyshire, north Staffordshire and north-west Leicestershire, and the locations of GCR sites described in the text. Based on information from [British] Geological Survey memoirs (Aitkenhead et al., 1985; Chisholm et al., 1988) and maps of the area (Institute of Geological Sciences, 1976a, 1978, 1979b, 1983).



(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 7.4) 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 7.3) Simplified stratigraphical chart for the Lower Carboniferous succession of Derbyshire, north Staffordshire and north-west Leicestershire. CTR — Chee Tor Rock; LMDL — Lower Millers Dale Lava; MDB — Millers Dale Beds; SQB Station Quarry Beds. Areas of vertical ruling indicate non-sequences. Not to scale. Note that, unless otherwise stated, all major lithostratigraphical units shown on this chart are recognized as formations. Compilation based on information from Aitkenhead and Chisholm (1982) with additional details from Smith et al. (1967), Aitkenhead et al. (1985), Chisholm et al. (1988), Ambrose and Carney (1997, 1999) and Ambrose (1999).