Dovedale, Derbyshire–Staffordshire

[SK 131 584]–[SK 152 510]

Introduction

Situated on the Derbyshire-Staffordshire border between Thorpe and Hartington, the Dovedale GCR site offers an outstanding array of natural cliff sections through the Milldale Limestones (mainly Chadian) and includes the best exposed deep-water 'knoll reef' (carbonate mud-mound) complex in the North Staffordshire Basin — the largest exposed development of its kind in England. In addition, the site reveals important evidence of the lateral facies passage from the topmost beds of the Milldale Limestones (basin facies) into the Holkerian Woo Dale Limestones (shelf facies). Shelf facies strata of the overlying Bee Low Limestones (Asbian) also occur at this locality. The site extends for some 10 km between Wolfscote Dale [SK 131 584]–[SK 142 570] and Biggin Dale [SK 150 587]–[SK 142 570] in the north, to Thorpe Cloud [SK 152 510] and Bunster Hill [SK 143 514] in the south (Figure 7.24). It includes the subsidiary valley sections at Sharplow Dale [SK 148 522], Hall Dale [SK 135 537], Nabs Dale [SK 145 535] and east of Coldeaton Bridge [SK 146 561], together with the many recent karstic landforms (pillars and caves) between Dove Holes [SK 142 535] and Dovedale Castle [SK 148 514] south of Milldale [SK 139 548].

The first significant account of the site geology was by Parkinson (1950a) who produced an informative map of the area. Later work by Parkinson and Ludford (1964) and Ludford (1970) contributed further important details. However, the most comprehensive accounts of Dovedale geology are by Aitkenhead *et al.* (1985) and Chisholm *et al.* (1988); the former, in consideration of the area between Wolfscote Dale and Milldale (the northern half of the site), and the latter, in consideration of the area between Milldale and Thorpe Cloud (the southern part of the site). More specific works on the palaeontology and sedimentology of Lower Carboniferous rocks exposed here are those by Jackson (1919, 1941a), Parkinson (1964), Thach (1964), Chapman (1984), Schofield and Adams (1985) and Bridges and Chapman (1988). Two of the more significant of these were by Schofield and Adams (1985), on the sedimentology of the Woo Dale Limestones, both at this site and in adjacent areas of the Derbyshire Platform, and Bridges and Chapman (1988) on the sedimentology of the carbonate mud-mound complex in the Milldale Limestones.

Description

The Milldale Limestones (Parkinson, 1950a) as re-defined by Aitkenhead and Chisholm (1982) and as subsequently used by Aitkenhead *et al.,* (1985) comprise a 'knoll reef' facies (= Dovedale Limestone of Parkinson, 1950a) and an 'inter-reef' (Aitkenhead *et al.,* 1985) or 'bedded' facies (Chisholm *et al.,* 1988). The formation crops out in a series of natural cliff sections either side of the River Dove in the core of the *N-S-trending* Dovedale Anticline. Detailed work by Bridges and Chapman (1988) has demonstrated that the Dovedale 'reefs' represent deep-water carbonate mud-mounds rather than true 'ecologic reefs' (Dunham, 1970) and this view is adopted in the account below.

Although isolated carbonate mud-mounds occur to the south-west and east of Milldale, the principal outcrop (a composite development hereafter referred to as the 'mud-mound complex') occurs to the south of Milldale between Ravens Tor [SK 1412 5385] and Thorpe Cloud, occupying an area of approximately 6 km^2 (Figure 7.24). Outcrops of the 'bedded facies' are best exposed around Milldale and between Milldale and Iron Tors [SK 146 563] to the north.

Chisholm *et al.* (1988) estimated that the Milldale Limestones arc around 320 m thick in the Dovedale area, with maximum mud-mound thicknesses ranging from 180 m to 300 m. The mud-mounds comprise irregular bodies of massive (largely unbedded) pale-coloured micritic limestone. Typically these contain a variety of cavity and cavity-fill structures including the problematical 'stromatactis', and a macrofauna consisting of crinoids, brachiopods, fenestrate bryozoans, ostracodes, gastropods together with a few bivalves, corals, trilobites, goniatites and nautiloids. A Chadian age for the mud-mound facies is indicated by the presence of *Levitusia humerosa, Spirifer bollandensis, Fascipericyclus, Ammonellipsites, Dzhaprakoceras, Merocanites, Polaricyclus* '*Pericyclus*' *minimus, Eonomismoceras, Cummingella raniceps, Phillipsia gemmulifera* and *Phillibolina worsawensis* (Jackson, 1919, 1941a; Chisholm *et al.,* 1988; Tilsley,

1988; Riley, 1991). A rich brachiopod fauna from the mud-mound complex at Thorpe Cloud is reported by Brunton and Tilsley (1991).

Bridges and Chapman (1988) recognized a distinctive facies suite in the mud-mound complex that included a mound-core facies, mound-flank facies (coarse and fine) and an intermound facies (coarse and fine). The mound-core facies consists of massive wackestones with, in addition to those fossil groups mentioned above, a diverse array of skeletal fragments set in a peloidal and clotted micrite matrix. The most common skeletal fragments are of assorted sponges (hyalosteliids, moravamminids and aoujgaliids), but foraminifera, calcispheres and echinoid remains also occur. Cryptalgal laminites, graded laminites, small-scale slump structures, fissures and fissure-fill breccias are also found in this facies.

The associated flank and intermound facies comprise a varied mix of 'bedded' carbonate lithologies ranging from crinoidal packstones and algal-encrusted intraclast floatstones in the mound-flank (coarse) facies to grainstones and rudstones in the intermound (coarse) facies and a packstone-wackestone association in both the mound-flank (fine) facies and intermound (fine) facies (Bridges and Chapman, 1988). The lateral facies transition from mound-core to inter-mound facies is beautifully exposed at Ravens Tor (Figure 7.25).

Away from the mud-mound complex, the typical 'bedded' facies of the Milldale Limestones is poorly fossiliferous. It comprises grey bioclastic grainstones with subordinate developments of a dark cherry rnicritic limestone (Aitkenhead and Chisholm, 1982). On the [British] Geological Survey maps of the Buxton and Ashbourne districts (Institute of Geological Sciences, 1978, 1983) the latter are mapped separately as the 'dark facies' of the Milldale Limestones. Although a Chadian age is indicated for the majority of these beds (Aikenhead and Chisholm, 1982), microfossil evidence indicates the upper part of the 'bedded' facies of the Milldale Limestones may be of Asbian age (Chisholm *et al.,* 1988). This accords with the best available field evidence from near Gypsy Bank [SK 142 565] and south of Alstonefield (Institute of Geological Sciences, 1978) where the topmost beds of the Milldale Limestones appear to pass laterally into the Woo Dale Limestones (= Iron Tors Limestone of Parkinson, 1950a) (Figure 7.24); a formation which at outcrop is generally regarded as Holkerian–early Asbian age (Aikenhead and Chisholm, 1982; Aitkenhead *et* al., 1985).

In the Dovedale area, Schofield and Adams (1985) recognized two separate members of the Woo Dale Limestones. The lower Vincent House Member (Aitkenhead and Chisholm, 1982) comprises 70 m of bioclastic grainstone 'with a diverse bioclast suite' and subordinate developments of packstone and wackestone with abundant intraclasts and scattered fenestrae. Above this, the Topley Pike Member (20 m) consists of peloidal grainstone with an array of fenestral fabrics (Schofield and Adams, 1985). These beds are overlain by massive-bedded pale-grey calcarenites of the Bee Low Limestones (Asbian). A thickness of around 190 m is recorded for this formation in the Wolfscote Hill area (Aitkenhead *et al.,* 1985), but at this site only parts of the succession are exposed, these occurring in discontinuous outcrops along the valley sides of Wolfscote Dale and Biggin Dale (Figure 7.24). This shallow-shelf facies, which passes laterally into Asbian 'knoll reef' and 'apron-reef' limestones in the Beresford Dale–Gratton Hill area, is described in the Wetton to Beresford Dale GCR site report (this chapter).

Interpretation

The mud-mounds ('knoll reefs') of the Milldale Limestones represent deep-water 'Waulsortian' carbonate mud-mounds; buildups that are of a similar character to those recorded in successions of broadly equivalent age in other parts of Europe and in North America (Lees, 1964, 1982; Lees *et al.,* 1977, 1985; Miller and Grayson, 1982; Lees and Miller, 1985). The generally accepted view favours a microbial origin both for the lime mud that formed main structure of the buildups and for at least some of the cavity-filling cements within them. The formation of the cavities themselves remains contentious, although the circulation of phreatic marine pore-water beneath the organically coated mud-mound surfaces may have been influential in their development (Bridges and Chapman, 1988).

Cyanobacteria are thought to have been particularly influential in the formation of the mud-mounds (Bridges and Chapman, 1988). These may have contributed to the deposition of lime sediment in various ways — most notably by the photosynthetically induced precipitation of fine-grained calcium carbonate within and around the bacterial elements, by the breakdown of bacteria-released ammonia in conditons of high pH, or by the binding and trapping of lime mud in

adhesive bacterial films at the sediment-water interface. Other less significant factors include the addition of skeletal remains derived from organisms that lived on or above the mud-mound surfaces and the deposition of fine-grained sediment 'imported' by deep-water drift (Bridges and Chapman, 1988).

The role of deep-sea currents as nutrient suppliers to growing deep-sea mud-mounds is well documented (Wright and Faulker, 1990; Wright, 1991; Bridges *et al.*, 1995). In this context it is interesting to note that the geometry and orientation of the Dovedale mud-mound complex is thought to have been shaped or moulded under the influence of a south-easterly flowing deep-sea current (Bridges and Chapman, 1988). The same current may also have been responsible for the formation of some of the mound's internal sedimentary features (e.g. graded laminites and inclined bedding surfaces).

Careful observation of the relationship between the mound-core and mound-flank facies enabled Bridges and Chapman (1988) to determine that the Dovedale complex was a composite buildup that grew to an elevation of some 50–80 m above the local sea floor with palaeoslopes along its flanks of up to 25° or 30°. The same authors regarded the occurrence of slump structures and fissures in the mound-core facies as evidence of the gravitational instability of the mud-mound palaeoslopes and, following earlier microfacies work by Lees *et al.* (1985) and Lees and Miller (1985), they also established that original water depths over the complex ranged from 220 m to 280 m.

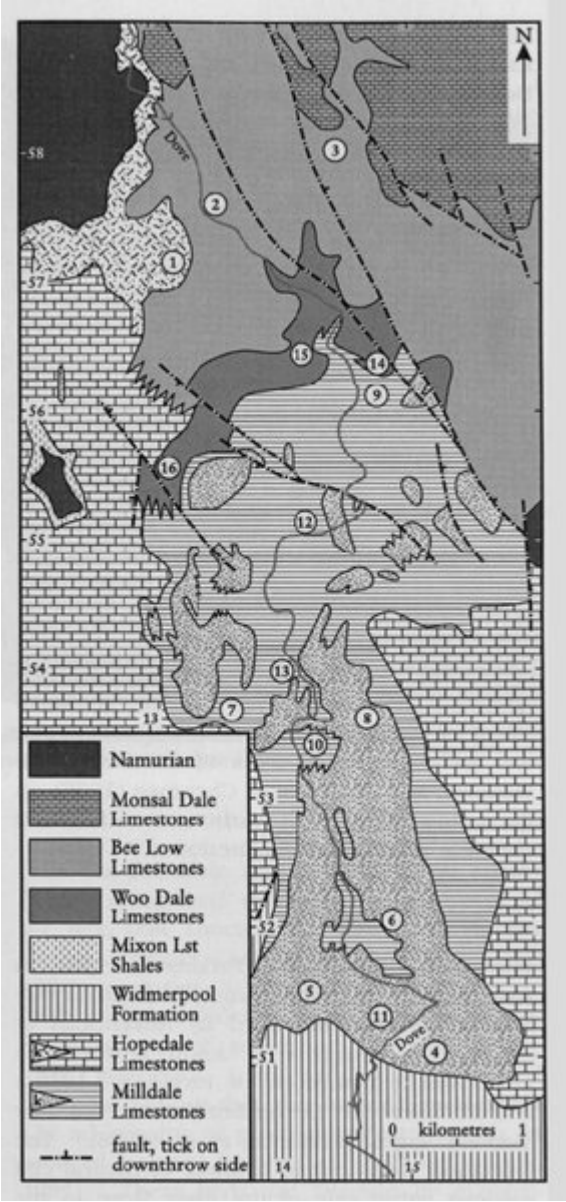
Regional sequence thickness and facies variations coupled with geophysical evidence indicate that the Milldale Limestones were formed as a relatively deep-water facies in the North Staffordshire Basin–Widmerpool Gulf areas, and upon a S- to SW-dipping carbonate ramp that developed over a similarly inclined tilt-block in the underlying basement (Maroof 1976; Smith *et al.,* 1985; Gutteridge, 1987; Chisholm *et al.*, 1988; Gawthorpe *et al.,* 1989). Although the greater part of this formation, including the mud-mound facies, is of Chadian age, the topmost parts of the formation may be as young as the Holkerian or early Asbian (Chisholm *et al.,* 1988). This, together with field evidence from the northern part of the site, strongly supports the idea of the Milldale Limestones being, at least in part, the lateral and basinal equivalent of the Woo Dale Limestones (shallow-water shelf facies) developed over the Derbyshire Platform to the north-east (Parkinson and Ludford, 1964; Aitkenhead *et al.,* 1985; Bridges and Chapman, 1988).

In consideration of the depositional environment of the Woo Dale Limestones, Schofield and Adams (1985) argued that, over much of the Derbyshire Platform, the Vincent House Member represented an open shelf facies, while the Topley Pike Member developed principally as a tidal-flat facies — although a higher energy beach facies was suggested for beds of this member in the Alstonefield area. Although difficulties arise in the interpretation of the succession around Alstonefield, the upward transition from the Vincent House Member to the Topley Pike Member was most probably the result of shoaling caused by the southward migration of a prograding tidal-flat complex (Schofield and Adams, 1985).

Conclusions

The 'knoll reefs' in the Milldale Limestones at this site form part of the largest and best exposed deep-water 'Waulsortian' carbonate mud-mound complex in Britain, which is one of the finest composite carbonate buildups of Early Carboniferous age in Europe. The complex developed in the North Staffordshire Basin towards the foot of a south-westerly sloping carbonate ramp in water depths of around 220–280 m. The site is a particularly valuable educational resource and is widely used both In the teaching of carbonate sedimentology and for research into the origin of carbonate mud-mound structures and Dinantian sedimentary basins.

References



(Figure 7.24) Simplified geological map of the Dovedale region illustrating the distribution of 'knoll reef' (carbonate mud-mound) facies (k) in the Milldale Limestones and the positions of localities referred to in the text: 1- Gratton Hill; 2 — Wolfscote Dale; 3 — Biggin Dale; 4 — Thorpe Cloud; 5 — Bunster Hill; 6 — Sharplow Dale; 7 — Hall Dale; 8 — Nabs Dale; 9 — Coldeaton Bridge; 10 — Dove Holes; 11- Dovedale Castle; 12 — Milldale; 13 — Ravens Tor; 14 — Iron Tom; 15 — Gypsy Bank; 16 — Alstonefield. Compilation based on [British] Geological Survey maps of the area (Institute of Geological Sciences, 1978, 1983).

(Figure 7.25) General view of the carbonate mud-mound facies developed in the Milldale Limestones at Ravens Tor, Dovedale. Note the lateral transition from the massive mud-mound core facies (centre) to bedded flank and intermound facies (right). (Photo: P.J. Cossey.)