River Hodder, Lancashire

[SD 646 435]–[SD 708 389]

Introduction

The River Hodder GCR site is a river section [SD 646 435]–[SD 708 389] to the north-west and west of Clitheroe, approximately 15 km long (Figure 6.11). It shows the thickest (> 1.5 km) early- to mid-Viséan sequence in the Craven Basin, preserved over the hanging wall (down-throw side) of a deep basement fault that was active during deposition as the crust was stretching (extension). At the end of the Carboniferous Period, this fault was compressed (inverted), through shortening of the crust by earth movements associated with continental collision and mountain building (Variscan Orogeny) in southwest Britain. The Carboniferous rocks were thus intensely folded, as a result of which (and because of river meandering) many intervals are repeated at various points along the section. Cleavage is also developed on the northern Hank of this folding, which is centred around Limekiln Wood [SD 6630 4330]. The site is the type section for the Hodder Mudstone Formation (Riley, 1990a) and two of its constituent members (Limekiln Wood Limestone and Chaigley Limestone) and for the Hodderense Limestone Formation (see (Figure 6.2)). The Pendleside Limestone Formation and the basal part of the Lower Bowland Shale Formation are also exposed. It is also the type locality for several trilobite and ammonoid (goniatite) species (see Phillips, 1836). The River Hodder offers the best British section for examining a Viséan deep-water mixed clastic–carbonate succession in an extensional basin setting. Detailed descriptions of the sections are given by Earp *et al.* (1961) and Aitkenhead *et al.* (1992). Riley (1990a) defined the lithostratigraphy and reviewed the depositional history. Ammonoid faunas were also monographed by Riley (1996).

Description

At the base of the succession is the Limekiln Wood Limestone Member (late Chadian), exposed in tightly folded periclines at Limekiln Wood [SD 6630 4330]–[SD 6715 4330] (see (Figure 6.11)). Although the base of this unit is not seen, it typically comprises about 120 m of graded crinoidal packstones and grainstones, some with significant packstone lithoclasts derived from the (older) Clitheroe Limestone Formation. Bed thickness is generally less than 0.6 m. Silicification and chert is common, with beekite replacing the surfaces of crinoids. Interbedded dark-grey mudstones are silty and micaceous, similar in character to the overlying Phynis Mudstone Member. The limestones are rich in brachiopod debris and crinoids. Disarticulated trilobites referable to *Brachymetopus maccoyi, Phillipsia gemmulifera* and *Phillibole,* and crinoid calices, especially *Actinocrinites* and *Gilbertsocrinus,* occur, together with the coprophagous gastropod *Platyceras.* The foraminifera *Eotextularia* and *Eblanaia* are particularly common. Towards the top of the member, on the northern limb of the Plantation Farm Anticline (Figure 6.1) and (Figure 6.11), is a shaly carbonate lithoclast debris bed rich in crinoid calices including, in addition to the above, *Amphoracrinus, Bollandocrinus, Pimlicocrinus, Platycrinites* and *Pleurocrinus.*

The Phynis Mudstone Member (late Chadian) is exposed in both limbs of the Plantation Farm Anticline immediately either side of the Limekiln Wood Limestone Member outcrop, and on the northern limb the mudstones are cleaved. About 200 m are present on the thicker southern limb. They comprise silty calcareous mudstones with some dark calcisiltite beds. Thin (< 2 cm) graded lags composed entirely of archegoniid trilobite debris occur near the base, but generally the member is sparsely fossiliferous with scattered crinoid ossifies occurring.

The Arundian Chaigley Limestone Member (*c.* 200 m thick) is exposed in two meanders and associated tributaries between Paper Mill Wood [SD 6800 4330] and Agden Wood [SD 6870 4260] (Figure 6.11). Limestone beds are packstones, generally more than 0.6 m thick, graded with prod and flute marks on their erosive bases. The bioclast component is dominated by brachiopod and crinoid debris. Cummingellid trilobites are common. Foraminifera are abundant and include the primitive archaediscids *Uralodiscus* and *Glomodiscus,* denoting an Arundian age. Interbedded with the packstones are fissile black shales containing scattered micrite nodules (similar to Namurian 'bullions), and reworked nodules in the packstones yield the ammonoids *Parahammotocyclus chaigleyensis* (type locality), *Bollandites,*

Bollandoceras and *Dzhaprakoceras hispanicum.* One shale band contains a coquina of the hemipelagic facies bivalves *Dunbarella* and *Pteronites,* with bryozoans attached to the *Dunbarella* valves. This bed strongly resembles similar occurrences in Silesian marine bands and is called the 'Dunbarella Bed'; it is known from several localities in the basin. Siltstones and rarer fine-grained sandstones also occur, some containing plant debris and siderite nodules. Soh-sediment deformation structures (e.g. convolute ripples and slumps) are also present and gravity slide structures are apparent around Agden Wood.

Overlying the Chaigley Limestone Member, mudstone dominates, with thin calcisiltites and wackestones. Slumps are common. Some 30 m upstream from Higher Hodder Bridge [SD 6975 4115] a debris flow occurs and this contains disarticulated brachiopods, the coral *Rotiphyllum* and numerous trilobites including *Griffithides holwellensis* (Hahn), originally described from the Holkerian succession of the Mendips (at the Holwell Quarry GCR site; see Benton *et al.,* in press, and Simms *et al.,* in press) and *Weberiphillipsia.* This bed is also exposed at Teddy Wheel [SD 7070 3985]. Stratigraphically higher mudstone beds, 400 m downstream from Teddy Wheel, yield pyritized ammonoids Including *Dimorphoceras* (possibly the lowest stratigraphical appearance worldwide) and *Bollandites*; the rare trilobite *Pseudospatulina* also occurs. At Great Falls [SD 7035 3999], a 0.2 m-thick packstone turbidite occurs just below the top of the unit. It is from this bed that Metcalfe (1981) obtained a rich conodont asssemblage of *Gnathodus* and *Mestognathus.*

The Hodderense Limestone Formation is exposed at several points in the section, upstream from Doeford Bridge [SD 6470 4350] and downstream from Higher Hodder Bridge; with the type section occurring between the Higher and Lower Hodder bridges in the gorge at Great Falls (Figure 6.11). Logged sections (after Riley, 1990a) are presented in (Figure 6.12). The formation comprises thin beds (generally < 0.3 m) of pale-grey wackestone–floatstone, interbedded with pale- to dark-blue and olive mudstones. It is much more shaly than at other localities and slump folds are also present. This is in stark contrast to the facies developed at Ashnott, on an intrabasinal palaeohigh, which is much less shaly and reduced In thickness. The section at Great Falls is the thickest measured in the formation, even when the repetition due to slumping is removed. Small dark bluish-grey irregular micrite nodules occur throughout, but are most concentrated in the limestones, where many are probably reworked or concentrated by bioturbation and/or winnowing. It is these nodules that give the limestones their characteristic blotchy appearance. Bed boundaries are commonly uneven. Ammonoids are abundant and include the zonal form *Bollandoceras hodderense* (type locality), *Merocanites applanatus, Nomismoceras rotiforme,* and the trilobite *Latibole.*

Immediately overlying the Hodderense Limestone Formation, at Great Falls, is another packstone turbidite, 0.3 m thick, containing numerous *Bollandoceras submicronotum, Nomismoceras rotiforme* and the lowest stratigraphical occurrence of *Beyrichoceras* in the Craven Basin. This bed, which marks the base of the Pendleside Limestone Formation, has also yielded a valve of the Holkerian marker brachiopod *Davidsonina carbonaria.* The Pendleside Limestone Formation (Figure 6.11) occupies much of the river gorge upstream to Black Wheel [SD 6980 4000]. It is about 180 m thick and is much more shaly than the Pendleside Limestone Formation at Pendle Hill (see GCR site report, this chapter). It also differs in that soft-sediment deformation is common and slumps are present at several horizons. The sharp-based, graded limestone beds are generally finer-grained here than at Pendle. Within the shales, deep-water trilobites, including *Phillibole polleni* (type locality) and *Vandergrachtia vandergrachtii* (type locality), are common at certain levels.

There is a conformable passage into the overlying Lower Bowland Shale Formation at Black Wheel (Figure 6.11), the basal shale having yielded the ammonoids *Entogonites grimmeri* and *Goniatites budsoni* (wrongly identified by Earp *et al.* (1961) *as G. crenistria*)indicating the basal B_{2a} ammonoid zone (Riley, 1990b, 1993). *Entogonites* is a rare but distinctive ammonoid with ribbed quadrangular coiling and a short stratigraphical range. Its presence allows correlation between the western USA–Alaska (Titus and Riley, 1997) and Britain eastwards into Germany (Nicolaus, 1963).

Interpretation

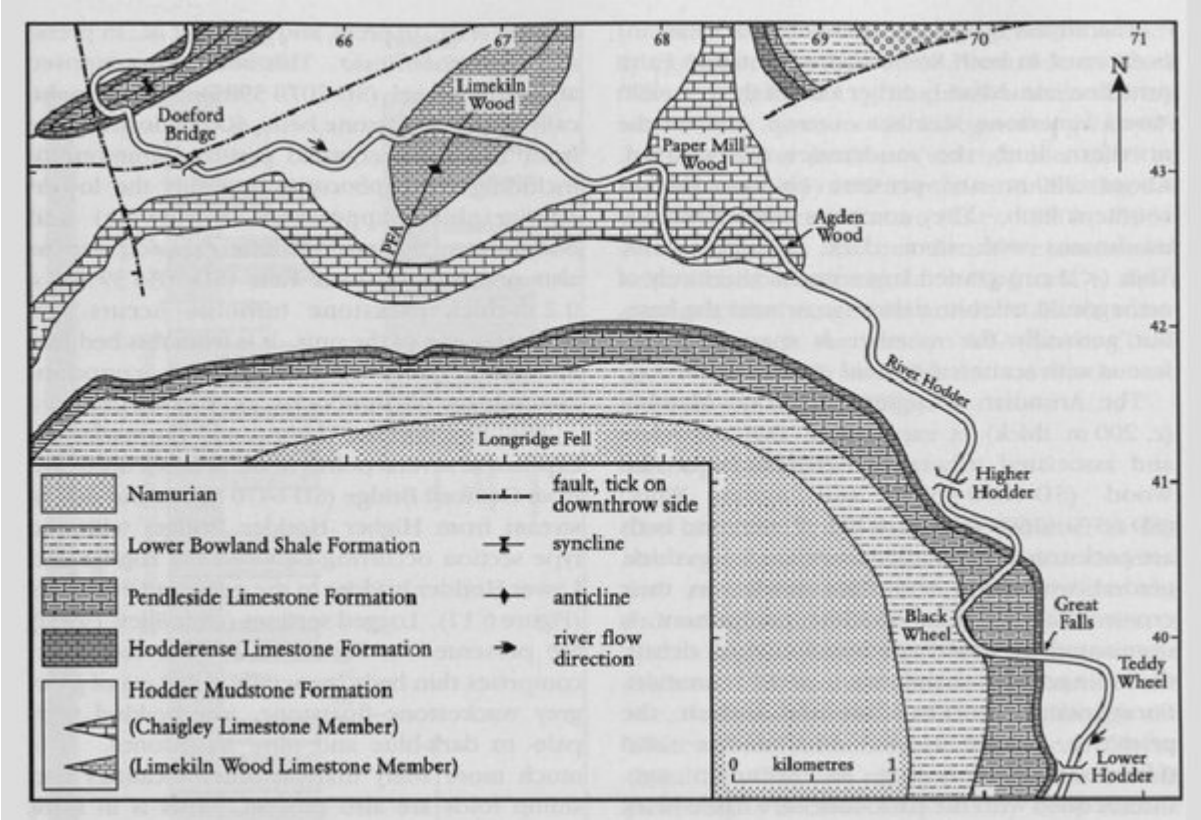
The Limekiln Wood Limestone Member at this site represents shedding of carbonate material into an intrabasinal low developed within the footwall of an active basement fault. The source (palaeohigh) was a tilt block (Grayson and Oldham, 1987) running just to the north of the site, from south-west to north-east through the Whitewell and Ashnott areas. During

early Viséan (basal late Chadian) times, even the intrabasinal palaeohighs became drowned by deep marine water, intrabasinal carbonate production mainly ceased, and only fine-grained terrigenous material reached the basin centre (Phynis Mudstone Member). Later in Chadian times, shallow-water ramp carbonates began to form, attached to the cratonic areas surrounding the Craven Basin. These ramps prograded southwards (see Sykes Quarries GCR site report, this chapter), but it was not until Arundian times, after they had been active for long enough, that these ramps were able to export significant carbonate into the basin. The limestone turbidites of the Chaigley Limestone Member were probably sourced by the carbonate ramp attached to the South Lake District High, with the Arundian highstand marked by the Dunbarella. Bed. The coeval Embsay Limestone Member, present in the eastern part of the Craven Basin around Skipton and Lothersdale (e.g. see Dowshaw Deff Quarry GCR site report, this chapter), is cleaner with more grainstones and was probably sourced from the Askrigg Block and Central Lancashire High margins. These ramps were switched off at the end of Arundian times by sea-level fall associated with tectonic activity (see Dowshaw Deff Quarry GCR site report, this chapter; Davies *et al.,* 1989; Barclay *et al.,* 1994). Once more, during early Holkerian times, terrigenous clastic supply dominated. Holkerian transgression eventually drowned the cratonic areas, largely cutting off clastic supply and providing ample accommodation space for renewed carbonate ramps to form. The basin centre became too distal to receive significant carbonate turbidites from these ramps, resulting in sediment starvation. This gave rise to the deposition of the widespread hemipelagic cephalopod limestones of the Hodderense Limestone Formation, which may be compared with the Sea Mount Member of the Castletown Formation, Isle of Man (Dickson *et al.,* 1987). Towards the end of Holkerian times, rapid and regular alternations of low (lowstand) and high (highstand) sea level began to take effect. These were glacio-eustatic in origin, driven by the waxing and waning of distant Gondwanan polar ice caps (Britain was close to the equator in Early Carboniferous times). During lowstands, the carbonate areas were emergent. During highstands, the platforms were drowned and the resulting accommodation space was soon filled as copious supplies of detrital carbonate were shed into the basin as turbidites in the Pendleside Limestone Formation. Conversely, each lowstand temporarily shut off carbonate supply. The Pendleside Limestone Formation in the Hodder section, with its slumps, finer grain size and high mud content, represents a distal facies equivalent deposited farther away from the source platforms than that at Pendle Hill (see GCR site report, this chapter). During late Asbian times, the source platforms surrounding the basin became rimmed with microbial reefs (e.g. at Settle, Malham and Cracoe Knolls and Swinden Quarry, see GCR site reports and (Figure 5.2), Chapter 5). The reefs obstructed the export of carbonate and interfered with the exchange of sea water between the basin and the surrounding platforms. Carbonate supply became more localized and black shale deposition, associated with basin anoxia, ensued (Lower Bowland Shale Formation).

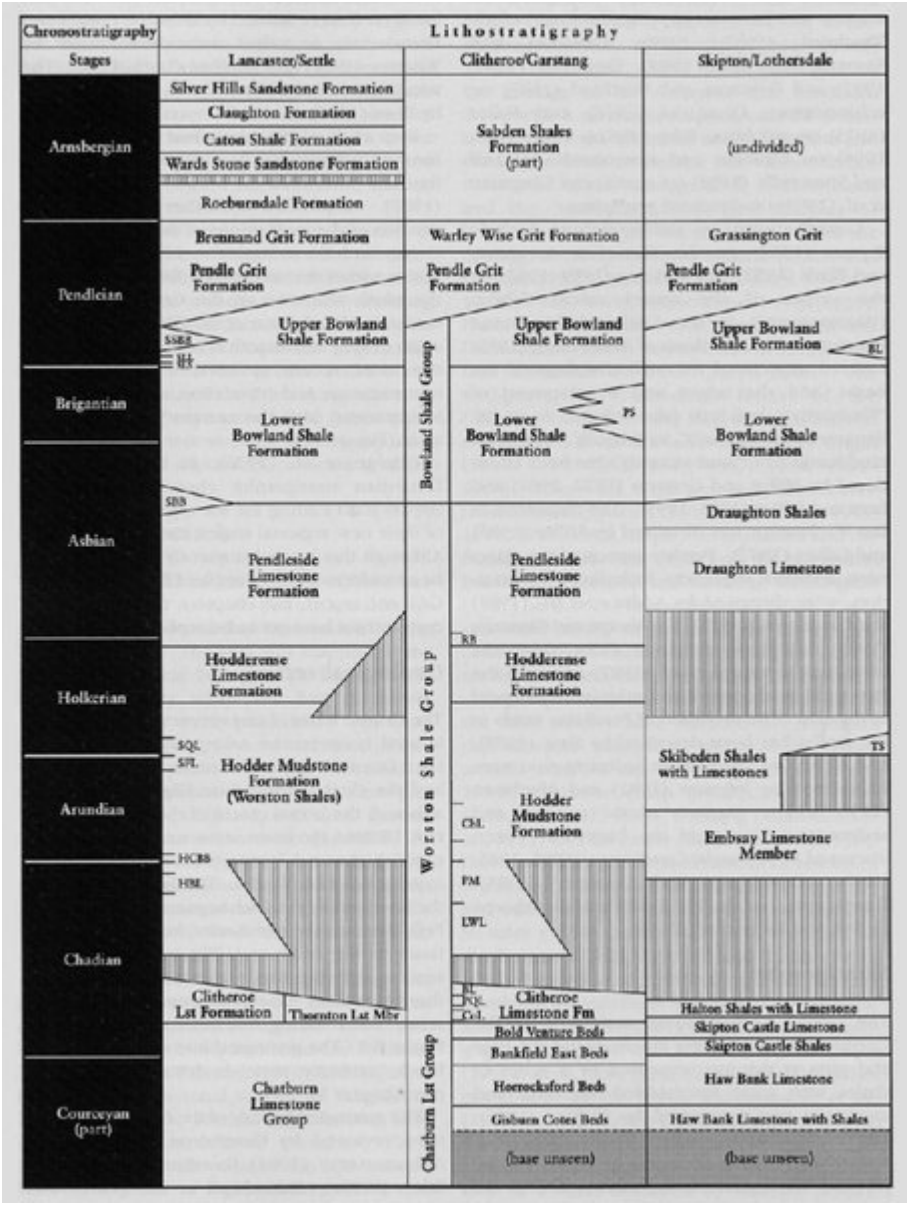
Conclusions

The River Hodder section is the best exposed and thickest Viséan marine hemipelagic deep-water sequence in Europe, possibly the world. It is one of only two localities in Britain that have yielded ammonoids of Arundian age (there are less than a dozen worldwide); it also provides an ammonoid record for the Holkerian Stage. It is therefore an essential section for understanding mid-Dinantian ammonoid evolution and biostratigraphy. There is still much potential for developing ammonoid and trilobite biostratigraphy in this section, thus improving our knowledge of deep-water environments during the Viséan Epoch. The section also demonstrates well the sequence stratigraphical relationship between the basin centre and intrabasinal highs (Whitewell-Ashnott), regional tectonics (cratons) and extrabasinal events in the source areas (carbonate ramps and platforms) and beyond (glacio-eustasy and polar ice caps). The carbonate turbidites are some of the most spectacular Lower Carboniferous examples in the world, rivalled only by outcrops in west-em Asia (Kazakhstan, Tien Shan).

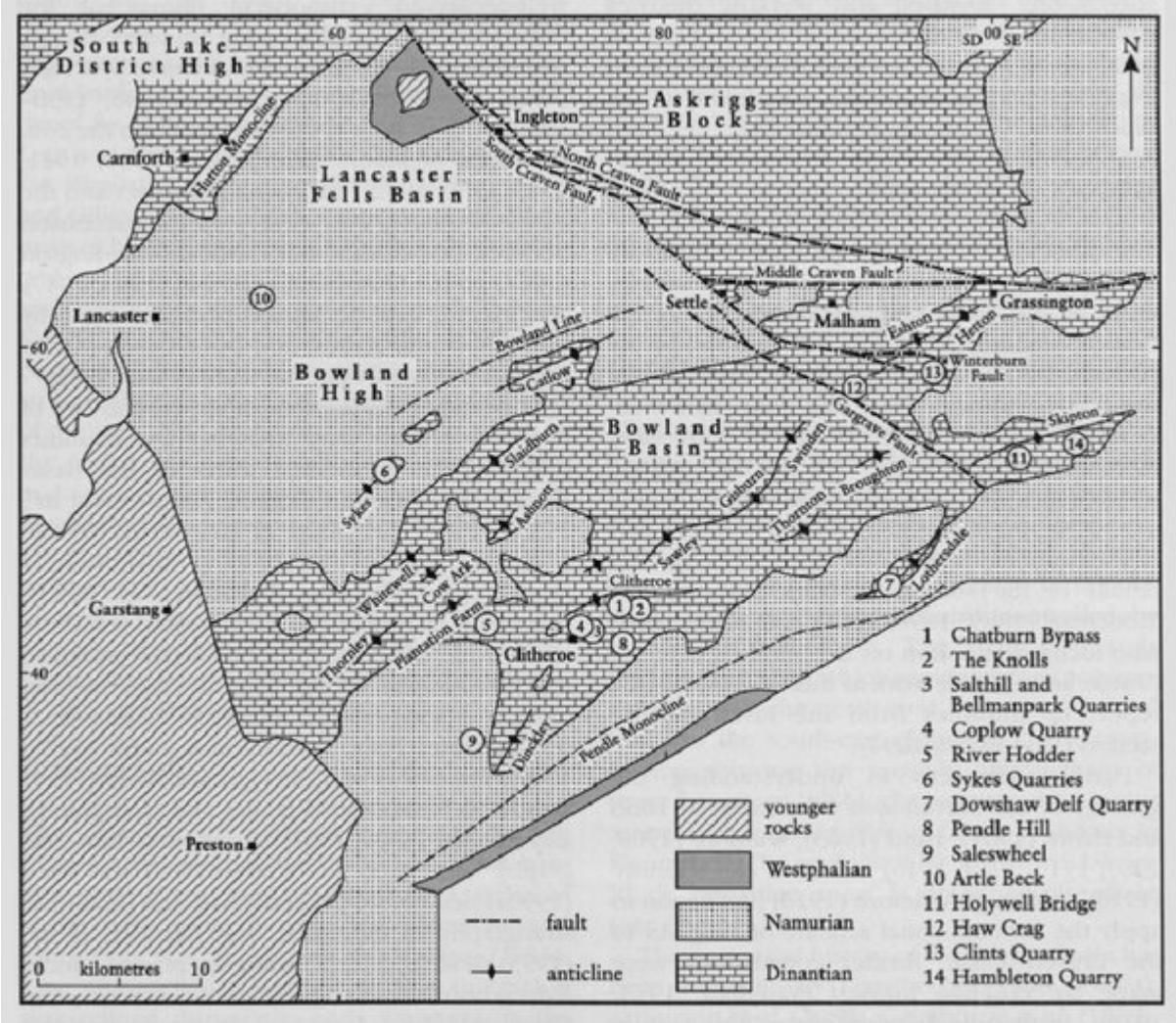
References



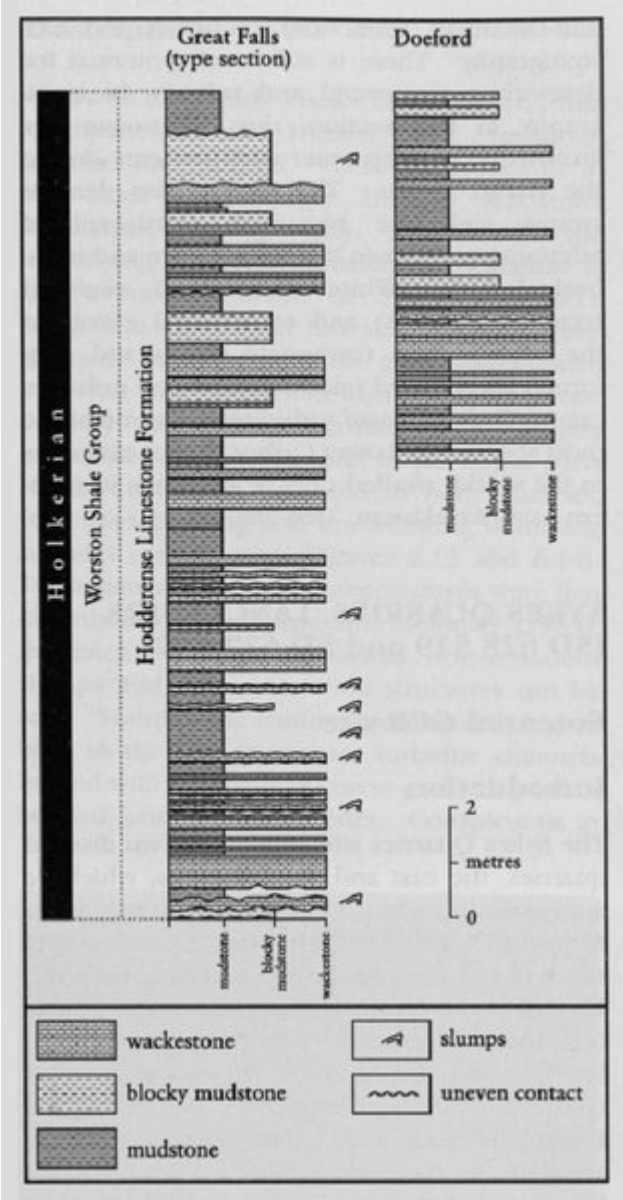
(Figure 6.11) Simplified geological map illustrating the distribution of Carboniferous strata at the River Hodder GCR site. Based on information from [British] Geological Survey maps of the area (Institute of Geological Sciences, 1975a; British Geological Survey, 1990). Note that areas depicted here as the Hodder Mudstone Formation, the Lower Bowland Shale Formation and the Namurian include, respectively, the following undifferentiated units: the Phynis Mudstone Member; the Pendleside Sandstones Member; and the Upper Bowland Shale and Pendle Grit formations. (PFA — Plantation Farm Anticline.)



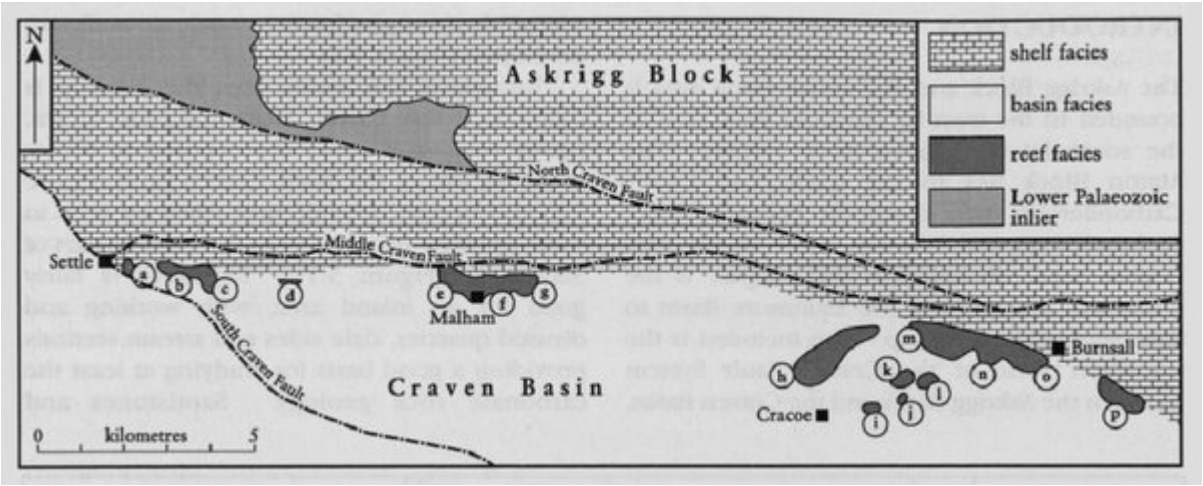
(Figure 6.2) Simplified stratigraphical chart for the Lower Carboniferous succession of the Craven Basin. (HBL — Hetton Beck Limestone Member; HCBB Haw Crag Boulder Bed; SFL — Scaleber Force Limestone Member; SQL — Scaleber Quarry Limestone Member; SBB — Scaleber Boulder Bed; SLS — Sugar Loaf Shales; SLL — Sugar Loaf Limestone; SSBB School Share Boulder Bed; CoL — Coplow Limestone Member; PQL — Peach Quarry Limestone Member; BL — Bellman Limestone Member; LWL — Limekiln Wood Limestone Member; PM — Phynis Mudstone Member; ChL — Chaigley Limestone Member; FIB — Rad Brook Mudstone Member; PS — Pendleside Sandstones Member; TS — Twiston Sandstone Member; BL — Berwick Limestone.) Areas of vertical ruling indicate non-sequences. Not to scale. Compilation based on Hudson and Mitchell (1937), Metcalfe (1981), Arthurton et al. (1988), British Geological Survey (1989), Riley (1990a, 1995), Aitkenhead et al. (1992), Brandon et al. (1995, 1998).



(Figure 6.1) Geological map of the Craven Basin illustrating the distribution of Carboniferous outcrops and the locations of GCR sites described in the text. Note that in the Bowland Basin area, the hinge traces of major folds within the Ribblesdale Fold Belt are also shown. The Central Lancashire High lies to the south of the Pendle Monocline beneath the area obscured by the key. Based on Riley (1990a) and Brandon et al. (1998).



(Figure 6.12) Comparative sections of the Holkerian Hodderense Limestone Formation (Worston Shale Group) at the River Hodder GCR site. After Riley (1990a).



(Figure 5.2) Simplified geological map of the Craven Reef-Belt, illustrating the distribution of Dinantian reef, shelf and basin facies at the southern margin of the Askrigg Block, with Namurian outcrops omitted for clarity. Reef outcrops are as follows: a — Albert Hill; b — High Hill; c — Scaleber; d — High South Bank; e — Burns; f — Cawden; g — Wedber Brow; h — Swinden; i — Skelterton Hill; j — Carden; k — Butter Haw Hill; 1- Stebden Hill; m — Elbolton; n — Thorpe Kail; o — Byra Bank; p — Hartlington Kail. Based on Brunton and Mundy (1988a) and Mundy (2000).