Settle, North Yorkshire

[SD 845 624]–[SD 870 639]–[SD 844 644]–[SD 827 638]

Introduction

The Settle GCR site (formerly referred to as the 'Langcliffe–Attermire' GCR site) stretches across several square kilometres to the east of Settle, from High Hill in the west to Great Scar in the east, and from Langcliffe Scar in the north to Scaleber in the south (Figure 5.20). It is an area of complex geology between the North and South Craven faults in which various formations of Arundian to Pendleian age are magnificently displayed. The site lies in the transition zone between the Askrigg Block and the Craven Basin. In the north, shelf limestones are seen, but south of the Middle Craven Fault the shelf-marginal reef complex is crossed and strata take on a more basinal aspect. The area has aroused considerable geological interest since the classic description of the geology of Yorkshire by Phillips (1836). The most comprehensive accounts of the site geology are by Garwood and Goodyear (1924), Hudson (1930a), Arthurton *et al.* (1988) and Mundy (2000).

Description

Because of the size and complexity of this site, its description has been divided into two parts, separated by the Middle Craven Fault ((Figure 5.20)a).

A conformable Holkerian to Brigantian succession, approximately 200 m thick, deposited in shallow-shelf environments, occurs in the area to the north of the Middle Craven Fault. The lithostratigraphy was revised by Arthurton *et al.* (1988) and has been described for the Malham GCR site (see GCR site report, this chapter). It is summarized in (Figure 5.21).

Only the upper part of the Kilnsey Limestone Member is seen within the site, although it shows its thickest known development in the Stockdale Farm Borehole, which was drilled just outside the site boundary [SD 854 638] (Arthurton *et al.,* 1988). Where exposed, for example at the base of Little Banks [SD 847 639], the Kilnsey Limestone Member consists of bedded, medium-grey bioclastic packstones and grainstones. The Cove Limestone Member crops out in the ground immediately north of the of the scars developed in the overlying Gordale Middle Craven Fault ((Figure 5.20)a) where it Limestone Member (e.g. at the base of Attermire tends to form the steep grassy slopes at the bases Scar — [SD 842 641]. It occurs similarly at the base of Langcliffe Scar in the northern part of the site [SD 838 650]. The Cove Limestone Member has similar characteristics to that of the type section at Malham (see GCR site report, this chapter). Minor cyclicity in the Holkerian limestones north of Settle was described by Jefferson (1980) who recognized 'cycles' by the quantitative analysis of grain types seen in thin- section. Five minor cycles were recognized in the 55 in of exposed strata.

The Gordale Limestone Member forms the main cliffs of Attermire and Langcliffe scars (Figure 5.22). Its contact with the underlying Cove Limestone Member is defined in the type section at Gordale Scar (see Malhana GCR site report, this chapter) at the top of the lowest scar (Arthurton *et al.,* 1988). In this area the succession is slightly thinner than at Gordale (73 m), but is otherwise similar. Particular features of note include two macrofossil bands 11 m and 2 m thick, developed respectively 29 m and 67 m above the base, and several palaeokarstic surfaces (Arthurton *et al.,* 1988; Mundy, 2000). These authors record details of a good section in the cliff at Victoria Cave [SD 838 650] where four palaeokarstic surfaces occur, each of which is associated with a palaeosol clay and/or rhizocretions. South of the cave, cross-stratified grainstones can be seen both above and below a palaeokarst.

Compared to the Malham GCR site, a greater thickness of the Brigantian Wensleydale Group is exposed here and the broad characteristics of the limestones within this unit are shown in (Figure 5.21). The Lower Hawes Limestone is exposed at Great Scar [SD 858 643], where it is 21 m thick. A foraminiferal fauna including stellate archaediscids and *Climacammina* has been recovered from the lower part of the limestone. Oncoids are prominent in the upper part of the unit. These oncoids contain *Girvanella* filaments and *Aphralysia.* Together they form the Girvanella Nodular Bed that

Garwood and Goodyear (1924) used for correlation throughout northern England. In this site the Girvanella Nodular Bed is 10 m thick, substantially thicker than elsewhere, and the oncoid-bearing horizons are interbedded with crinoidal packstones (Arthurton *et al.,* 1988). The Great Scar section also has a notable macrofossil band in the upper part of the Hawes Limestone, containing gigantoproductids, *Latiproductus latissimus, Pugilis pugilis* and colonies of *Lithostrotion* (Arthurton *et al.,* 1988).

The rather fissile crinoidal limestones of the Upper Hawes Limestone and Gayle Limestone are about 18 m thick at Great Scar and these are succeeded by a mudstone a few metres thick (Dunham and Wilson, 1985). The Hardraw Scar Limestone is 13 m thick and rather variable. It is mostly a fairly dark-coloured wackestone and packstone, but there is a paler, grainier unit in the middle (Arthurton *et al.,* 1988). Chert nodules and silicified fossils are also common. Arthurton *et al.* (1988) recorded a rich fauna from the Hardraw Scar Limestone at Great Scar, including *Diphyphyllum lateseptatum, Siphonodendron junceum, S. pauciradiale, Actinocyathus floriformis, Palaeosmilia murchisoni, Antiquatonia sulcata* and *Pugilis pugilis.* A band rich in trepostome bryozoans exposed in an old quarry [SD 863 644] also contains prominent silicified *Actinoconchus lamellosus.*

South of the Middle Craven Fault

Although shelf limestones do occur south of the Middle Craven Fault, the principal geological features of interest are the marginal reef complex, the Scaleber complex, the Namurian succession and localized areas of dolomitization and silicification.

The Scaleber complex includes exposures in and around Scaleber Beck at the southern end of the site ((Figure 5.20)a), close to the South Craven Fault. Exposures are referred to two locally developed members of the Kilnsey Formation, the Scaleber Force Limestone Member and the Scaleber Quarry Limestone Member (Mundy and Arthurton, 1980; Arthurton *et al.,* 1988), and to the Pendleside Limestone Formation, a formation better known from the Craven Basin (see Chapter 6). The succession has been described by Garwood and Goodyear (1924), Hudson (1930a,b), Arthurton *et al.* (1988) and Mundy (2000). The lower member, the Scaleber Force Limestone Member is seen in the waterfall at Scaleber Force and in the gorge below [SD 841 625]. It consists of dark packstones containing *Siphonodendron martini* separated by shaly partings. Arthurton *et al.* (1988) recorded a gradational contact with the overlying Scaleber Quarry Limestone Member, the contact between the two members being taken at the highest mudstone parting seen in the waterfall section. The Scaleber Quarry Limestone Member consists of fairly dark-coloured bioclastic packstones, which are locally cherry. A 12 m section is seen in Scaleber Quarry itself [SD 841 626]. The locality is well known for its coral fauna and is the type locality for a number of taxa including *Siphonodendron scaleberense* (Nudds and Somerville, 1987) and *Lithostrotion ischnon,* a cerioid lithostrotionid also referred to as *L. arachnoideum* (see Garwood and Goodyear, 1924; Hudson, 1930b; Mitchell, 1989; Riley, 1993), a form now considered as the junior synonym of *L. areneum* (Nudds, 1980).

The Scaleber Quarry Limestone Member is unconformably overlain by the Scaleber Conglomerate or Boulder Bed in a streamside exposure at [SD 842 627]. Elsewhere this conglomerate rests directly on the reef limestone (Arthurton *et al.,* 1988) and has been included as part of the Pendleside Limestone Formation. This conglomerate consists of partly dolomitized boulders of limestone from the marginal reef complex containing *Goniatites globostriatus* and *G. crenistria* of B_{2b} and P_{1a} age respectively, together with blocks containing oncoids and *Saccaminopsis* representing the Lower Hawes Limestone derived from the platform margin (Arthurton *et al.,* 1988; Mundy, 2000). Careful examination of geopetal fabrics in this unit has confirmed the presence of inverted blocks up to 50 m in length (Mundy, 2000).

The marginal reef complex, which Mundy (1994, 2000) refers to as the 'Cracoean' facies, outcrops in a belt from High Hill to Scaleber in the south-western part of the site ((Figure 5.20)a). The northern part of High Hill comprises northerly dipping beds of the Malham Formation (Gordale Limestone Member) and this passes southwards into and overlaps reef limestones ((Figure 5.20)b). Reef boundstone facies from High Hill contain stromatolites, bryozoans (Arthurton *et al.,* 1988) and lithistid sponges (Rigby and Mundy, 2000). Arthurton *et al.* (1988) record a fauna indicating an Asbian age for the exposed marginal reef complex. This includes *Davidsonina septosa* and B_{2b} goniatites such as *Goniatites wedberensis, Bollandites castletonensis* and a tumid form of *Bollandoceras.*

The eastern part of the site south of the Middle Craven Fault consists mainly of Namurian rock (Figure 5.20)a. In the area around Sugar Loaf Hill [SD 837 637], approximately 25–30 m of poorly exposed shales and up to 12 m of limestone rest unconformably on Brigantian Wensleydale Group limestones (Figure 5.20)b. These beds are assigned respectively to the Sugar Loaf Shales and the Sugar Loaf Limestone (Arthurton *et al.,* 1988; Mundy, 2000). The shales have yielded sponge remains ('*Hyalostelia*' *parallela*)*,* brachiopods (*Buxtonia, Pleuropugnoides greenleightonensis* and *Productus concinnus*)and trepostome bryozoans, whilst the limestones yielded a rich brachiopod–molluscan fauna in which *P. concinnus* is abundant. With the exception of one small exposure of limestone just outside the site, these are the only outcrops of the Sugar Loaf Shales and the Sugar Loaf Limestone known to exist. These two units are the lateral equivalents of the lower part of the Upper Bowland Shales seen locally within the transition zone (see (Figure 5.3) and (Figure 5.5)). The Upper Bowland Shales, which rest conformably on Lower Bowland Shales in the Craven Basin, diachronously overstep older limestones of the reef-belt at this site (see (Figure 5.5) and (Figure 5.20)a) (Arthurton *et al.,* 1988).

The Upper Bowland Shales are exposed in Scaleber Beck and in tributaries just south of the site boundaries. Close to the top of this unit, the Cravenoceras malhamense Marine Band forms a feature along the hillside south of Stockdale Beck [SD 845 631] to [SD 848 632]. Arthurton *et al.* (1988) recorded *Posidonia corrugata, P. membranacea* and *Cravenoceras malhamense* from this locality. Above the Bowland Shales and forming the topographically elevated area in the south-eastern corner of the site ((Figure 5.20)a) is the poorly exposed and highly faulted ground of the overlying Pendle Grit Formation (British Geological Survey, 1989).

A feature of the Askrigg Block–Craven Basin transition zone is local metasomatic replacement of the limestones by silica and dolomite. At this site there is only slight silicification, for example of the Scaleber Quarry Limestone Member at [SD 841 626], but there is major dolomite replacement, particularly in the faulted ground around High Hill, Sugar Loaf Hill and Scaleber Beck (Arthurton *et al.,* 1988; Mundy, 2000; and see (Figure 5.20)a). These discordant dolomite bodies appear to follow the trend of NW–SE-trending faults (Mundy, 2000) and are thought to be derived from dolomitizing fluids escaping the Bowland Shales during mudrock diagenesis (Gawthorpe, 1987b). The dolomites are coarse-grained, ferroan, and weather to brown, partly de-dolomitized mosaics. Crystals have the curved crystal faces and strongly undulose extinction of 'saddle' or 'baroque' dolomites (Arthurton *et al.,* 1988).

Interpretation

The shelf limestone succession north of the Middle Craven Fault records cyclic shallow marine deposition. In the Holkerian succession, the cyclicity, recognized on the basis of micro-facies (Jefferson, 1980), is subtle, reflecting moderate changes in relative sea level. During Asbian times, marine deposition was punctuated by periods of emergence, indicated by the palaeokarstic surfaces present in the Gordale Limestone Member. The significance of the cyclicity in this part of the succession is discussed elsewhere (see Malham GCR site report, this chapter). The nomenclature relating to the Wensleydale Group succession follows that for the sections in Wensleydale itself (see (Figure 5.4)), but at this site the succession is much thinner and the siliciclastic deposits between the named limestones are mostly absent. Clearly the influence of the Yoredale deltas was much reduced at the southern margins of the Askrigg Block and the area was dominated by shallow marine carbonate-producing environments.

Garwood and Goodyear (1924) used the Girvanella Nodular Bed to define the base of the D_2 (Brigantian) in this area. However, farther north In the Brough area, the lithological change to dark-grey limestone, which marks the onset of the Wensleydale Group, occurs a little below the level of the Girvanella Nodular Bed and is accompanied by the appearance of the first Brigantian macrofauna (Burgess and Mitchell, 1976; and see Janny Wood GCR site report, this chapter). At this site, however, a Brigantian macrofauna appears with the Girvanella Nodular Bed roughly halfway up the Lower Hawes Limestone, but Brigantian foraminifera have been recorded from the lower part of the section at Great Scar and thus the base of the Brigantian Stage is now taken to coincide with the base of the Wensleydale Group (Arthurton *et al.,* 1988; and see (Figure 5.3) and (Figure 5.21).

South of the Middle Craven Fault, relationships between the units are more complex (Mundy, 2000). These are illustrated in the cross-section shown in (Figure 5.20)b. The marginal reef complex is the lateral equivalent of the Malham

Formation, but is much eroded such that there is little evidence for the original fore-reef slope (Arthurton *et al.,* 1988). The macrofauna indicates an entirely Asbian age for the remaining exposed part of the reef, but the record of the P_{ia} goniatite *Goniatites crenistria* from a block in the Scaleber Boulder Bed indicates (according to Mundy, 2000) that the reef may have persisted into Brigantian times, although Riley (1993) and the present authors (see (Figure 1.4), Chapter 1), take the P_{la} goniatite zone to mark the top of the Asbian Stage.

Garwood and Goodyear (1924) regarded the Scaleber succession as D_2 (Brigantian). Hudson (1930a,b), however, recognized the presence of S_2 (Holkerian) faunas in the Scaleber Quarry Limestone Member. An Arundian age for the Scaleber Force Limestone Member is suggested by the presence of *Siphonodendron martini* and the absence of cerioid lithostrotionids, and foraminiferal assemblages from an adjacent borehole have confirmed this view (Arthurton *et al.,* 1988). The abundance of cerioid lithostrotionids plus the foraminifera from the adjacent borehole confirm the Scaleber Quarry Limestone Member as Holkerian in age. These two units, which are only known from these exposures and from adjacent boreholes, most probably represent upper-ramp deposits formed at a time when gentle slopes persisted out into the Craven Basin (Gawthorpe, 1986).

By Asbian times a marginal reef complex had been established along a line just south of the Middle Craven Fault, which may have persisted into Brigantian times. In later Brigantian times uplift of the southern margin of the Askrigg Block led to erosion of the reef complex. As water depths increased, the Bowland Shales were deposited, onlapping the eroded surface of the limestone complex (Arthurton *et al.,* 1988).

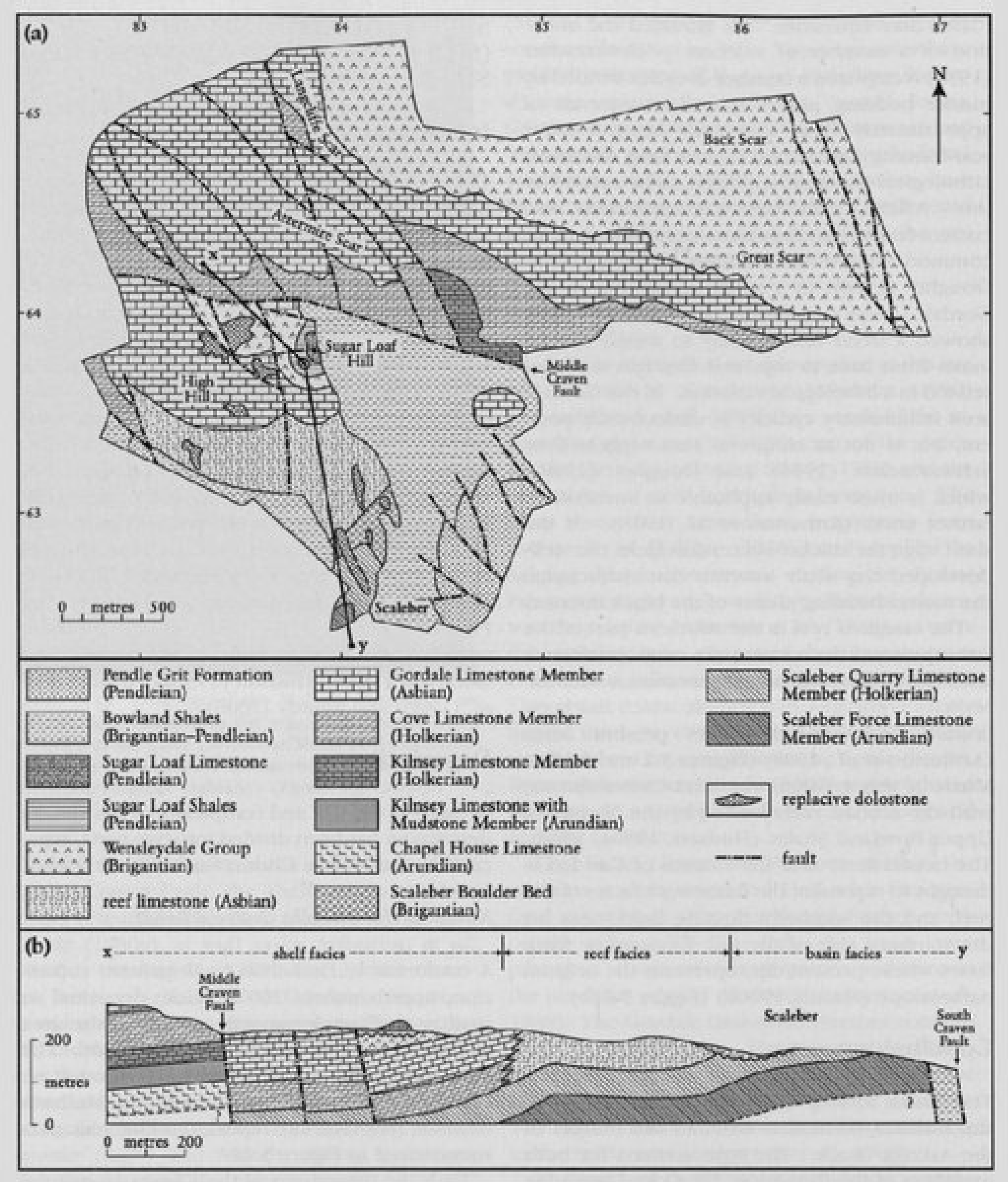
Faunal evidence equates the Sugar Loaf Shales with beds of E_l age above the Undersett Limestone farther north, a correlation from which the lateral equivalence of the Sugar Loaf Limestone and the Main Limestone of the northern Pennines can be deduced (Arthurton *et al.,* 1988). A Pendleian age for these units is suggested by Arthurton *et al.* (1988).

The mineralization, including late dolomiti-zation and silicification, was a hydrothermal process. With regard to the areas of dolomite around High Hill and Sugar Loaf Hill, this is confirmed by the presence of 'saddle' or 'baroque' dolomites which form in warm waters (Radke and Mathis, 1980). The age and origin of mineralizing fluids is discussed by Dunham and Wilson (1985).

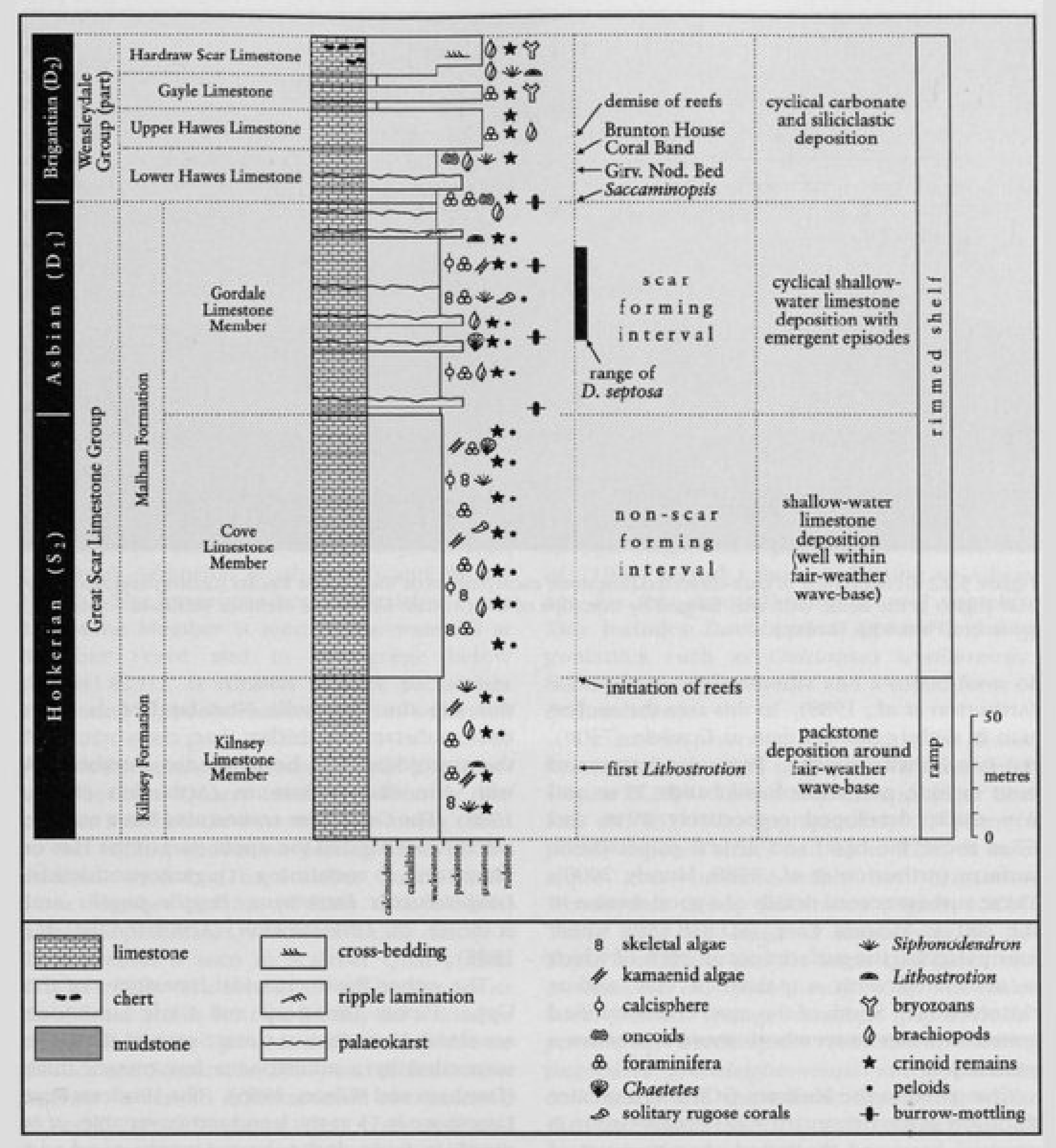
Conclusions

This locality is one of the most important sites in northern England, with key exposures across the southern margin of the Askrigg Block. Virtually the whole of the exposed Lower Carboniferous succession in the area, from Arundian to early Namurian age, can be examined within the site. In addition to the well-displayed faunas and successions of the Askrigg Block and shelf-margin reef complex, unique features include the Scaleber complex, which properly belongs to the Craven Basin, and the Sugar Loaf Shales and Sugar Loaf Limestone of early Namurian age. The site is particularly important for demonstrating the relationships between shelf, shelf-margin and basinal successions and as such is an extremely valuable locality for both teaching and research.

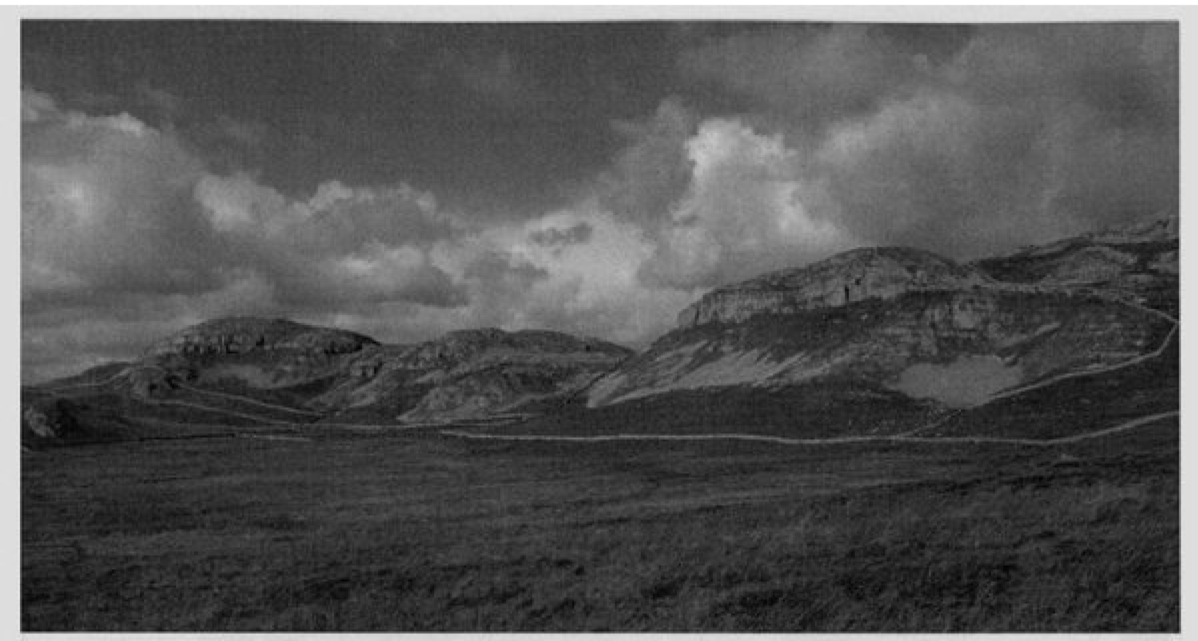
References



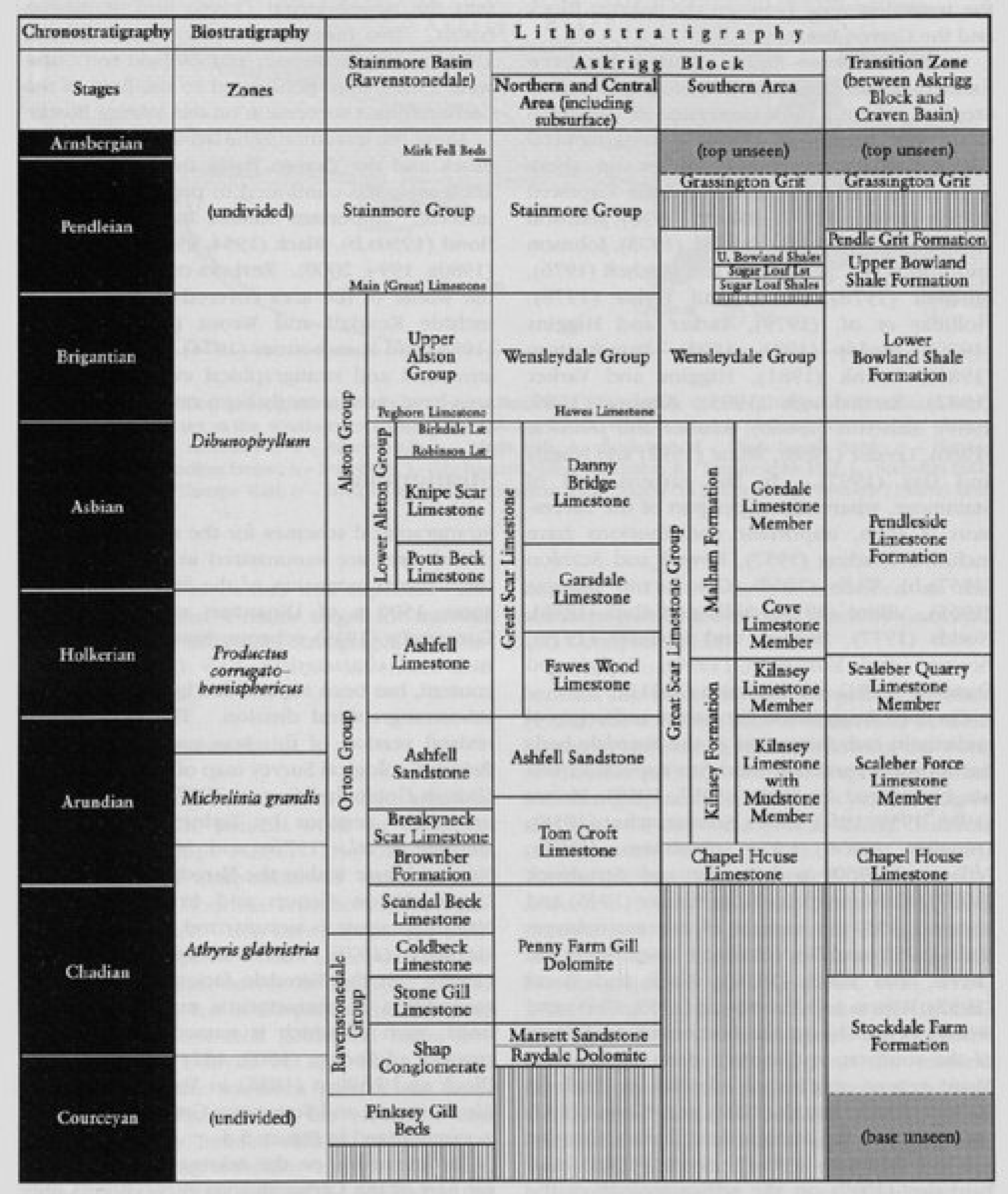
(Figure 5.20) (a) Geological map of the Settle GCR site east of Settle. After British Geological Survey (1989). Points x and y mark the approximate line of the section illustrated in (b). (b) Cross-section showing relationships between the shelf, shelf-margin and basin between Warrendale Knotts and the South Craven Fault. Based on Mundy (1980b, 2000) and Mundy and Lord (1982), and including information from British Geological Survey (1989).



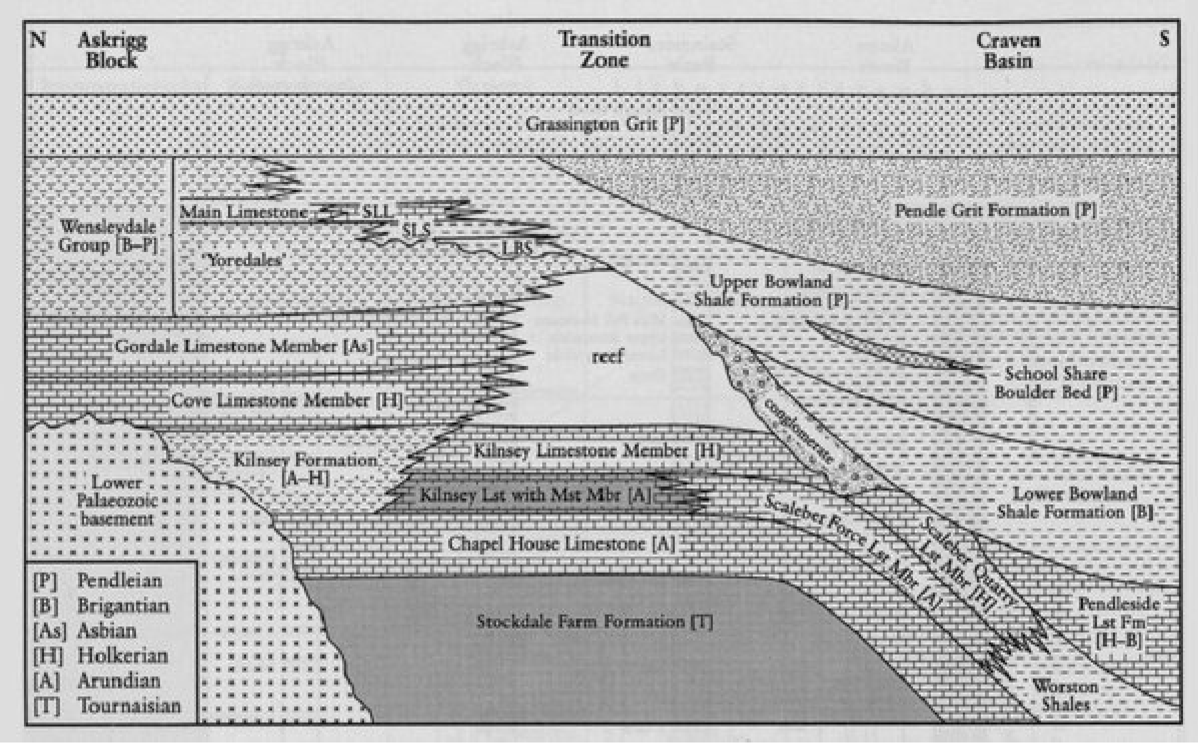
(Figure 5.21) Composite log of the Lower Carboniferous succession between the North and Middle Craven faults at the southern end of the Askrigg Block close to Settle. After Mundy (2000), and including information from Arthurton et al. (1982, 1988). (Girv. Nod. Bed — Girvanella Nodular Bed.)



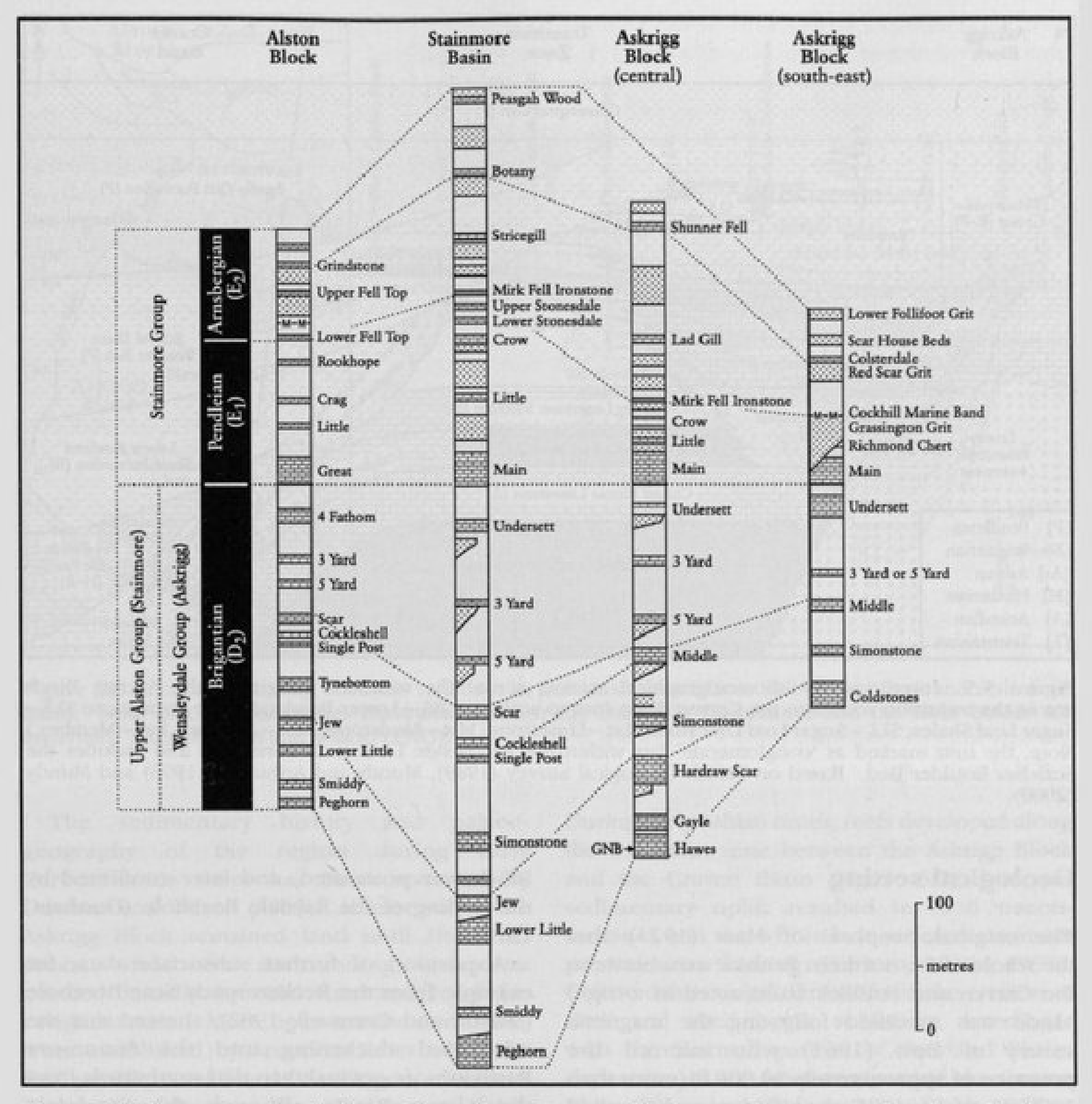
(Figure 5.22) General view of fault-dissected limestone escarpments of Warrendale Knotts (centre) and Attermire Scar (right) at the Settle GCR site, formed by outcrops of the Gordale Limestone Member (Malham Formation, Asbian). (Photo: P.J. Cossey.)



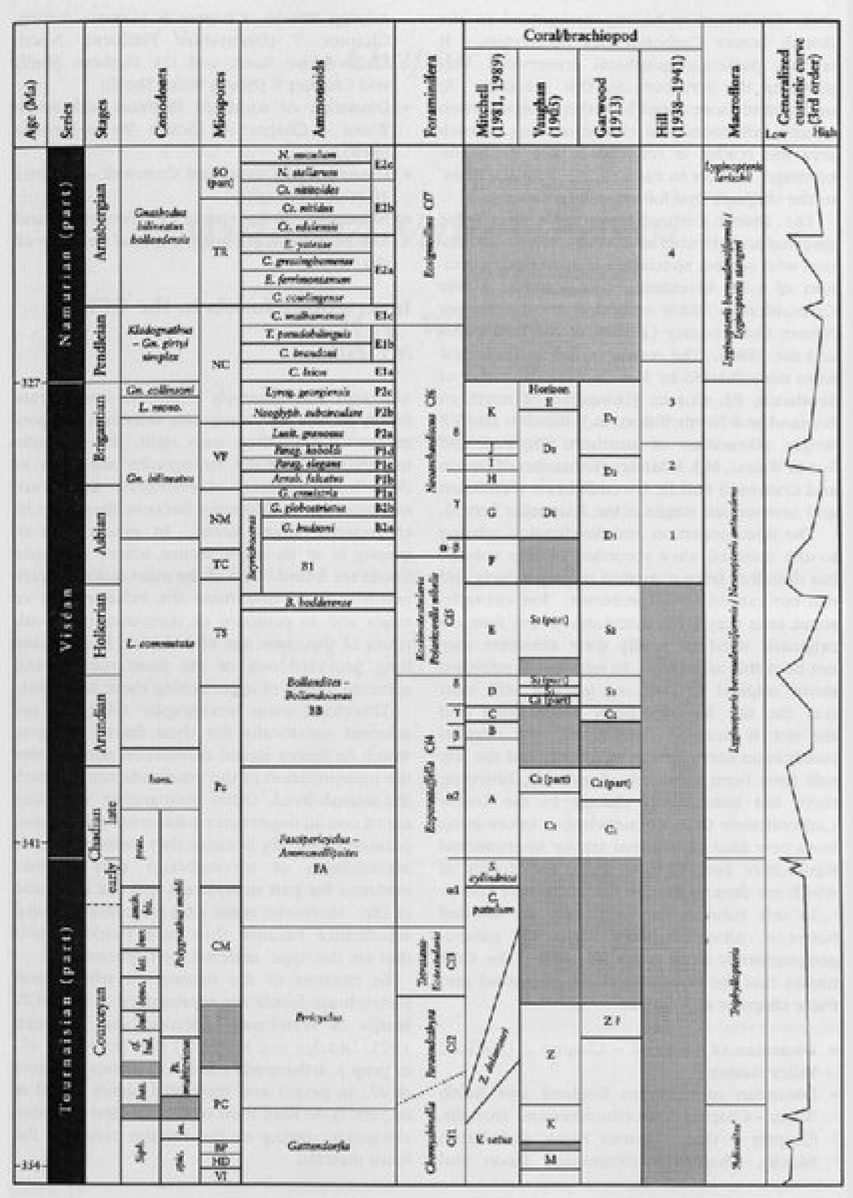
(Figure 5.3) Simplified stratigraphical chart for the Lower Carboniferous sequence of the Askrigg Block and Stainmore Basin. Compilation based upon and modified after George et al. (1976), Dunham and Wilson (1985), Arthurton et al. (1988), British Geological Survey (1997b,c), and Mundy (2000). Zonal biostratigraphy (Chadian–Brigantian only) after Garwood (1913). For further details of the Wensleydale Group, Upper Alston Group and Stainmore Group successions, see (Figure 5.4). Areas of vertical ruling indicate non-sequences. Not to scale.



(Figure 5.5) Interpretative lithostratigraphical section across the southern margin of the Askrigg Block across the transition zone into the Craven Basin (not to scale). (LBS — Lower Bowland Shale Formation; SLS Sugar Loaf Shales; SLL — Sugar Loaf Limestone; Lst — Limestone; Mst — Mudstone; Mbr — Member; Fm — Member.) Note, the unit marked as 'conglomerate' lies within the Pendleside Limestone Formation and includes the Scaleber Boulder Bed. Based on British Geological Survey (1989), Mundy and Arthurton (1996) and Mundy (2000).



(Figure 5.4) The stratigraphy of selective Upper Alston Group and Stainmore Group successions from the Alston Block, Stainmore Basin and Askrigg Block. Note that all units with a brickwork ornament are 'Limestones' unless otherwise specified. (GNB — Girvanella Nodular Bed.) Based on Ramsbottom (1974) and Ramsbottom et al. (1978).



(Figure 1.4) Chronostratigraphical and biostratigraphical classification schemes for the Lower Carboniferous Subsystem. After Riley (1993, fig. 1) with additional information for the Pendleian and Arnsbergian stages supplied by the same author. Absolute age data from Guion et al. (2000) based mainly on information by Lippolt et al. (1984), Hess and Lippolt (1986), Leeder and McMahon (1988) and Claoue-Long et al. (1995). Ammonoid abbreviations used in this figure: N. — Nuculoceras; Ct. — Cravenoceratoides; E. — Eumorphoceras; C. — Cravenoceras; T. — Tumulites; Lyrog. — Lyrogoniatites; Neoglyph. — Neoglyphioceras; Lusit. — Lusitanoceras; Parag. — Paraglyphioceras; Arnsb. — Arnsbergites; G. — Goniatites; B. — Bollandoceras. Conodont abbreviations used: Gn. — Gnathodus; Gn. collinsoni — Gnathodus girtyi collinsoni; L. mono. — Lochriea mononodosa; L. — Lochriea; horn. — Gnathodus homopunctatus; prae. — Mestognathus praebeckmanni; and,. — Scaliognathus anchoralis; bis. — Polygnathus bischoffi; bur. — Eotaphrus burlingtonensis; lat. — Doliognathus latus; bout. — Dollymae. bouckaerti; bul. — Eotaphrus bultyncki; has. — Dollymae bassi; siph. — Siphonodella; Ps. — Pseudopolygnathus; in. — Polygnathus inornatus; spit. — Polygnathus spicatus. Stipple ornament shows interzones (conodonts and miospores) or non-sequences (brachiopods).