Chapter 5 Stainmore Basin and Askrigg Block

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Introduction

The Askrigg Block and Stainmore Basin area is bounded to the west by the Dent Fault and to the south by the Craven Fault System. The Alston Block lies to the north and Lower Carboniferous strata disappear beneath Upper Carboniferous and Permian cover to the east (Figure 5.1). Included in this chapter is the westwards extension of the Stainmore Basin to Ravenstonedale and Shap. Also included is the transition zone of the Craven Fault System between the Askrigg Block and the Craven Basin, where shelf-margin features such as reefs are developed (Figure 5.2).

Throughout this entire area the outcrop is dominated by Lower Carboniferous strata. Lower Palaeozoic rocks are exposed in inliers along the line of the North Craven Fault (Figure 5.2) and Upper Carboniferous strata are seen in some outliers, particularly in the eastern part of Stainmore (Figure 5.1). Exposure is fairly good for an inland area, with working and disused quarries, dale sides and stream sections providing a good basis for studying at least the carbonate rock geology Sandstones and mudstones tend to be less well exposed. The area has also been a major target for mineral exploration and additional stratigraphical information has been gained from boreholes and mines in the area.

History of research

The overall geological succession of the area was established in the seminal work on Yorkshire geology by Phillips (1836). He defined the major units of Carboniferous strata — the Basement Beds, Mountain Limestones, Yoredales and Millstone Grit — that have formed the basis for much subsequent work. Later work by the [British] Geological Survey in the latter part of the 19th century led to the publication of some of the earliest one-inch geological maps and memoirs (e.g. Dakyns *et al.,* 1890, 1891). Meanwhile, in the southern part of the area, attention was focused on the structure and origin of poorly bedded masses of limestone forming 'knolls' (Tiddeman, 1889, 1891; Marr, 1899; Wilmore, 1910) and on the geology of the Ingleborough district (Hughes, 1908). The importance of fossils in the division and correlation of the Lower Carboniferous succession was appreciated by Garwood (1913, 1916) who used the section in Ravenstonedale as a 'standard' to which he compared other sections in north-west England. This work was extended to the southern part of the Askrigg Block by Garwood and Goodyear (1924).

Subsequently, the presence of a 'rigid block' beneath the Pennines was recognized by Marr (1921), the southern part of which later became known as the Askrigg Block, following the work of Hudson (1938a). Further important faunal and stratigraphical studies of this period include the work of Garwood (1922, 1929), Hudson (1924, 1929, 1930a,b, 1932, 1941, 1944a), Turner (1927, 1950, 1955, 1956, 1959a, 1962), Anderson (1928), Miller and Turner (1931) and Carruthers (1938). Bisat's work on goniatites has also been important in establishing the biostratigraphy of the area (Bisat, 1914, 1924, 1928, 1934). During the war years the [British] Geological Survey re-investigated the northern Pennine area, concentrating on the mineral deposits. This work resulted in several publications, some of which include stratigraphical information (e.g. Dunham and Stubblefield, 1945) and culminated in the appearance of the economic memoir for the area (Dunham and Wilson, 1985).

Interest in sedimentology as well as stratigraphy led to an expansion in research during the 1950s, which has continued to the present day. This work can be conveniently considered under three regional headings: the Stainmore Basin, the main part of the Askrigg Block, and the transition zone between the Askrigg Block and the Craven Basin.

In the Stainmore Basin, attention has been focused on the area between Shap and Kirkby Stephen, where a thick succession of Dinantian strata can be seen. Faunal, stratigraphical and palaeoenvironmental studies on these dominantly carbonate rocks include Capewell (1955), Rowley (1969), Ashton (1970), Johnson and Marshall (1971), Rose *et al.* (1973), Johnson and Nudds (1975), Burgess and Mitchell (1976), Mitchell (1978), Nudds and Taylor (1978), Holliday *et al.* (1979), Varker and Higgins (1979), Nudds (1981, 1993), Ramsbottom (1981), Strank (1981), Higgins and Varker

(1982), Barraclough (1983), Kimber (1984, 1987), Bancroft (1986b), Kimber and Johnson (1986), Leeder (1988), White (1992) and Nudds and Day (1997). In the eastern part of Stainmore, where the upper part of the succession is seen, important contributions have included Reading (1957), Rowell and Scanlon (1957a,b), Wells (1958), Owens and Burgess (1965), Elliot (1975), Mills and Hull (1976), Nudds (1977), Burgess and Holliday (1979), Brenner and Martinsen (1990), Hodge and Dunham (1991) and Fairbairn (2001).

On the Askrigg Block, the nature and origin of cyclicity in carbonates and in the Yoredale beds has aroused particular interest. Aspects of this are considered by Hicks (1957, 1959), Moore (1958, 1959, 1960, 1984), Schwarzacher (1958), Doughty (1968, 1974), Waltham (1971), Jefferson (1980) and Leeder and Strudwick (1987). Other work includes Rayner (1946) and Joysey (1955) on aspects of the macrofauna; Wells (1955) and Hey (1956) on lower Namurian cherts; and Black (1950), Black and Bond (1952), Wilson and Thompson (1959, 1965) and Wilson (1960a,b) on the Carboniferous System of the southern and eastern parts of the area. More recent studies of significance include Hallett (1970), Strank (1981) and White (1992) on aspects of the foraminiferal faunas; Cousins (1977), Izzidien (1984), Scott (1984) and Fairbairn (1999) on the sedimentology of the carbonate rocks; Walker (1967) and Martinsen (1993) on aspects of the clastic sedimentology; the Settle Memoir of Arthurton *et al.* (1988); Burgess (1986) on the stratigraphy of the Sedbergh area; and Brandon *et al.* (1995) on the biostratigraphy and correlation of lower Namurian successions across the Askrigg Block into the neighbouring Craven and Stainmore basins. Two boreholes, at Raydale (Dunham, 1974) and Beckermonds Scar (Wilson and Cornwell, 1982), have penetrated to the base of the Carboniferous succession on the Askrigg Block.

Along the transition zone between the Askrigg Block and the Craven Basin the origin of the knoll reefs has continued to provide the major interest. Important studies include those of Bond (1950a,b), Black (1954, 1958) and Mundy (1980a, 1994, 2000). Reviews of the geology of the whole of the area covered in this chapter include Kendall and Wroot (1924), Rayner (1953) and Ramsbottom (1974). Aspects of the structural and stratigraphical evolution of this area have most recently been reviewed by Kirby *et al.* (2000).

Stratigraphy

Stratigraphical schemes for the area covered by this chapter are summarized in (Figure 5.3). In the western extension of the Stainmore Basin, some 1500 m of Dinantian strata are seen. Garwood's (1913) scheme, based on a combination of characteristic rock types and fossil content, has been superseded by a more formal lithostratigraphical division. The most recent revised version of this was published on the British Geological Survey map of Kirkby Stephen (British Geological Survey, 1997b) and is based on earlier versions by Taylor *et al.* (1971), George *et al.* (1976) and Mitchell (1978). Nomenclature within the Yoredale facies of the Upper Alston Group and in the overlying Namurian strata is summarized by Burgess and Holliday (1979) and Dunham and Wilson (1985). In the Yoredale facies it is based on recognition of characteristic marine limestone units, each of which is named following the practice of Forster (1809, 1821) on the Alston Block and Phillips (1836) in Yorkshire. Upper Alston Group and Stainmore Group stratigraphy is summarized in (Figure 5.4).

Farther south, on the Askrigg Block, the lowest part of the Carboniferous succession is only exposed in the west, in the Sedbergh-Garsdale area, but it is also known from the Beckermonds Scar and Raydale boreholes. The stratigraphical divisions from these areas, described by Wilson and Cornwell (1982) and Burgess (1986), have been applied to the Askrigg Block part of the Kirkby Stephen area (British Geological Survey, 1997b) and to the Hawes area (British Geological Survey, 1997c) and are shown in (Figure 5.3). In the southern part of the block, Ramsbottom (1974) and George *et al.* (1976) set up a new stratigraphy based on the Horton area (Figure 5.4), but Arthurton *et al.* (1988) revised this for the Settle area, particularly in the light of new borehole information (Figure 5.3). They also changed the status of the Wensleydale Formation to a group, the individually named Yoredale limestones becoming formations.

The stratigraphy of the Craven Reef-Belt at the southern margin of the Askrigg Block is complex, because of local facies variations. Local stratigraphical names in use are discussed in the appropriate site descriptions. The relationship between shelf and basin units in the Settle area described by Arthurton *et al.* (1988) is shown in (Figure 5.5) and details of stratigraphical schemes for the Craven Basin are discussed in Chapter 6.

Geological setting

The original proposal of Marr (1921) that the whole of the northern Pennine area between the Craven and Stublick faults acted as a 'rigid block' was modified following the magnetic survey of Bott (1961) who inferred the presence of approximately 10 000 ft (more than 3000 m) of Lower Carboniferous and possible Devonian rocks beneath the Stainmore area, contrasting with the few hundred metres known from the Alston Block to the north and the Askrigg Block to the south. Bott (1961) suggested that the Closehouse–Lunedale–Butterknowle Fault System was the southern boundary of the Alston Block, and further work (Bott, 1967; Johnson, 1967) confirmed the presence of the Stainmore Basin between the two blocks which also extends westwards to Ravenstonedale and Shap. The line of the Stockdale Disturbance (Figure 5.6) was suggested to mark the position of the southern margin of the basin. Futhermore, the presence of the Wensleydale Granite beneath the Askrigg Block was postulated, and later confirmed by the drilling of the Raydale Borehole (Dunham, 1974).

Acquisition of further subsurface data, for example from the Beckermonds Scar Borehole (Wilson and Cornwell, 1982), showed that the northward thickening into the Stainmore Basin is more gradual than that southwards from the Alston Block, although the Stockdale Disturbance marks a line where the rate of thickness increase accelerates (Figure 5.6). The realization that the Askrigg Block was a northerly dipping 'tilt-block' during Dinantian times and that the Stainmore Basin was a 'half-graben', similar to those recognized in other areas, led to some suggested changes in the nomenclature for these structural units (Grayson and Oldham, 1987), but these have not, on the whole, been adopted. The inferred pattern of thickness variations in Dinantian successions across the Askrigg Block and Stainmore Basin is shown in (Figure 5.6). A more detailed evaluation of basin evolution in this area is considered by Collier (1991).

The sedimentary history and palaeogeography of the region during Early Carboniferous times has been reviewed by Dunham and Wilson (1985). At least part of the Askrigg Block remained land until Holkerian times, while the surrounding area was covered initially by tidal flats and local fan conglomerates. More open marine conditions were established by Arundian times when the first prolific coral faunas developed. Strata at Ravenstonedale are all indicative of fairly shallow-water conditions. To what extent a deeper-water basinal facies (*sensu stricto*) might be represented in the thick subsurface successions to the east has yet to be established. In the latter part of Arundian times, the Ashfell Sandstone, a fluvio-deltaic sand-body sourced from the east or north-east, interrupted carbonate deposition. Shallow marine carbonate deposition continued throughout Holkerian and Asbian times, although there is evidence for subaerial exposure at regular intervals.

Along the southern margin of the block there is a complex relationship between faulting and sedimentation (Kirby *et al.,* 2000; Mundy, 2000). During early Asbian times, reefs developed along the transition zone between the Askrigg Block and the Craven Basin (Figure 5.2), but syn-sedimentary uplift resulted in local unconformities and the whole belt suffered extensive pre-Namurian faulting (Hudson, 1930a, 1932). Coarse debris units, derived from the erosion of shelf and shelf-margin sediments, interfinger with the 'normal' pattern of Bowland Shales deposition in the northern part of the Craven Basin (Dixon and Hudson, 1931; Black, 1957).

At the end of Asbian times, carbonate deposition across much of the area finally gave way to the mixed carbonate and siliclastic deposits of Yoredale facies, which developed in 11 broadly shallowing-upward cycles during Brigantian and early Namurian times. Moore (1958, 1959, 1960) interpreted the Yoredale facies as the product of shifting deltas building out onto a shallow subsiding shelf: Mechanisms for the generation of the cyclicity are reviewed by Leeder and Strudwick (1987). Cherts are a significant part of upper Yoredale cycles in Swaledale and their origin was discussed by Wells (1955) and Hey (1956). Towards the top of the Pendleian Stage there is a marked change in facies. The Grassington Grit rests with progressively wider unconformity on successively older Brigantian strata towards the edge of the Askrigg Block. Fluvio-deltaic environments predominated at this time and the marine component of the successions is less evident.

GCR site coverage

GCR sites across the Askrigg Block–Stainmore Basin region are located in three separate areas. These include an area to the north-west around Ravenstonedale and Shap, widely regarded as the type area for the Lower Carboniferous

succession in northern England and where Courceyan–Brigantian successions are particularly well developed (thick and complete); an area to the south in the Craven District, where a wide variety of Arundian–Brigantian sedimentary facies are developed in the transition zone between the southern margin of the Askrigg Block and the Craven Basin; and a northern to central district where excellent sections of Brigantian–Arnsbergian Yoredale successions are known. A diverse array of ancient sedimentary environments are represented by the successions at the selected localities, and more than half of these include stratotype sections of either regional or international significance.

Sites in the Ravenstonedale–Shap district towards the western end of the Stainmore Basin Include the following:

- **Wasdale Beck** (Courceyan, Shap Conglomerate, alluvial-fan deposits);
- **Pinskey Gill** (Courceyan, type locality for the Pinskey Gill Beds, marginal marine facies);
- **Stone Gill–Scandal Beck** (Chadian–Arundian, type locality for the Stone Gill Limestone, Coldbeck Limestone, Scandal Beck Limestone and Breakyneck Scar Limestone, marginal marine to open marine facies);
- **Ash Fell Edge** (Arundian–Holkerian stage boundary, Ashfell Sandstone–Ashfell Limestone, deltaic to open marine facies);
- **Little Asby Scar** (regional stratotype for the Asbian Stage at the base of the Potts Beck Limestone, open marine facies);
- **Janny Wood** (regional stratotype for the Brigantian Stage at the base of the Peghorn Limestone, Yoredale facies).

While most of these sites include features of intrinsic sedimentological or palaeontological interest, all except Wasdale Beck are stratigraphically significant because they contain successions that extend across formation and/or stage boundaries.

Typically, GCR sites of the 'transition zone' at the southern edge of the Askrigg Block reveal mixed successions dominated by block and/or basin-margin facies with relatively minor developments of basin facies. These include three of the largest Lower Carboniferous GCR sites in Britain in an area of spectacular limestone scenery located towards the southern margin of the Yorkshire Dales National Park:

- **Malham** (Holkerian–Brigantian, Kilnsey Formation to Wensleydale Group, type locality of Malham Formation, Asbian reef limestones);
- **Settle** (Arundian–Pendleian, Scaleber Force Limestone to Pendle Grit, type locality for various locally developed lithostratigraphical units, Asbian reef limestones);
- **Cracoe Knolls and Swinden Quarry** (Asbian reef complex).

The value of these sites as an educational resource is considerable. Further sites of particular stratigraphical and sedimentological interest in this area are

- **Meal Bank Quarry** (unusual Asbian shelf limestone-coal association);
- **School Share** (non-sequence at the Dinantian–Namurian boundary associated with a carbonate debris bed at the base of the Upper Bowland Shales).

In northern and central areas, Lower Carboniferous successions are typically of Yoredale facies and are dominated either by carbonate rocks or by a carbonate–clastic deposit mix.

Carbonate-dominated successions:

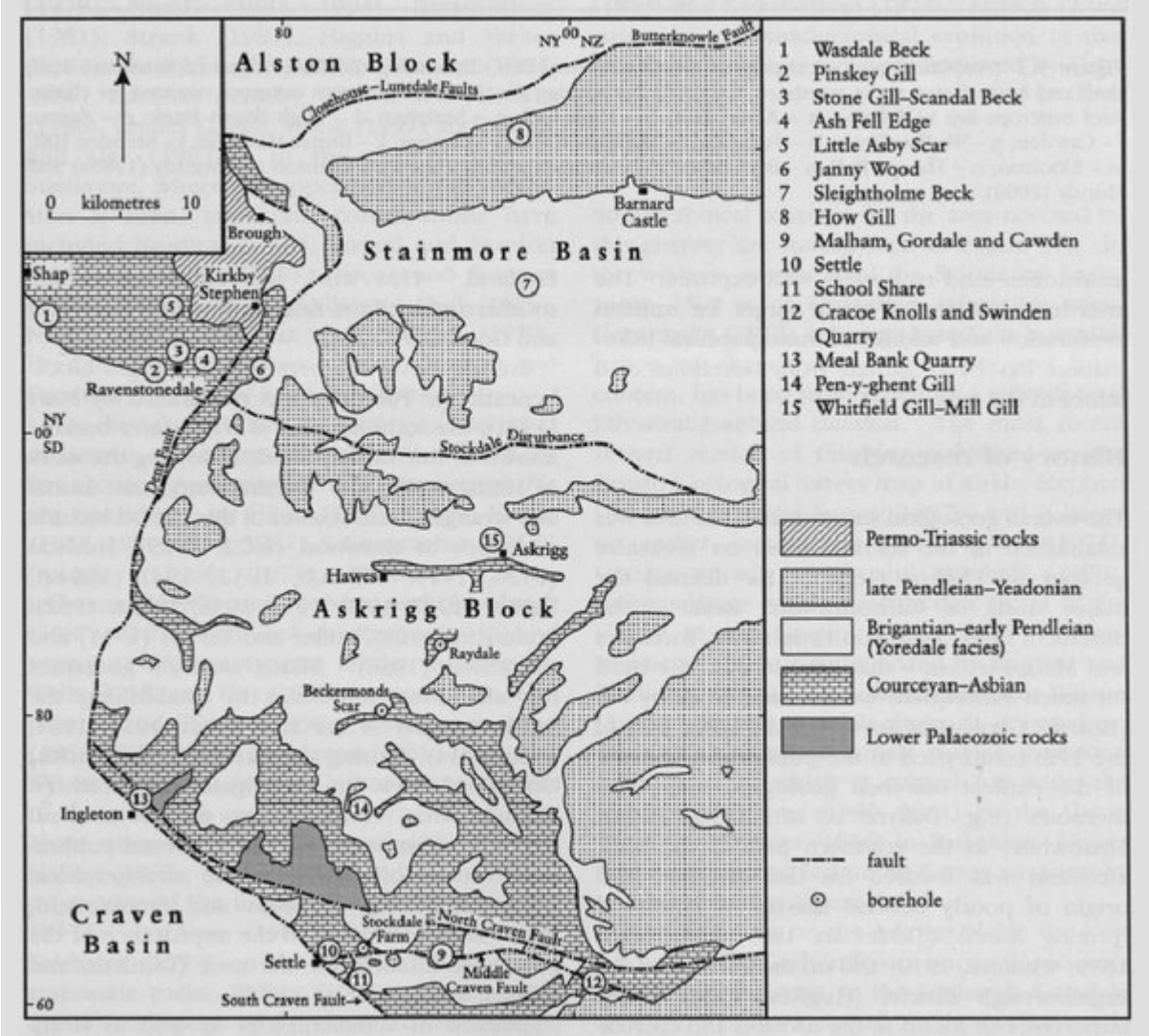
- **Pen-y-ghent Gill** (Brigantian, lower Wensleydale Group, Hawes Limestone to Hardraw Scar Limestone, Girvanella Nodular Bed, marine facies).

Mixed carbonate-siliciclastic successions:

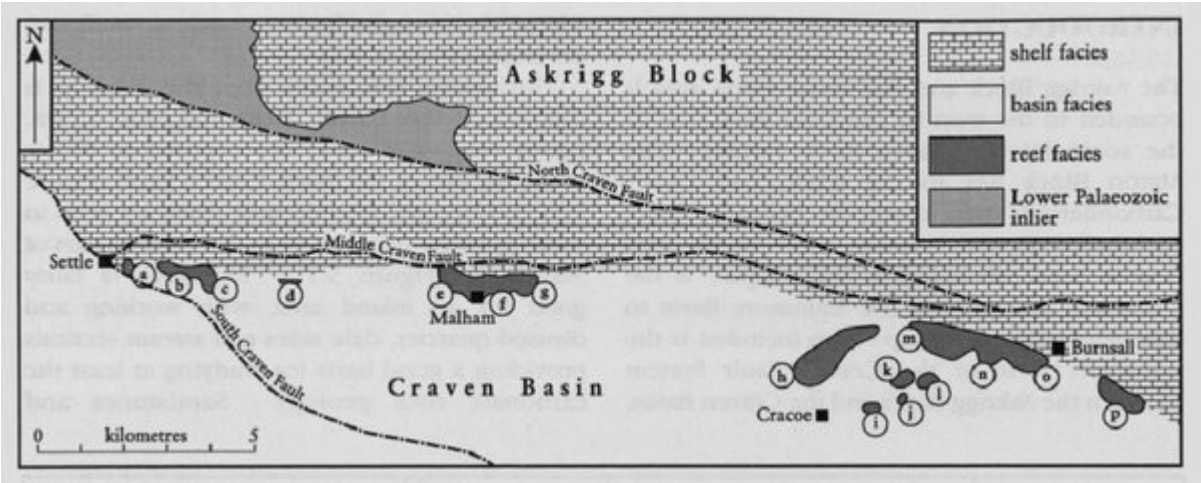
- **Whitfield Gill–Mill Gill** (Brigantian, Wensleydale Group, deltaic and marine facies);
- **Sleightholme Beck** (Pendleian, Great Limestone Cyclothem, deltaic, marine and barrier-island facies);

- **How Gill** (Arnsbergian, Botany Limestone, deltaic and marine facies).

References

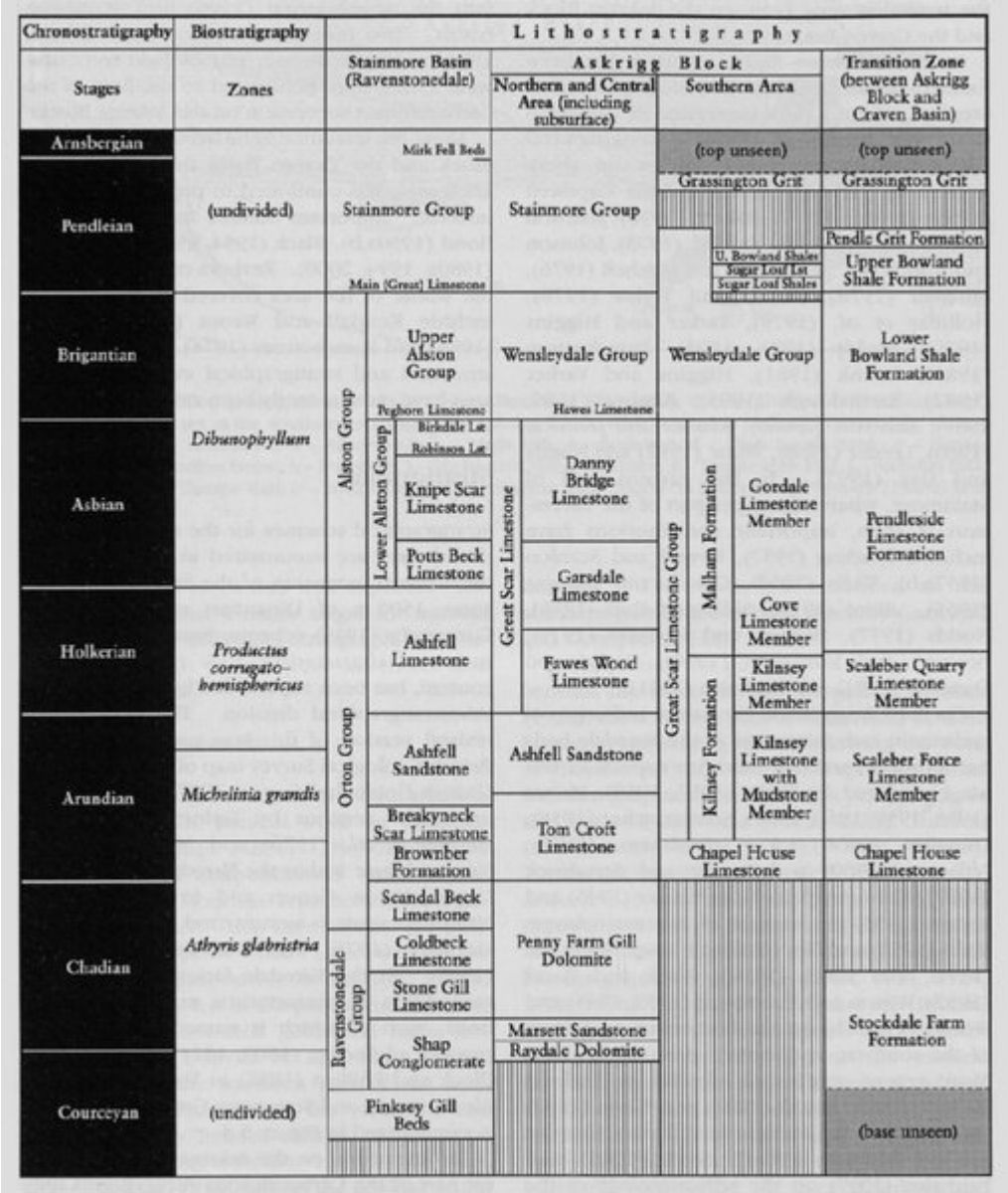


(Figure 5.1) Geological map of the Askrigg Block and Stainmore Basin illustrating the distribution of Carboniferous outcrops and the locations of GCR sites described in the text. Note that outside the area delineated by the bounding faults, only the geology of the Ravenstonedale area is shown, and that within this area igneous rocks are omitted. After Dunham and Wilson (1985).

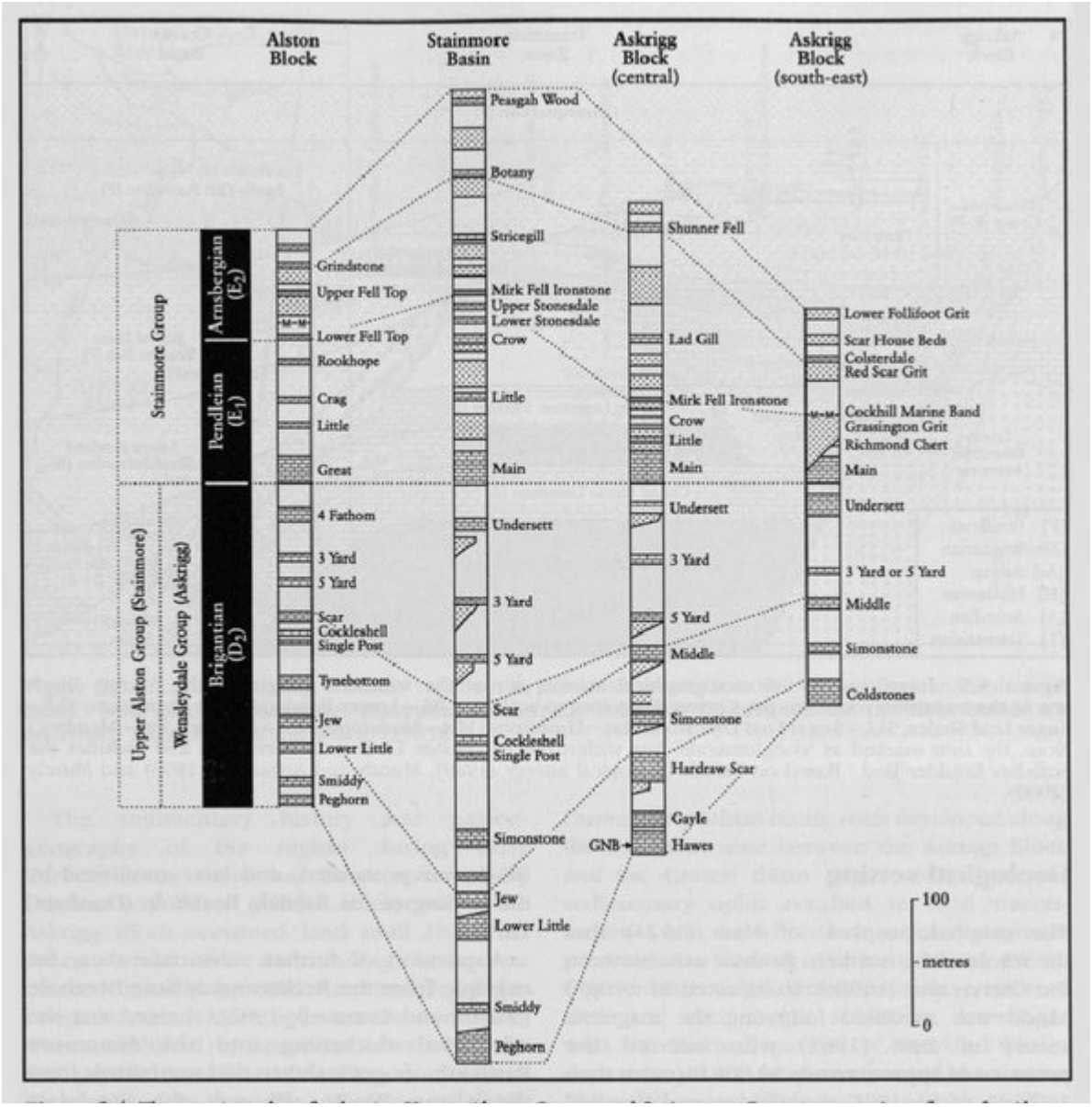


(Figure 5.2) Simplified geological map of the Craven Reef-Belt, illustrating the distribution of Dinantian reef, shelf and basin facies at the southern margin of the Askrigg Block, with Namurian outcrops omitted for clarity. Reef outcrops are as follows: a — Albert Hill; b — High Hill; c — Scaleber; d — High South Bank; e — Burns; f — Cawden; g — Wedber Brow;

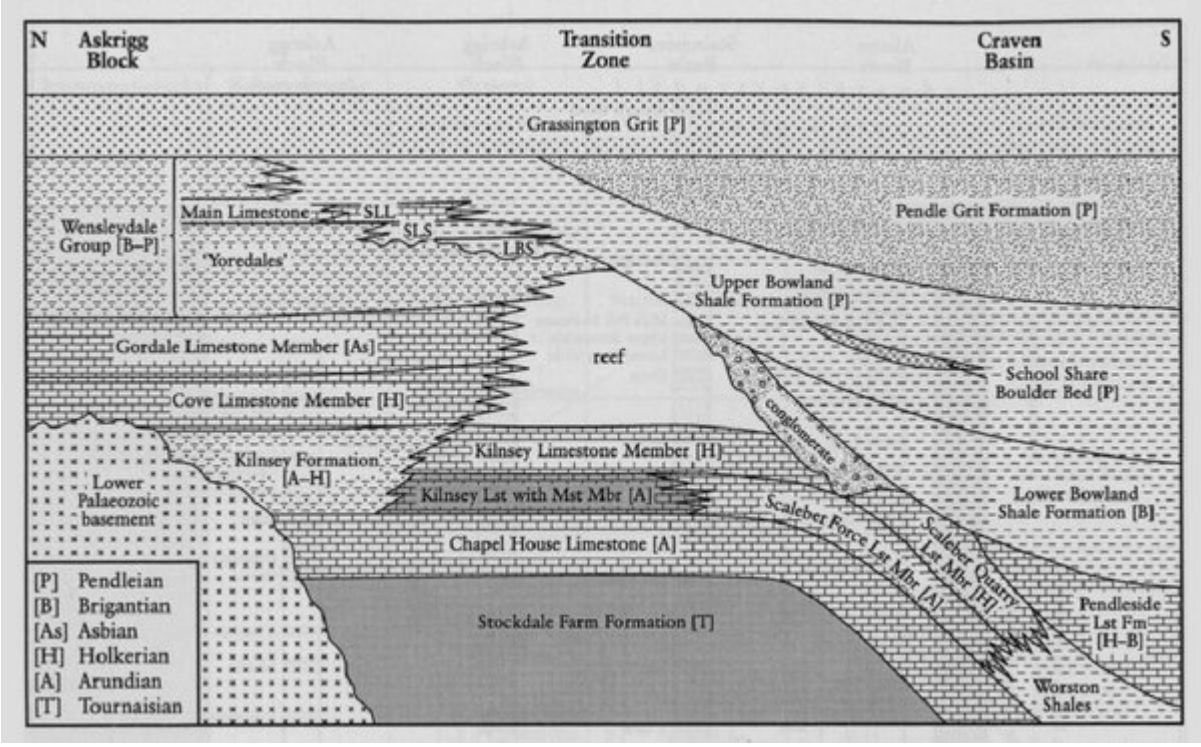
h — Swinden; i — Skelterton Hill; j — Carden; k — Butter Haw Hill; 1- Stebden Hill; m — Elbolton; n — Thorpe Kail; o — Byra Bank; p — Hartlington Kail. Based on Brunton and Mundy (1988a) and Mundy (2000).



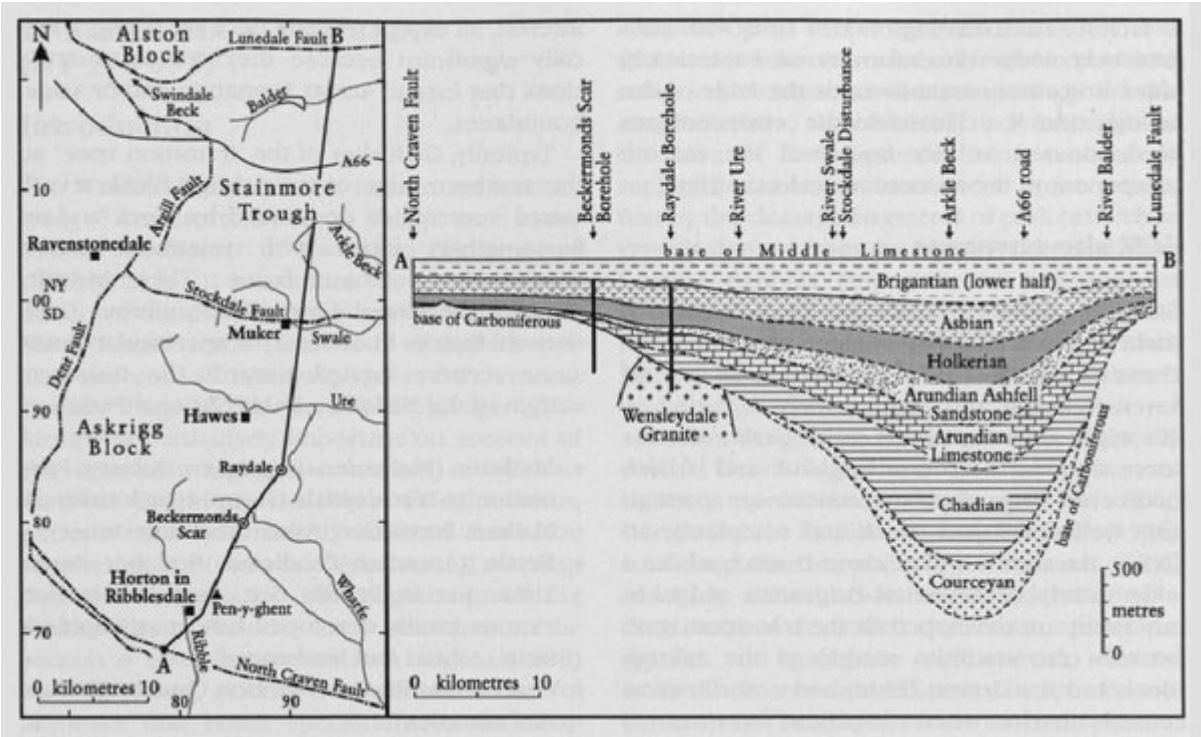
(Figure 5.3) Simplified stratigraphical chart for the Lower Carboniferous sequence of the Askrigg Block and Stainmore Basin. Compilation based upon and modified after George et al. (1976), Dunham and Wilson (1985), Arthurton et al. (1988), British Geological Survey (1997b,c), and Mundy (2000). Zonal 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 5.4) 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 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 5.6) Section illustrating thickness variations in Dinantian strata across the Askrigg Block and Stainmore Basin. Note that the thicknesses illustrated between the Stockdale Disturbance and the River Balder are uncertain. After Dunham and Wilson (1985).