Kirkbean, Dumfries and Galloway

[NX 987 563]–[NX 996 588] and [NX 977 543]

Introduction

The Lower Carboniferous rocks of the Kirkbean Outlier are well exposed in the foreshore sections that make up the Kirkbean GCR site on the northern shore of the Solway Firth, 16 kin south of Dumfries (Figure 3.7). The site includes two separate sections: the northern section starts on the coast approximately 1.5 km east of Kirkbean [NX 9955 5886] and extends 3 km south (to [NX 9867 5624]), exposing a section through the Gillfoot Sandstone Formation, the Powillimount Sandstone Formation and the Arbigland Limestone Formation. The second section, just over 1 km to the south [NX 977 543], exposes rocks of the Southerness Limestone Formation and overlying Gillfoot Sandstone Formation. These sequences may span a Chadian to Asbian time interval (Craig, 1956; Deegan, 1973; George *et al.,* 1976; Purnell, 1989, 1992; British Geological Survey, 1993a; Maguire *et al.,* 1996).

The site is important in providing the type section of all the formations referred to above (Craig, 1956; British Geological Survey, 1993a) and in defining the evolution of a shallow-marine shelf area that was periodically inundated by a westward-prograding fluvial system (Maguire *et al.,* 1996). Together they offer the best exposed and most complete Lower Carboniferous succession of mixed marine and fluvial facies in the western part of the Northumberland Trough (Solway Basin).

The stratigraphical terminology used to define the Kirkbean succession has evolved considerably since the time of Horne (1896) and Pringle (1948). The terminology most widely used today (see Greig, 1971; Deegan, 1973; George *et al.,* 1976; Ord *et al.,* 1988; Maguire *et al.,* 1996) derives from the lithostratigraphical scheme of Craig (1956), a modified version of which, based on the British Geological Survey map of the Dalbeattie district (British Geological Survey 1993a), is used in the account below (see (Figure 3.3)).

While early site descriptions focused attention on palaeontological aspects (Jolly, 1869; Thomson, 1887; Smith, J., 1910; Craig, 1956), recent workers have concentrated their effort on studies of a sedimentological, palaeoecological and structural nature (Frolicher, 1977; Ord *et al.,* 1988; Maguire *et al.,* 1996). The most useful accounts of the site geology are given by Craig (1956), McMillan (1996), Maguire *et al.* (1996) and Lintern and Floyd (2000).

Description

The strata exposed in the northern section of the site essentially young eastwards, and moving southward along the coast progressively older formations are encountered (Figure 3.7). However, the structure is complicated by folding and faulting, and the dip and strike of the beds vary considerably. The main structural feature of the southern section is the broad anticline exposing the Southerness Limestone Formation on the foreshore.

The Southerness Limestone Formation includes the oldest strata encountered within the site. It has no stratigraphically defined base, the lowermost beds cropping out in the core of the anticline at Southerness Point [NX 971 541] (Craig, 1956). The top is defined by the base of the overlying Gillfoot Sandstone Formation (Craig, 1956). The Southerness Limestone Formation comprises approximately 140 m of alternating shales, sandstones and limestones, with sedimentologically distinctive lower and upper parts (Maguire *et al.,* 1996). The lower part is made up of interbedded black shales, limestones (some argillaceous), and rare calcareous, very fine- to medium-grained sandstones. The limestone beds are intensely bioturbated skeletal wackestones and packstones, up to 60 cm thick and commonly highly foss& ferous (Maguire *et al.,* 1996). The fauna, as recorded by Craig (1956), is dominated by brachiopods (*Cleiothyridina glabistria, Crania quadrata, Composita ambigua, Antiquatonia teres, Echinoconchus punctatus, Punctospirifer scabricosta* and *Syringothyris exoleta*)and bivalves (*Modiola megaloba, Nuculopsis gibbosa* and *Sanguinolites plicatus*), but also includes the coral *Zaphrentis delanouei. Orbiculoidea* and '*Somphospongia*' nodules ('algal' structures) are also reported from these beds (Frost *et al.,* 1976). The limestones of the formation have also yielded a very limited conodont

fauna including *Cavusgnathus unicornis, Clydagnathus windsorensis, Patrognathus capricornis, Vogelgnathus kyphus* and V. *pesaquidi* (Purnell, 1992). The black shales are horizontally laminated, range from less than 15 cm to more than 1 m thick, and are generally unfossiliferous. The sandstones of the lower part of the formation are confined to one sheet-like horizon of more than 2 m of very fine- to medium-grained sandstone, with horizontal laminae, some planar cross-stratification and current-ripple lamination. The upper part of the formation is, however, dominated by sandstones with black shales. The sandstones are intensely bioturbated, moderately to poorly sorted and very fine- to medium-grained. Where not burrowed, they exhibit ripple cross-lamination, planar bedding and wave-ripple lamination. The medium-grained sandstones tend to be more than 30 cm thick and may amalgamate to form units in excess of 1 m thick, with well-developed trough and planar cross-stratification.

The Gillfoot Sandstone Formation extends from the base of the sandstone with carbonate rods, exposed 460 m north of the lighthouse at Southerness [NX 978 542], to 'a grey calcareous breccia/conglomerate with fragments less than one inch in size' exposed between Southerness and Carsethorne (Craig, 1956). The thickness of the formation has been estimated at 120–180 m. It is dominantly composed of red-purple sandstones, conglomerates and shales. A few thin limestones and some of the sandstone beds contain a fauna that includes bivalves, brachiopods, bryozoans and corals (Craig, 1956), and the conodont *Cavusgnathus unicornis* (Purnell, 1992). The character of the formation changes upwards, with the upper part composed of 50% flat-laminated shale units up to 1.8 m in thickness, and 50% moderately to poorly sorted, very fine- to medium-grained sandstones with horizontal lamination and current-ripple lamination. Some of the coarser sandstone units reach thicknesses of 2 m and exhibit stacked unidirectional trough and planar cross-stratification (Maguire *et al.,* 1996).

The 150 m-thick Powillimount Sandstone Formation conformably overlies the Gillfoot Sandstone Formation (Craig, 1956). This highly variable unit comprises interbedded black shales, grey muddy limestones, sandstones, and a coal with associated seatearth containing rootlets. Bed thicknesses vary from a few centimetres to more than 2.5 m. The limestones are bioturbated and contain variable proportions of skeletal debris; identifiable fossils include the 'algae' (cyanobacteria) *Girvanella, Bevocastria* and *Ortonella,* gastropods, ostracodes, orthoconic nautiloids, and corals (Craig, 1956). Sandstones are similar to those of the underlying formation, except that in places they preserve hummocky cross-stratification, horizontal lamination, and wave-ripple lamination (Maguire *et al.,* 1996). The 25 m-thick Thirlstane Sandstone Member at the top of the formation is particularly distinctive. It has a tabular, sheet-like geometry, with a sharp erosive base and disorganized lag of dark purple-red sandstone clasts overlain by coarse-grained sandstone with pockets of very coarse sandstone with mudstone intraclasts and abundant woody fragments (Maguire *et al.,* 1996). This basal interval is overlain by a continuous sequence of stacked, trough cross-stratified, moderately sorted, fine- to medium-grained sandstone. Locally, spectacular soft-sediment deformation, sand volcanoes and slumps are developed (see Ord *et al.,* 1988).

Above the Thirlstane Sandstone Member, and locally faulted against it, is the Arbigland Limestone Formation, a formation that is thought to be at least 300 m thick (Craig, 1956) in the Kirkbean area. In its lower part, the formation comprises black shales and 15–75 cm-thick sheet-like beds of moderately to poorly sorted, very fine- to medium-grained sandstones, commonly with carbonaceous woody debris. Burrow mottling is common and *Chondrites* and *Diplocraterion* are also preserved (Maguire *et al.,* 1996) (Figure 3.8). Some sandstone beds within the formation are erosive based, with low-angle and hummocky cross-stratification (Maguire *et al.,* 1996). The upper part of the formation consists of interbedded black shales and poorly sorted skeletal wackestones and packstones. These limestones are pervasively bioturbated, and contain localized concentrations of skeletal debris rich in crinoids, corals and other fossils. Craig (1956) recorded a diverse fauna from these beds, including corals (*Siphonophyllia benburbensis, Carcinophyllum kirsopianum, Lithostrotion clavaticum* and *Hapsiphyllum enniskilleni*), brachiopods (*Echinoconchus punctatus,* '*Dielasma hastata*', *Punctospirifer scabricosta, Martinia glabra* and gigantoproductids), bryozoans, bivalves and orthoconic nautiloids.

Recently, Veale and Parnell (1996) reported sub-millimetre-sized thoriferous bitumen nodules from the Southeness Limestone and Arbigland Limestone formations.

Interpretation

The rocks described above have been interpreted by Maguire *et al.* (1996) as recording a prolonged period of deposition in a shallow marine setting with periodic inundation by prograding fluvial systems (Figure 3.9). In more detail, the Southeness Limestone Formation was deposited on a tectonically stable, open marine shelf, with the transition from the lower, limestone-dominated part to the sandstone-dominated sequence above reflecting increased clastic input. This culminated in the inundation of the area by the coastal-plain deposits of the Gillfoot Sandstone Formation. These rocks were deposited on a low-relief alluvial plain traversed by entrenched fluvial channels, with the major transport direction towards the west. The rocks of the Powillimount Sandstone Formation mark a return to open marine conditions; the input of clastic material originating from an actively prograding fluvial channel system, and the development of in-situ coal suggesting deposition on a marine shelf next to a swampy coastal plain. The Thirlstane Sandstone Member records a major episode of westwardsprogradation of a braided fluvial system onto the shelf. This was followed by a return to open marine shelf conditions, with the deposition of the Arbigland Limestone Formation. The upward increase in the proportion of limestones in the formation reflects a decrease in the availability of sand as fluvial influences waned.

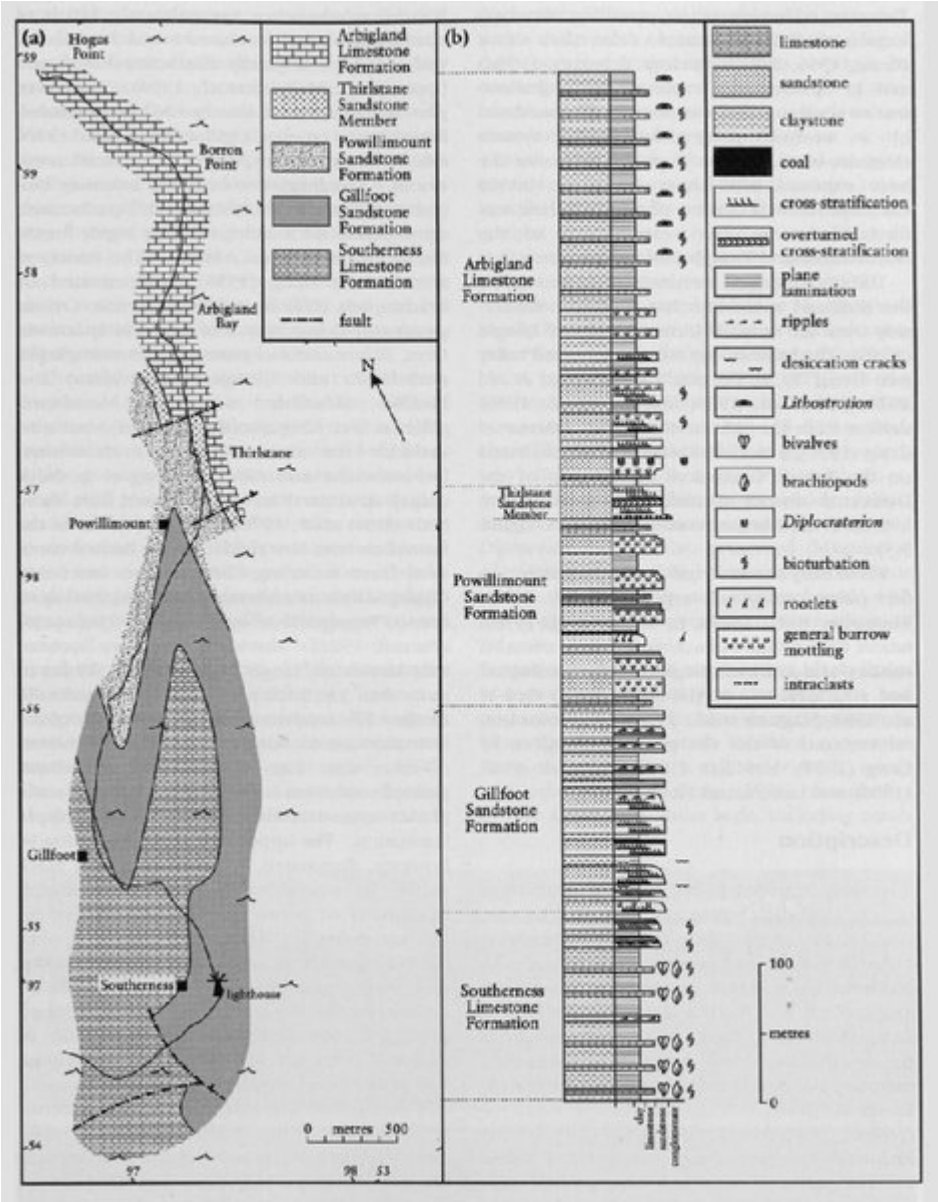
Correlation of these rocks is poorly constrained, primarily because facies changes between this site and rocks to the east make lithostratigraphical correlation almost impossible, and the faunal content is rather limited for reliable biostratigraphical correlation. Pringle (1948) correlated the Southerness Limestone Formation with the beds in the Newcastleton area now considered to be part of the lower Middle Border Group. Craig (1956) correlated the 'Syringothyris/Derbyia Band' in the lower part of the Southerness Limestone Formation with its lateral equivalent, the Harden Member in the Esk district. He equated the Gillfoot Sandstone Formation and the Powillimount Sandstone Formation with the rocks now considered as belonging to the Middle Border Group, and the Arbigland Limestone Formation with the Upper Border Group. The algal horizons in the Southerness Limestone Formation were believed by Ramsbottom (1973) to represent the regressive beds of Major Cycle 2 and were therefore correlated with the Hillend Algal Member of Bewcastle (see Whitberry Burn GCR site report, this chapter). George *et al.* (1976) correlated the Southerness Limestone Formation with the Harden Member and the Cambeck Formation on the basis of their faunal similarity. These authors placed the base of the Chadian Stage in the Kirkbean Outlier at the horizon of the Syringothyris Limestone Member, and followed the correlation of Ramsbottom (1973) in tentatively placing the base of the Arundian Stage at the horizon of algal nodules 28 m above the Syringothyris Limestone Member. They placed the base of the Holkerian Stage at the base of the Arbigland Limestone Formation, and the base of the Asbian Stage at the point of first entry, in the same unit, of a coral–brachiopod fauna comparable with that of the Clattering Band of Bewcastle (see Oakshaw Ford GCR site report, this chapter). The limited conodont evidence from the Southerness Limestone Formation and Gillfoot Sandstone Formation indicates a correlation with the Holkerian Cambeck Formation at Bewcastle (Purnell, 1989, 1992). Although the reasons for revision were not given, the recent British Geological Survey map (British Geological Survey 1993a) proposed rather different correlations, assigning all but the base of the Arbigland Limestone Formation to the Upper Bordcr Group. The basal few metres of the Southerness Limestone Formation were assigned to the Lower Border Group, and the rest of the formation, together with the Gillfoot Sandstone Formation and the Powillimount Sandstone Formation, were assigned to the Middle Border Group. Chronostratigraphically, the base of the Arundian Stage was correlated with a position in the upper part of the Southerness Limestone Formation, the base of the Holkerian Stage with a horizon in the lower part of the Powillimount Sandstone Formation, and the base of the Asbian Stage with a position in the lower part of the Arbigland Limestone Formation. Comparing the fauna reported by Craig (1956) with the ranges of taxa as shown in Riley (1993) does little to help resolve matters. Brachiopods from the Southerness Limestone Formation include taxa that have Chadian, Chadian–Arundian, Arundian, and Asbian ranges, whereas the only reported coral is known only from the Courceyan Stage. The fauna from the Arbigland Limestone Formation (Craig, 1956) includes taxa with Asbian–Brigantian, Arundian and Brigantian, Arundian, and Asbian indicated ranges respectively (Riley 1993). Further research aimed at resolving the relationship between these strata and those elsewhere in the Northumberland Trough could lead to significant improvements in understanding the evolution of the basin.

Conclusions

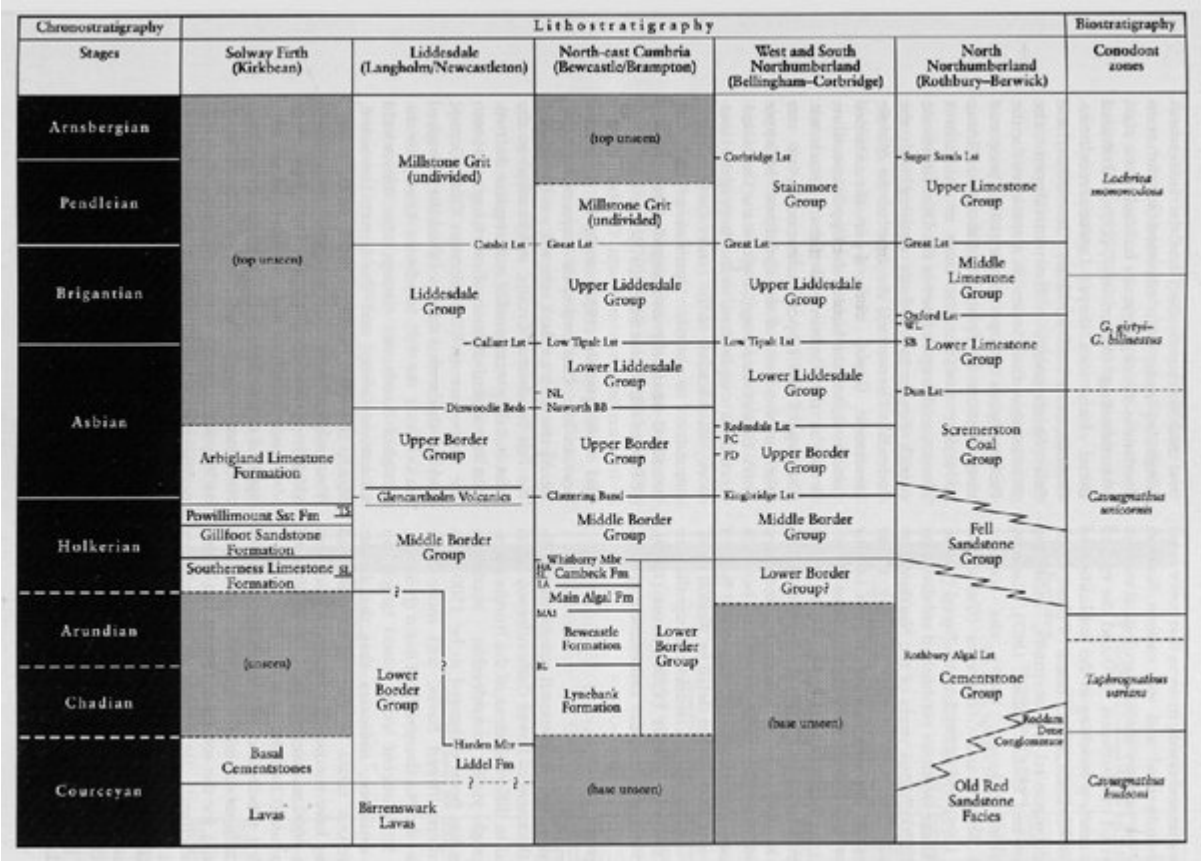
The Kirkbean GCR site offers the best mixed marine and fluvial succession of Lower Carboniferous age in the western part of the Northumberland Trough, and the finest sections of the Southerness Limestone, Gillfoot Sandstone, Powillimount Sandstone and Arbigland Limestone formations in southern Scotland. These strata record deposition on a

tectonically stable shelf within the Northumberland Trough and provide an exceptional sedimentary record of the changing palaeoenvironments of this shelf area as it evolved through a time interval that may span most of Viséan time. Despite correlation difficulties, the Kirkbean section remains vital to our understanding of the structural and stratigraphical evolution of the Solway Basin.

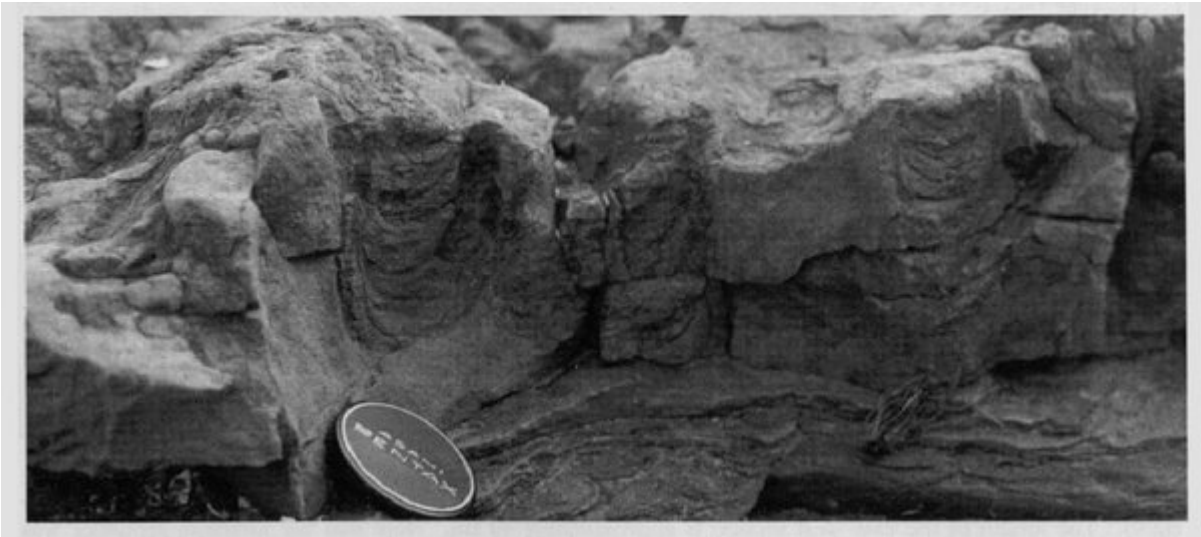
References



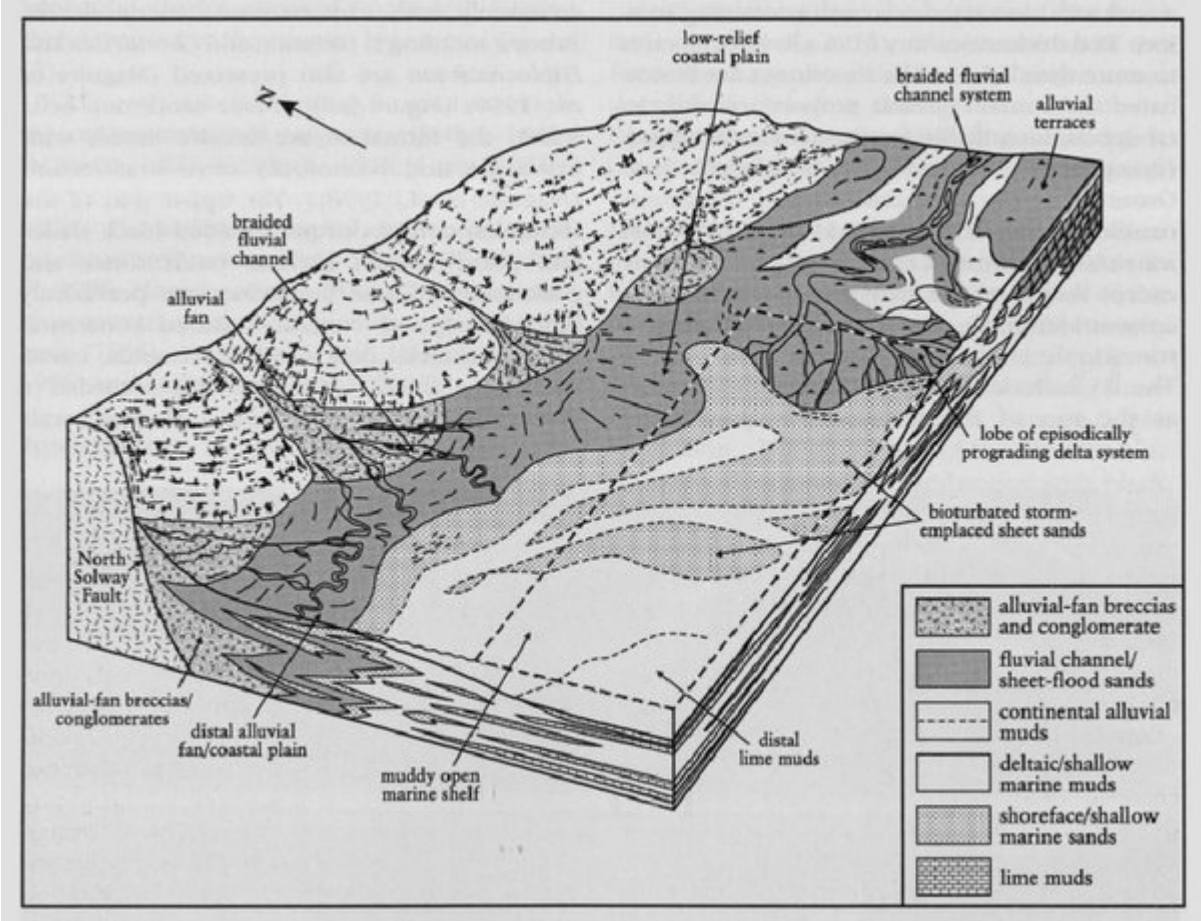
(Figure 3.7) (a) Geological map and (b) simplified sedimentary log of the Lower Carboniferous succession at the Kirkbean GCR site, using the lithostratigraphical nomenclature of the British Geological Survey (1993a). (a) After Craig (1956); (b) courtesy of K. Maguire.



(Figure 3.3) Simplified Lower Carboniferous stratigraphical chart of the Northumberland Trough. Compilation based on information from Lumsden et al. (1967), Day (1970), George et al. (1976), Ramsbottom et al. (1978), Frost and Holliday (1980), Armstrong and Purnell (1987), Smith and Holliday (1991), Purnell (1992), British Geological Survey (1993a), Turner et al. (1993), Chadwick et al. (1995), Johnson et al. (1995) and Maguire et al. (1996). Note that the implied correlations between the lithostratigraphy and both the biostratigraphy and the chronostratigraphy remains uncertain in many areas. SL — Syringothyris Limestone Member; TS — Thirlstane Sandstone Member; BL — Bogside Limestone Member; MAI — Main Algal 1 Member; LA — Lower Antiquatonia Member; HA — Hillend Algal Member; Naworth BB — Naworth Bryozoa Band; NL — Naworth Limestone; PD — Plashetts Dun Limestone; PC — Piper's Cross Limestone; SB — Spirifer Band; WL — Watchlaw Limestone; Lst — Limestone; SSt — Sandstone; Mbr — Member; Fm — Formation. Conodont zones from Armstrong and Purnell (1987) and Purnell (1989, 1992). Not to scale.



(Figure 3.8) Diplocraterion yoyo from interbedded marine shelf beds (laminated siltstones and bioturbated sandstones) of the Arbigland Limestone Formation at the Kirkbean GCR site. (Photo: P.J. Cossey.)



(Figure 3.9) Schematic representation of Dinantian depositional environments along the northern margin of the Solway Firth and palaeogeographical setting of the Kirkbean succession (area within rectangular outline, lower right). The length of the east–west section is approximately 40 km. Note that the Kirkbean sequence was deposited in a tectonically stable area away from the North Solway Fault, hence the absence of alluvial-fan breccias at the Kirkbean GCR site. After Maguire et al. (1996).