Ellery Sike, Cumbria

[NY 546 757]–[NY 543 763] and [NY 541 759]–[NY 545 758]

Introduction

The Ellery Sike GCR site, a composite stream section comprising parts of the River White Lyne [NY 5458 7568]–[NY 5431 7626] and Ellery Sike [NY 5414 7592]–[NY 5453 7576], 1.5 km north-west of Bewcastle, offers the finest section of the Lower Border Group, Lynebank Formation (Chadian) and the oldest exposed Carboniferous succession in the Bewcastle area. The site is of considerable importance to the regional correlation of Carboniferous successions throughout northern England and southern Scotland for, unlike the equivalent strata exposed to the east, it contains marine faunas that include stratigraphically significant microfossils. The section also provides a critical insight into the nature of Lower Carboniferous palaeoenvironments in the Northumberland Trough at an early stage in its history.

Garwood (1931) dealt in some detail with the sequence exposed in Ellery Sike, assigning it to his lowest subdivision, the Lynebank Beds, and suggesting that it was close to the local base of the Carboniferous System. In the [British] Geological Survey re-survey of the area (Day, 1970) the term 'Lower Border Group' was introduced to replace the Cementstone Group, but Garwood's subdivisions were only slightly modified. This terminology was followed in all subsequent work, except that the collective term 'beds' of Garwood (1931) and Day (1970), was replaced with 'formation' to accord with modern stratigraphical practice. In the 1970s, detailed sedimentological work by Leeder on the Lower Border Group succession at this site (and elsewhere) led to significant improvements in our understanding of Lower Carboniferous palaeoenvironments, palaeogeography and basin evolution (Leeder, 1974a,b, 1975a,b).

Description

The base of the Lynebank Formation is nowhere exposed (Day, 1970), but the outcrops in the banks and bed of Ellery Sike and the River White Lyne upstream of their confluence have long been recognized as the oldest strata in the area (Garwood, 1931). The Lynebank Formation occupies the core of the NNE–SSW-oriented Bewcastle Anticline. This structure was formed during Variscan inversion of the basin (Chadwick *et al.,* 1995), and the strata of this site form part of the eastern limb of the anticline, dipping at approximately 40°. The exposed sequence (see (Figure 3.10)) comprises approximately 130 m of alternating limestones, shales and sandstones (Day, 1970; Leeder, 1974b, 1975a). Towards the base of the section, a 6 m-thick limestone unit is exposed, approximately 30 m above which lies the 8.75 m-thick Ellery Sike Limestone Member. These two units comprise well-bedded packstones and wackestones with locally abundant crinoid ossides, brachiopods, brachiopod fragments and spines, ostracodes, uncommon gastropods and tentaculitoid microconchids (forms previously regarded as vermiform 'gastropods'; see Weedon, 1991). Thinner limestone beds, up to about 75 cm in thickness, occur throughout the sequence. These represent a diverse range of lithofacies, including microconchid boundstones and packstones, oncoid–peloid wackestones, crinoid–ostracode wackestones and lime mudstones (Leeder, 1975a; Purnell, 1989). The siliciclastic part of the sequence is dominated by silty shales and fine sandstones comprising several cycles. These include coarsening-upward sequences, grading from fissile shales with bivalves, through rippled and cross-stratified siltstones with plant fragments, to fine sandstones with cross-stratification, including some small-scale trough cross-stratification, and fining-upward sequences of cross-stratified fine sandstones (Leeder, 1974b).

Fossils occur throughout the sequence (see Ramsbottom in Day, 1970). Bivalves, including *Nuculopsis, Sanguinolites, Schizodus, Myalina* and pectinids occur in the shales, together with ostracodes and rarer orbiculoid brachiopods. Brachiopods, including *Athyris concentrica* and *Pustula interrupta,* are abundant in some of the limestones. A diverse algal flora is also recorded from limestones (Day, 1970) and of particular interest is the development of microconchid boundstones, up to approximately 50 cm thick in the Ellery Sike section (Figure 3.11). Conodonts, including *Cavusgnathus hudsoni, Clydagnathus windsorensis, Mestognathus praebeckmanni, Polygnathus bischoffi* and *Taphrognathus varians,* have also been recovered from limestones at the site (Armstrong and Purnell, 1987; Purnell,

1992).

Interpretation

The geological context of the strata in Ellery Sike (i.e. in the core of the Bewcastle Anticline) provides good evidence that they arc the oldest beds in the area (Garwood, 1931), but their age and correlation with Lower Carboniferous strata elsewhere, both within the Northumberland Trough and beyond, have been the subject of long debate.

In his earlier work, Garwood (1913) included notes on the preliminary zonal position of the beds in the Northumberland Trough. Later, however, the coral–brachiopod zonation scheme he established for the Lower Carboniferous strata in the Ravenstonedale area to the south (Garwood, 1913) was applied to the Bewcastle sequence (Garwood, 1931). Garwood (1931) did not discuss the position of the Z_2–C_1 boundary, but recorded what he took to be a Z_2 fauna only from the lowermost 100 m of the Lynebank Formation. Subsequent workers essentially followed Garwood's age assignment of the Lynebank Formation (e.g. Rayner, 1953; George, 1958). Ramsbottom (in Day, 1970), however, noted that the zonal position of Lower Border Group strata below the Cambeck Formation could not be conclusively demonstrated; he assigned them to the C_1 Zone because the large thickness of rock (730 m) that contains an ostracode fauna 'essentially of Tournaisian type' (Robinson in Day, 1970) lies below beds of demonstrable C2 age. Leeder (1971, 1974b, 1975a,b) followed the correlations of Day (1970).

Ramsbottom (1973) positioned his cycle boundaries in the sequence on lithological criteria, but in the Northumberland Trough he followed previous authors in his placement of the Tournaisian–Viséan boundary (which he took to lie within the C_1 Zone). George *et al.* (1976) noted the paucity of confirmatory palaeontological evidence for the recognition of cycle boundaries within the Northumberland Trough, but in the absence of other information took cycle boundaries as convenient datum lines for the correlation of Dinantian stages. In addition to ostracode faunas, foraminifera in the lowest limestone of the Lynebank Formation were cited by George *et al.* (1976) as further evidence that these beds were of Courceyan age. Later, Ramsbottom (1977a) reported the discovery of conodonts identified as *Mestognathus beckmanni* and *Polygnathus bischoffi in* the basal limestone of the Lynebank Formation in Ellery Sike. These conodonts are known to occur together in Chadian strata elsewhere, and on this evidence, and the occurrence of Chadian foraminifera in the same limestone (*contra* George *et al.,* 1976), Ramsbottom (1977a) reassigned the whole of the Lower Border Group to the Chadian Stage (Viséan). Subsequently, Armstrong and Purnell (1987) and Purnell (1989, 1992) conducted a more detailed analysis of the conodonts in the Lynebank Formation in Ellery Sike. The occurrence of *M. beckmanni* in the lowest limestone was not confirmed (Purnell, 1989, 1992, *contra* Ramsbottom, 1977a) but the conodont fauna obtained provided strong evidence of a Chadian age.

The limestone, shale and sandstone sequence of the Lynebank Formation in Ellery Sike reflects the interplay of shallow-marine and deltaic depositional systems. The limestones were deposited in a range of shallow shelf environments including intertidal or shallow subtidal, and moderately to slightly restricted subtidal, below fair-weather wave-base. Brecciated horizons occur within the Lynebank Formation and these are probably collapse breccias, resulting from dissolution of evaporites encountered only in the subsurface (Ward in Chadwick *et al.,* 1993a, 1995). Periodically, during deposition of the Lynebank Formation, delta lobes prograded into the shallow marine seas of the Bewcastle area from the northwest, the emergent Southern Uplands providing a source of siliciclastic sediment (Leeder, 1974b). Coarsening-upward sequences at the Ellery Sike site record delta progradation, with pro-delta muds and silts overlain by delta-front sand-sheets or distributary mouth bar sands. These are overlain by fining-upward distributary channel sands (Leeder, 1974b). Delta progradation and abandonment was probably caused by lobe avulsion, possibly controlled by contemporaneous local tectonic activity (see Leeder and Strudwick, 1987).

In addition to proving substantial thicknesses of evaporites in the subsurface, recent hydrocarbon exploration has revealed that, contrary to the opinion of previous workers (e.g. Garwood, 1931), several hundred metres of syn-extensional sedimentary rock assigned to the Lower Border Group lie beneath the exposed Lynebank Formation (Chadwick *et* ed., 1995).

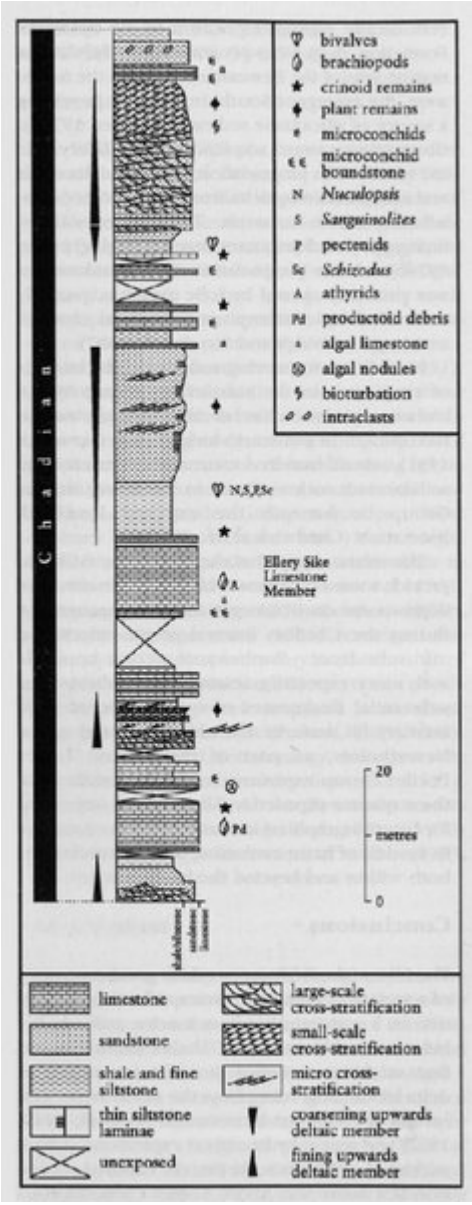
The strata exposed at the Ellery Sike GCR site provide some of the best evidence for the nature of depositional environments and palaeogeography during the Chadian interval of syn-extensional 'rift' subsidence. Furthermore, recent

borehole and, more especially, seismic data indicate that substantial thicknesses of syn-extensional sedimentary fill underlie the oldest exposed rocks. Nevertheless, as part of the marine Lower Border Group exposures in the Bewcastle area, the sequence exposed in Ellery Sike is important for biostratigraphical calibration and constraints in models of basin evolution, and in correlations both within and beyond the basin margins.

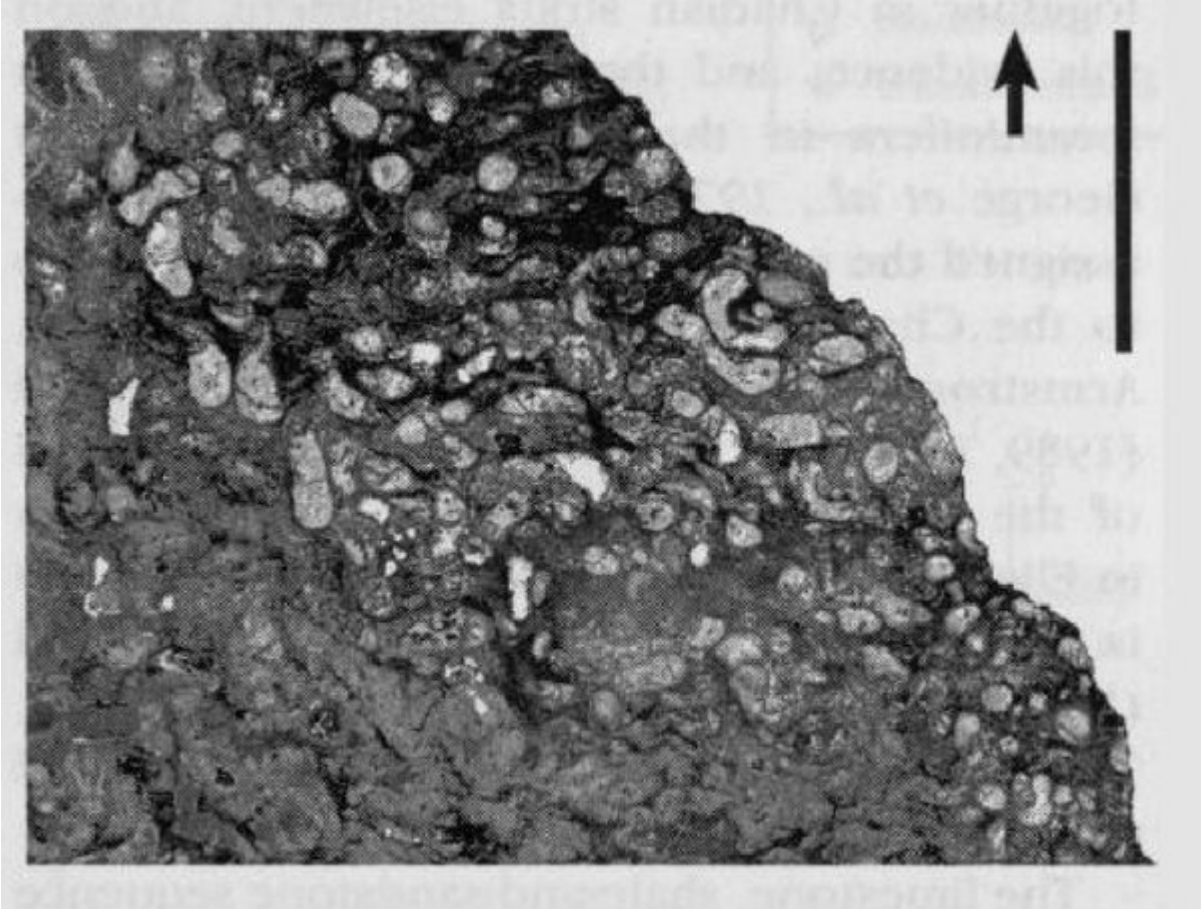
Conclusions

The Ellery Sike GCR site provides good exposures of a variety of limestone facies reflecting deposition in a restricted shallow marine gulf, mostly below normal wave-base. Shales, siltstones and fine sandstones record periodic incursions of delta lobes prograding from the north-west. The results of conodont biozonation (Purnell, 1989, 1992) and recent hydrocarbon exploration (Chadwick *et al.,* 1995) indicate that the exposed succession lies some way above Lower Carboniferous base in the Bewcastle area, where it is of considerable importance to regional biostratigraphical and chronostratigraphical correlations, and in reconstructions of the early Carboniferous palaeogeography of the Northumberland Trough.

References



(Figure 3.10) Sedimentary log of the Lynebank Formation (Lower Border Group) at Ellery Sike. After Leeder (1974b).



(Figure 3.11) Stained acetate peel of tentaculitoid microconchid ('vermetid gastropod' or 'serpulid') boundstone from the lower part of the Lynebank Formation at Ellery Sike. Note the framework of encrusting spar-filled microconchid tubes and the spaces between the organic framework filled with micritic sediment. An arrow symbol indicates the sedimentary 'way up' of the specimen. Sample obtained from the thin limestone immediately below the Ellery Sike Limestone Member illustrated in (Figure 3.10). Scale bar = 1 cm. (Photo: M.A. Purnell.)