Birky Cleugh, Cumbria

[NY 589 754]–[NY 594 754]

Introduction

The Birky Cleugh GCR site, a stream section less than 2 km east of Bewcastle [NY 5885 7540]–[NY 5943 7540], provides important exposures of the Lower Border Group succession that include the exceptional and stratigraphically significant type section of the Main Algal Formation. 'Algal' (cyanobacterial) facies are particularly well developed in this unit which has been considered 'the most important algal development … in the British Carboniferous' (Garwood, 1931). A diverse range of shallow marine limestone facies alternate with deltaic siliciclastics. In addition to its lithological diversity the importance of the Main Algal Formation derives from its use as a stratigraphical marker for regional correlations of the Lower Border Group sequence. Most authors have correlated the Main Algal Formation with algal developments elsewhere in the Northumberland Trough (Garwood, 1931; Anderson, 1950; Day, 1970; Leeder, 1974b, 1975a,b). George *et al.* (1976) correlated the Courceyan–Chadian boundary with the top of the Main Algal Formation. More recent micropalaeontological work suggests that these correlations are incorrect (Purnell, 1989, 1992). Lithostratigraphical terminology has generally followed that introduced by Garwood (1931). His Main Algal Series in the Bewcastle area is equivalent to the Main Algal Beds of Day (1970) and the Main Algal Formation of Leeder (1973, 1974b) and almost all subsequent work.

Description

The strata in Birky Cleugh dip gently to the north-east and provide an almost continuously exposed section through the whole of the Main Algal Formation. The base of the Main Algal Formation is defined at the base of Main Algal 1 Member (the 'Serpula cf. advena Band' of Garwood, 1931) which crops out in the right bank of Birky Cleugh at the western end of the site [NY 5885 7540]. The top is defined at the base of the Lower Antiquatonia Member of the overlying Cambeck Formation which rests on the Main Algal 14 Member towards the eastern end of the site [NY 5932 7538] (Figure 3.4). Above this, the Barron's Pike Sandstone Member crops out [NY 5946 7542]. Altogether, approximately 30 m of the lower part of the Cambeck Formation are also exposed.

In Birky Cleugh the Main Algal Formation comprises 85 m of alternating sandstone, silty shale and limestone. Within this sequence, Day (1970) recognized 14 algal limestone units ('Main Algal 1' to 'Main Algal 14'), the lowest of which is illustrated in (Figure 3.12), but Leeder (1974b, 1975a) divided the sequence into seven carbonate–clastic cycles. The siliciclastic components of Leeder's cycles (1974b, 1975a) vary in thickness up to 4 m. They are dominated by coarsening-upward sequences of silty shales and fine sandstones; some are sharp based with small-scale cross-stratification, others are distinguished by having a marine aspect to the basal shales. Approximately 10% of the Main Algal Formation in Birky Cleugh comprises coarse, erosive-based, cross-stratified, fining-upward sandstone units (Leeder, 1974b). A few thin shaly coals occur, and plant fragments and rootlets are also common, especially towards the tops of cycles. Other fossils include bivalves and ostracodes.

The limestones are of particular importance because of the diversity of facies represented. The limestone at the base of the Main Algal 1 Member, for example, (see (Figure 3.12)) grades upwards from a thin faintly ripple cross-laminated grainstone with peloids, ooids and intraclasts into 25–50 cm of boundstone and baffiestone containing abundant tentaculitoid microconchids (formerly vermiform 'gastropods'; see Weedon, 1991). This microconchid bioherm is overlain by a well-bedded, 3.5 m-thick sequence of unfossiliferous shaly lime mudstone, alternating with wackestones and packstones with ostracodes and peloids, undifferentiated fossil fragments and, towards the top, bivalves, brachiopods and crinoid remains (see (Figure 3.12); and Leeder, 1975a). Other limestone units within the Main Algal Formation vary in thickness up to approximately 5.5 m, but many are less than 1 m. A wide variety of lithofacies are preserved. These include mostly wackestones and packstones with associations of: oncoids and a few small 'algal' colonies encrusting orthoconic nautiloids (Figure 3.13); peloids, ooids, ostracodes and fossil fragments, often with ripple cross-lamination (and a few rippled bedding planes); ostracodes, fossil fragments, bivalves, rare microconchids, gastropods, plant fragments, intraclasts and lingulids; crinoid remains, fossil fragments, ostracodes and some bivalves; brachiopod and crinoid remains, commonly with fossil fragments and ostracodes. Carbonate facies are described in more detail by Leeder (1973, 1975a) and Purnell (1989); microconchid bioherms and oncoids from the Main Algal Formation are discussed by Leeder (1973) and Riding (1983) respectively.

The fossil flora of the Main Algal Formation in Birky Cleugh is dominated by 'algae', and Day (1970) lists 13 species from this locality. The fauna, however, is rather limited: brachiopods include *Antiquatonia teres, Lingula* cf. *mytilloides, Orbiculoidea nitida* and *Ovatia bioni*;bivalves include *Modiolus, Phestia attenuata, Pteronites latus* and *Sanguinolites striatus*; ostracodes include *Cavellina* cf. *longula,* and new species of *Glyptopleura* and *Knoxiella*;and the nautiloid *Dolorthoceras* is also known (Day, 1970). The limestones yield a low-diversity conodont fauna of *Cavusgnathus unicornis, Vogelgnathus kyphus, Hindeodus crassidentatus* and *Synclydagnathus* (Purnell, 1992). Birky Cleugh is the type locality for the Birky Cleugh Limestone Member and for *V. kyphus* (Purnell and von Bitter, 1992). The paratypes of the 'algae' *Ortonella kershopensis* and *Girvanella stamina* (forms now regarded as cyanobacteria — R. Riding, pers. comm., 1999) also derive from this locality (Garwood, 1931).

Towards the top of the section the Lower Antiquatonia Member is represented by more than 20 m of silty shales, mostly calcareous and fossiliferous, with thin limestones. The limestones are generally thin packstones less than 5 cm thick with very abundant brachiopods, brachiopod debris (including spines), crinoid debris and ostracodes, together with less common bivalves, rare bryozoans and echinoid spines. The thickness of these packstones varies laterally, with a few reaching 20 cm or more. A couple of wackestone units within the sequence are approximately 1 m thick. The shales contain a similar brachiopod-dominated fauna and the sequence contains a few traces of ripple cross-lamination. The fauna of the Lower Antiquatonia Member is dominated by brachiopods, including *Antiquatonia teres,* '*Camarotoechia*' *fawcettensis, Ovatia biota* and spiriferoids. Some paratype material of *Schuchertella ambigua* Garwood (1931) is also from this unit. Day (1970) includes a more complete faunal listing.

In Birky Cleugh the Barron's Pike Sandstone Member is also exposed. It comprises about 3 m of fine- to medium-grained planar-bedded sandstone with ripple cross-lamination and plant fragments.

Interpretation

The position of the Main Algal Formation in Birky Cleugh within the Lower Carboniferous sequence of the Bewcastle area is well constrained on lithostratigraphical evidence. However, the Main Algal Formation has been pivotal in the development of broader lithostratigraphical schemes within the Northumberland Trough, and in the application of chronostratigraphical subdivisions and biozonations. Because Birky Cleugh is the type section of the Main Algal Formation all correlations of this unit are implicitly correlations of the Birky Cleugh section.

Garwood (1931) included the algal limestones of the Newcastleton area to the north of Bewcastle in his 'Main Algal Series', but correlated algal developments elsewhere in the Northumberland Trough with an algal horizon near the top of the Cambeck Formation (see Whitberry Burn GCR site report, this chapter). Anderson (1950), however, correlated the Main Algal Formation of Bewcastle and Newcastleton with the algal horizons developed in the Kershopefoot, Kielder, upper Redesdale and Rothbury areas, thus providing a stratigraphical datum linking the Lower Border Group sections in northern Cumbria with Cementstone Group sections to the north and east. Day (1970) supported and re-inforced this correlation, but noted some faunal differences. For example, Robinson (in Day, 1970) indicated that ostracode assemblages from the Orbiculoidea Shale in Birky Cleugh lacked many of the species found in the Main Algal Formation in the Newcastleton area. Ramsbottom (in Day, 1970) conceded that the zonal position of the beds below the Cambeck Formation could not be determined with any confidence, but concluded that all the Lower Border Group below the Cambeck Formation, including the Main Algal Formation, was of Tournaisian (C_1) age. Later he interpreted the Main Algal Formation and the algal limestones of Rothbury as the regressive phase of his Major Cycle 1, and thus correlated them with other algal and 'regressive facies' in areas as distant as Bristol and Ireland (Ramsbottom, 1973). He equated this level approximately with the Tournaisian–Viséan boundary. Gueinn (in Neves *et al.,* 1972) indicated that samples from the Main Algal Formation in the Bewcastle area contain a Pu Zone miospore assemblage (sec (Figure 1.4), Chapter

1), but did not state whether the samples were from Birky Cleugh. Neves *et al.* (1972) used this occurrence of Pu Zone assemblages, in strata assigned a C_1 age by Day (1970), to correlate their miospore zones with macrofaunal biozonations.

Leeder (1974a,b, 1975a,b) introduced a more refined lithostratigraphical scheme for outcrops around Langholm and Newcastleton, erecting the Liddel Formation for the algal limestones in the Newcastleton area. Leeder (1974b) also maintained the correlation of these rocks and the overlying Harden Member with the Main Algal Formation and Lower Antiquatonia Member. This correlation provided the stratigraphical underpinning of his detailed reconstructions of sedimentary environments, palaeogeography and basin evolution (e.g. Leeder, 1974b, 1975a,b; Leeder *et al.,* 1989). However, Gueinn (in Leeder, 1974b), noted that miospore evidence did not support Leeder's correlations between Bewcastle and Newcastleton.

The correlation of the Courceyan–Chadian stage boundary into the Northumberland Trough area by George *et al.* (1976) was based primarily on the hypothesis that the Main Algal Formation was the regressive phase of Ramsbottom's (1973) Major Cycle 1. George (1978a) was critical of Ramsbottom's approach in general, and raised specific doubts about the validity of correlating the Main Algal Formation and the Rothbury Limestones to the east 'merely because they are algal' (George, 1978a). Armstrong and Purnell (1987), in their preliminary conodont biozonation of the Northumberland Trough, indicated that the age of the Main Algal Formation in Birky Cleugh was younger than previously thought (Arundian–Holkerian, not Courceyan or Chadian). However, the presence of *Cavusgnathus unicornis* appeared to support correlations with the Liddel Formation, which had been reported to contain *C. charactus* (Rhodes *et al.,* 1969). More detailed work (Purnell, 1989, 1992) confirmed the Arundian–Holkerian age of the Main Algal Formation, but revealed that the Liddel Formation is considerably older (Tournaisian). This has significant implications for models of Northumberland Trough palaeogeography, depositional history and basin evolution which rely on the time equivalence of these two formations.

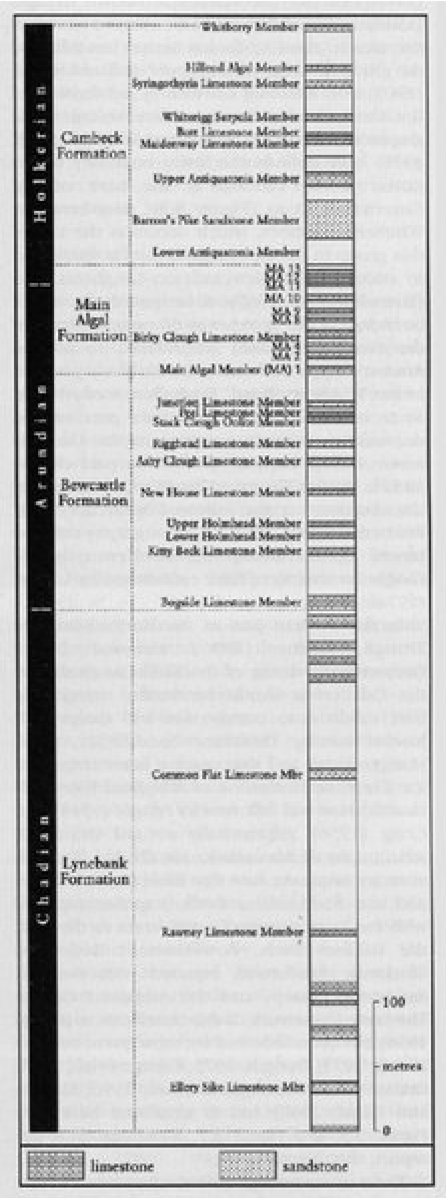
The siliciclastic facies exposed in Birky Cleugh preserve the deposits of deltas that periodically prograded down the axis of the trough from the east (Leeder, 1974b). Different styles of coarsening-upward cycles represent delta progradation, interdistributary bay fills, back-swamp levees and channel fills. Fining-upward sequences represent channel sand-bodies (Leeder, 1974b). The limestone facies reflect deposition under conditions ranging from intertidal or very shallow subtidal high-energy agitated conditions, within fair-weather wave-base (probably less than 4–6 m) through to more open marine, shallow subtidal settings, generally below fair-weather wave-base, but subject to periodic storm agitation. The Lower Antiquatonia Member represents the thickest development of limestones from these more open marine settings, but even in this unit, the relatively impoverished fauna suggests conditions were not fully marine. The Main Algal 1 Member and its overlying clastic sequence in Birky Cleugh has been the subject of especially detailed sedimentological analysis (Leeder, 1974b; Leeder and Strudwick, 1987). A deepening-upward trend in the carbonate unit was used by Leeder and Strudwick (1987) as an example of their tectono-sedimentary model of Yoredale-type cyclicity.

The Main Algal Formation in its type locality in Birky Cleugh provides some of the best evidence of palaeogeography and the diverse depositional environments established in the Northumberland Trough during the Arundian–Holkerian phase of syn-extensional 'rift' subsidence. This is the type locality of several macro-fossils and microfossils, and the exposed strata are also important because of their pivotal role in the development of lithostratigraphical and biostratigraphical correlations within the trough area and beyond.

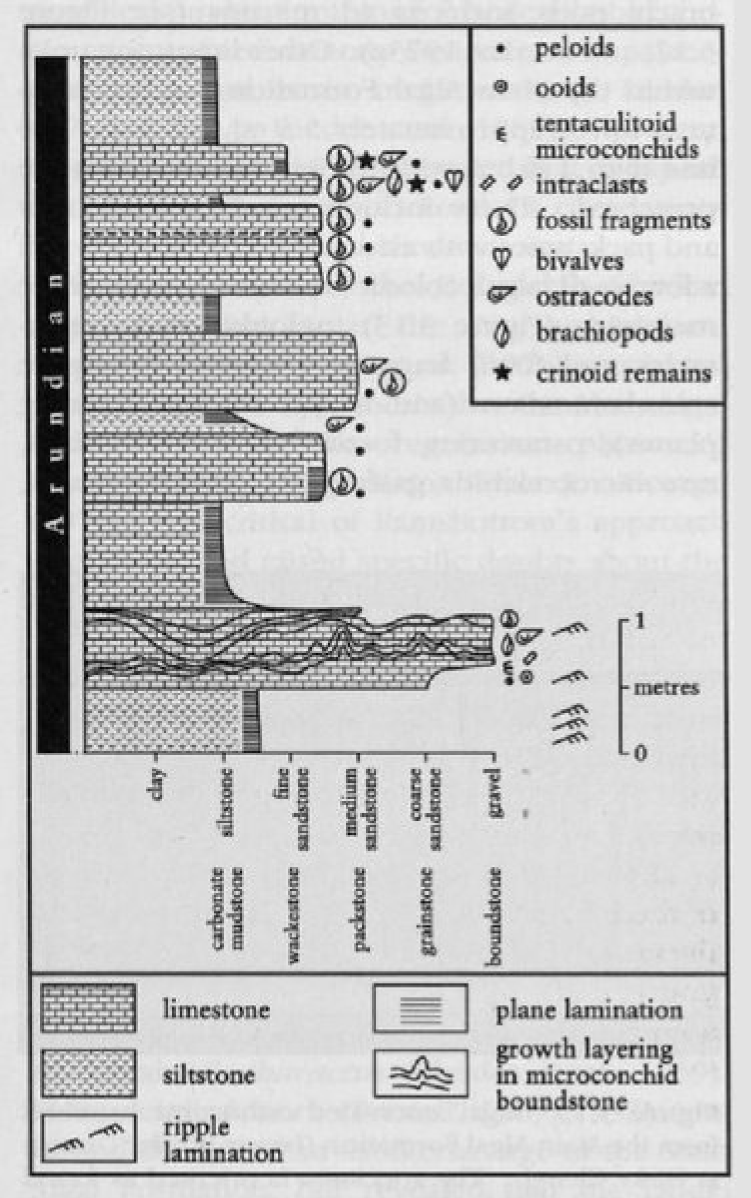
Conclusions

The Birky Cleugh GCR site offers outstanding exposure of a diverse range of shallow marine limestones, including important and unusual algal and microconchid patch reefs. These alternate with a clastic lithofacies deposited by delta lobes which prograded periodically down the axis of the Northumberland Trough from a source to the east. The chief importance of the site derives from its status as the type locality of the Main Algal Formation. The succession has been central to the development of lithological classification as well as to the correlation of Lower Carboniferous rocks across the Northumberland Trough. It also provides an important insight into the changing depositional environments and palaeogeography of northern England during the Arundian and Holkerian ages. Furthermore, the unusual limestone lithofacies include what has been considered to be among the most important British Carboniferous algal developments.

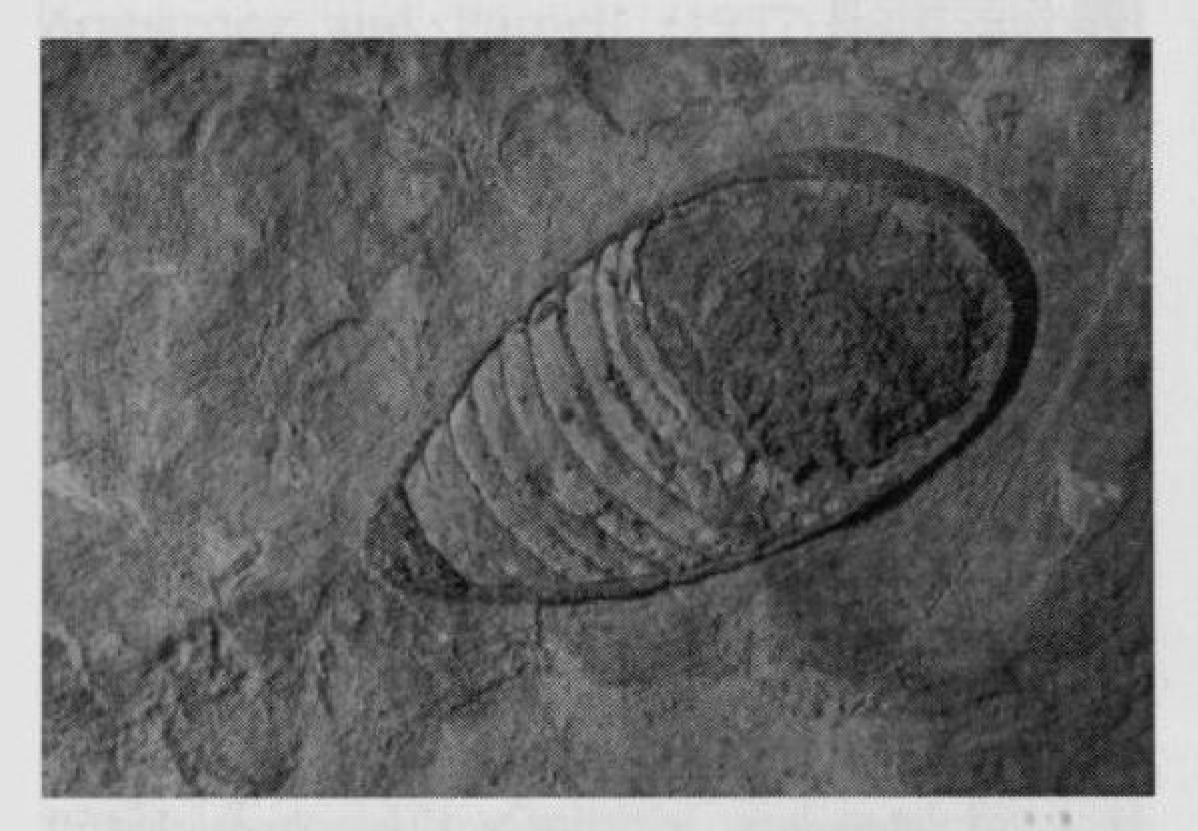
[References](#)



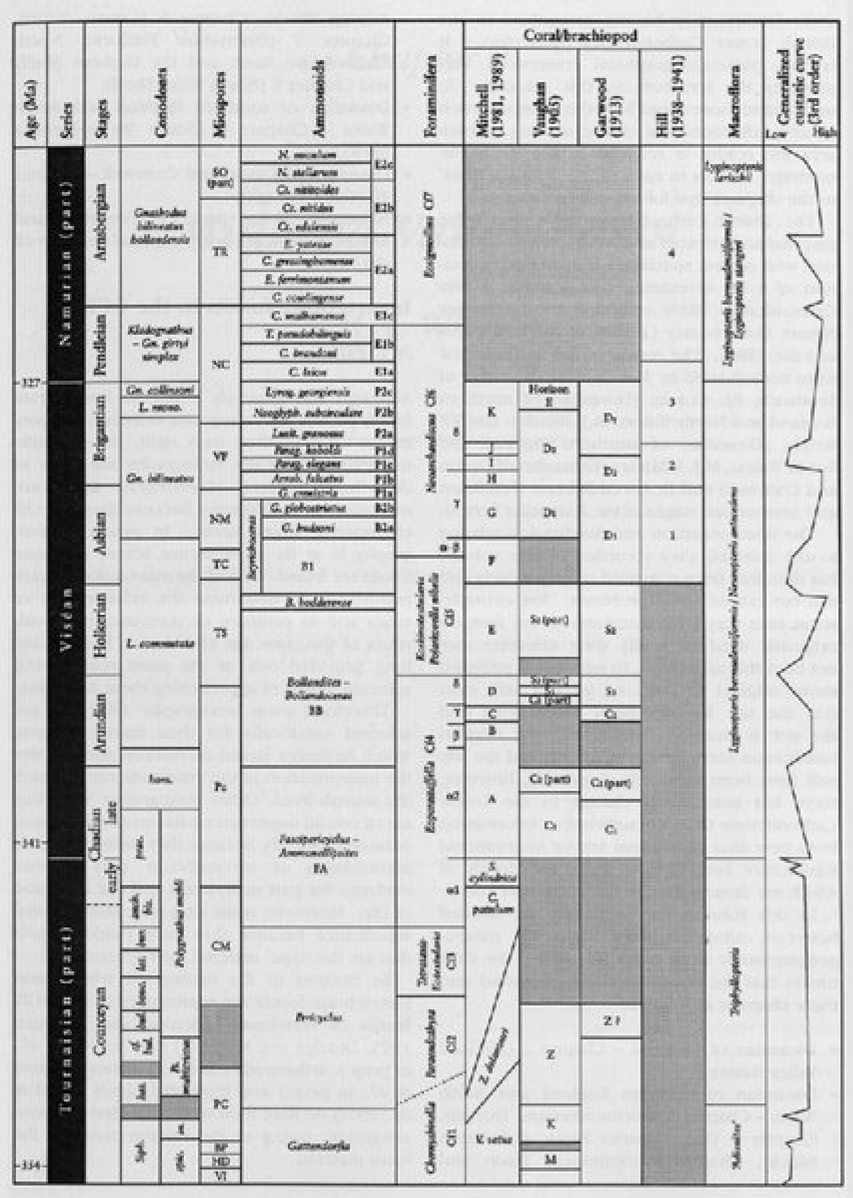
(Figure 3.4) Lithostratigraphical terminology for the Lower Border Group in the Bewcastle area. The position of MA 14 (Main Algal 14 Member) immediately below the Lower Antiquatonia Member is omitted for clarity. After Purnell (1992).



(Figure 3.12) Sedimentary log of the Main Algal 1 Member of the Main Algal Formation (Lower Border Group) at Birky Cleugh.



(Figure 3.13) 'Algal' encrusted orthoconic nautiloid from the Main Algal Formation (Lower Border Group) at Birky Cleugh. The specimen is oriented as found in the field, but the microbial laminae indicate that the orientation of the nautiloid varied during encrustation. The long axis of the section through the nautiloid is 6 cm. (Photo: M.A. Purnell.)



(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).