Foulden, Borders

[NS 921 552]

Introduction

Foulden is one of a network of Lower

Carboniferous localities (including Glencartholm, Granton Shore and East Kirkton, see (Figure 3.9)) that have yielded an important biota including arthropods that are both typical of the Lower Carboniferous of Scotland and Northern England and unique to its strata. Fossils were first collected in abundance from strata of the Cementstone Group sequence (see (Figure 3.7)b) at Foulden (around 348 million years old) in 1910–12 by T.M. Ovens, a local collector who died in 1912 at the age of nineteen. His collection of almost 150 specimens was described by Kidston (1923–5), White (1927) and Edwards (in White 1927). Little further collecting occurred until the 1960s when A.G. Long collected fossil cupules containing seeds. Excavations made at that time with the assistance of C.D. Waterston and R.J. Reekie of the Royal Scottish Museum yielded many plants, including a compressed pteridosperm, approximately 2 m in length.

In 1953 the site was recommended by the Geological Survey as a Site of Special Scientific Interest (SSSI) on account of the rich fauna and flora. Following a re-survey of the site in 1960, it was officially notified in 1961 as a geological SSSI by the Nature Conservancy Council. S.P. Wood visited the area several times prior to the excavations of 1980–1, principally to collect vertebrates. Excavations in 1980–1, funded jointly by S.P. Wood, the Nature Conservancy Council, the Hunterian Museum and the Royal Scottish Museum, yielded many new specimens, as well as stratigraphical and sedimentological information determined from careful bed-by-bed collecting. The biota from Foulden, and its taphonomy and palaeoecology were described in a thematic series of papers published in 1985 in the *Transactions of the. Royal Society of Edinburgh: Earth Sciences* (see References — which ones?). In addition to the fossil arthropod importance of this site, the area is also independently selected for the GCR for the Carboniferous-Permian Fish/Amphibia selection category (Dineley and Metcalf, 1999).

Description

The Foulden succession crops out in the bank of the Foulden Burn (the 'Crooked Burn' of Anon, 1927) near Foulden Newton Farm, 8.4 km northwest of Berwick-upon Tweed. The sequence dips 28° towards 170° and forms part of an unnamed formation within the Cementstone Group of the Calciferous Sandstone Measures (Francis 1983), the lithostratigraphy of which requires local study and definition. Miospores obtained by Clayton (1985) during the 1980–1 excavations indicate a late Tournaisian (TN3; = Courceyan Stage of the Dinantian) age (see (Figure 3.10)).

The arthropods at Foulden represent the earliest Carboniferous fauna with well-preserved terrestrial and non-marine representatives. The fossils come from the so-called 'Fish Bed', which consists of 0.39 m in the base of Bed16 (Wood and Rolfe, 1985; (Figure 3.11)), which is set in a unit of 1.1 m of finely laminated siltstone, becoming more shaly upwards. The Fish Bed is subdivided into an upper 0.31 m portion, separated from a basal bioturbated part where fossil fishes are less-well preserved. The Fish Bed sequence lies within the lower part of the Lower Carboniferous Cementstone Group of Berwickshire and is probably of Tournaisian (Courceyan) age. The Fish Bed is approximately 100 m above the base of the Cementstones, which, with the exception of Foulden, are sparsely fossiliferous and its fauna is mainly of ostracods, bivalves and fish fragments, plus some plant material.

The field and laboratory methodology used in the 1980–1 study at Foulden was based on that used on a Carboniferous fish bed in Illinois by Zangerl and Richardson (1963). A large slab was lifted and removed to the laboratory, having been marked up with a grid and north arrows. The Fish Bed is rubbly, which made re-assembly difficult. A polished vertical section was cut as a basis for the detailed log, and as the beds were stripped off one by one, their contents were plotted with reference to two marker horizons. The fossils were coded for three-dimensional burial position and orientation.

The careful plotting of the fossil content bed-by-bed showed that actinopterygian fishes and malacostracan crustaceans always occur at separate horizons (Figure 3.12). One level was crowded with small acanthodian fishes, showing a preferred orientation, and plant fragments. Other remarkable horizons were a rhipidistian-rich layer, a coprolite horizon and a bivalve-malacostracan horizon.

Fauna

Phylum UNCERTAIN

Polylurida aenigmatica Almond, 1985

Phylum ARTHROPODA

Subphylum Chelicerata

Order Xiphosura

Rolfeia fouldenensis Waterston, 1985 HOLOTYPE

Order Cyrtoctenida

Cyrtoctenus peachi Størmer & Waterston, 1968

Order Scorpiones

Gigantoscorpio cf. *willsi* Størmer, 1963

Trachyscorpio squarrosus Kjellesvig-Waering, 1986 HOLOTYPE

Subphylum Crustacea

Class Ostracoda

Shemonaella scotoburdigalensis (Hibbert, 1836)

other paraparchitids

'*Carbonita*' sp.?

other cyprids? or cavellinids?

Class Malacostraca

Subclass Hoplocarida

Bairdops elegans (Peach, 1908)

Subclass Eumalacostraca

Belotelson traquairi (Peach, 1882)

Tealliocaris (Peach, 1908)

Interpretation

Although the arthropods at Foulden represent low diversity, they are important for two main reasons: the xiphosurid *Rolfeia fouldenensis* Waterston, 1985 and the scorpion *Trachyscorpio squarrosus* Kjellesvig-Waering, 1986 are known from no other locality, and the malacostracan crustaceans represent a fauna from a different palaeoecological setting than other Carboniferous crustacean faunas.

The new xiphosuran genus *Rolfeia* was described from Foulden by Waterston (1985). In an analysis of the origin of the Limuloidea, Selden and Siveter (1987) considered *Rolfeia* to be the oldest member of the superfamily, and erected the family Rolfeiidae to accommodate it. The pivotal position of *Rolfeia* in the phylogeny of limuloids was later confirmed by the study of Anderson and Selden (1997).

Waterston (1985) reported the occurrence of fragments of the large scorpion *Gigantoscorpio* cf *willsi* at Foulden, and Waterston *et al.* (1985) confirmed the presence of *Cyrtoctenus peachi* Størmer & Waterston, 1968 there. Because they are large, only fragments of these animals are known from Foulden. The holotype, and probably only known specimen, of *Trachyscorpio squarrosus* Kjellesvig-Waering, 1986 comes from Foulden; fragments of this animal (which was approximately 25 cm in length) were reported from Glencartholm (see GCR site report) by Kjellesvig-Waering (1986), but Jeram (1994a) was unable to confirm the assignment of these fragments. *Trachyscorpio* belongs in the Mesoscorpionina (*sensu* Jeram, 1994a), a group of large scorpions, which were among the first to adapt to terrestrial life.

The malacostracan crustaceans show low diversity compared to Glencartholm and other Carboniferous localities. Briggs and Clarkson (1985, 1989) compared Foulden to Tarras Water Foot (see Glencartholm GCR site report) and Gullane, because all three sites possibly represent non-marine lake facies and show low diversity shrimp faunas. Of the three, Foulden is the richest (3 species). The ostracodes at Foulden were studied by Pollard (1985), who indicated that the fauna most probably belonged in the 'carbonaceous facies' of Robinson (1980), which seems to be indicative of an abundance of organic matter, but is an unreliable indicator of palaeoenvironment or stratigraphy.

The unique specimen of *Polylurida aenigmatica* Almond, 1985, was originally assigned to Myriapoda by the discoverers, but on closer examination was shown to lack myriapod, and even arthropod or annelid, characters (Almond 1985). The animal is vermiform, segmented, bilaterally symmetrical, with mineralized bars on each segment, and an arcuate, toothed structure at one end. Little can be deduced about its mode of life or affinities, but further specimens would help to elucidate these questions.

Clarkson (1985) discussed the trophic relations of the Crustacea and fish at Foulden. The large *Bairdops,* found only in the lower part of the Fish Bed, was a predaceous carnivore, probably feeding on *Belotelson* and small fish, similar to living stomatopods. *Belotelson,* which is commonest in the lower part of section B (Figure 3.12), was probably a low-level carnivore or scavenger (Schram, 1981). A striking feature that emerged from the detailed analysis of the Fish Bed was the reciprocal relationship between the palaeoniscids and crustaceans (Wood and Rolfe, 1985). *Belotelson* is very common in the lower, bioturbated part of the Fish Bed (Wood and Rolfe, 1985) and it is here also that the only *Bairdops* specimens are found. At Horizon B + 30 (Figure 3.12), there is an abrupt change; above this horizon there are no crustaceans or trace fossils, but palaeoniscids become abundant and persist to the top of the Fish Bed.

It is possible that the palaeoniscids came from a nearby lake during a time of high water level. The acanthodian-rich layer at Horizon A (Figure 3.12), possibly indicates an episode of mass mortality, but at the same horizon bioturbation became apparent once more and *Belotelson* returns, though fewer in number than before. Palaeoniscids occur together with crossopterygians in the upper part of the sequence, especially at Horizon A + 40–50 (Figure 3.12) where biotic diversity reaches a maximum. Presumably conditions were optimal here. The reciprocity between fish and crustaceans might be due to the crustaceans being the prey of the palaeoniscids, which appear at Horizon B + 30. The crustaceans were eliminated by the palaeoniscids and a stable predator–prey balance was not set up until later (Horizon A, (Figure 3.12)). This suggestion does not explain the return of bioturbating organisms as well as crustaceans at Horizon A + 30.

Another hypothesis put forward by Clarkson (1985) is that the faunal changes were caused by changes in salinity. Water level started high, allowing very large rhizodonts to live in the lake. The substrate was firm enough at that time to support a rich fauna of euryhaline bivalves. Repeated muddy turbidite flows then caused the substrate to become softer, but not so soft as to prohibit infauna. A balanced, though somewhat restricted, possibly brackish-water, assemblage then lived in the lake; fish were few, though the crustacean *Belotelson* was very common, preyed upon by *Bairdops.* Following a rise in water level, palaeoniscids invaded the lake, adapted to a different, presumably lower, salinity, which the crustaceans and infaunal elements could not tolerate. The mass-mortality episode, which killed many acanthodians, may have been caused by a fall in water level. At this time the lake returned to near its first level as did salinity, as indicated by the return of trace fossils as well as *Belotelson.* Both the fishes and the crustaceans may well have had some tolerance of changing salinity, but it seems evident that the rich biota from Horizon A (Figure 3.12) onwards (other than during the brief episode that killed the acanthodians) must have been optimal in terms of salinity condition and food availability for all the animals present. These conditions persisted until the lake finally silted up.

The scorpion fauna at Foulden is low diversity (two species) compared to Glencartholm, which has a diversity of eight species of scorpion. Single scorpion specimens also occur in the Scottish Lower Carboniferous at two other localities. A poorly preserved specimen of *Phoxiscorpio peachi* Kjellesvig-Waering, 1986 is known from the Viséan of Dalmeny railway cutting, Edinburgh, and two fragments of *Scoloposcorpio cramondensis* Kjellesvig-Waering, 1986 occurred in the Viséan of Cramond, near Edinburgh. A similar low diversity is seen in the eurypterids and other chelicerates from Foulden, though their fragments are quite widespread at other localities. Possibly, the forms that occur at Foulden were adapted to living in the unusual habitats and salinity conditions (see above) that occurred there.

Malacostracan crustaceans are widespread in the Scottish and Borders Lower Carboniferous strata, as discussed by Schram (1979), Briggs and Clarkson (1989) and Cater *et al.* (1989). At Willie's Hole, 5 km west of Foulden, *Pseudotealliocaris etheridgei* (Peach, 1908) is found, and at Pathhead Mill near Duns (Schram 1979, locality 8), Peach (1908) recorded'*Anthracophausia dunsiana*' (probably *Belotelson traquairi* (Peach 1908)). The differences between these faunas might suggest isolated temporary or semi-permanent lakes with endemic faunas. A number of other contemporaneous occurrences of fish and arthropods occur in the region, such as at Coomsdon Burn and Chattlehope Burn, Redesdale, south of the Cheviot Hills, Northumberland. The younger Glencartholm biota (Viséan Upper Border Group) was discussed by Schram (1983) (see GCR site report). Although it contains *Belotelson traquairi* and *Bairdops elegans,* there are many other species of crustaceans at Glencartholm, and the rich fish fauna has only the genus *Phanerosteon* in common with Foulden. There are numerous marine elements in the fauna, but since the Glencartholm section has not been sampled bed-by-bed, as has Foulden, it is not known from which horizons within the sequence they came. There may have been marine and non-marine alternations with specific faunas in particular layers. In general, the Glencartholm biota contrasts with that of Foulden, which is more restricted and lived in presumably a less saline habitat lacking fauna less tolerant of lowered salinities.

The Foulden biota consists largely of nektonic and nektobenthonic forms, with an infauna only in the early and late stages, and an epifauna only of vagile crustaceans, sessile bivalves and rare xiphosurids. Salinity and, to a lesser extent, the nature of the substrate were the primary determinants of the palaeoecology of the Foulden Fish Bed (Clarkson, 1985).

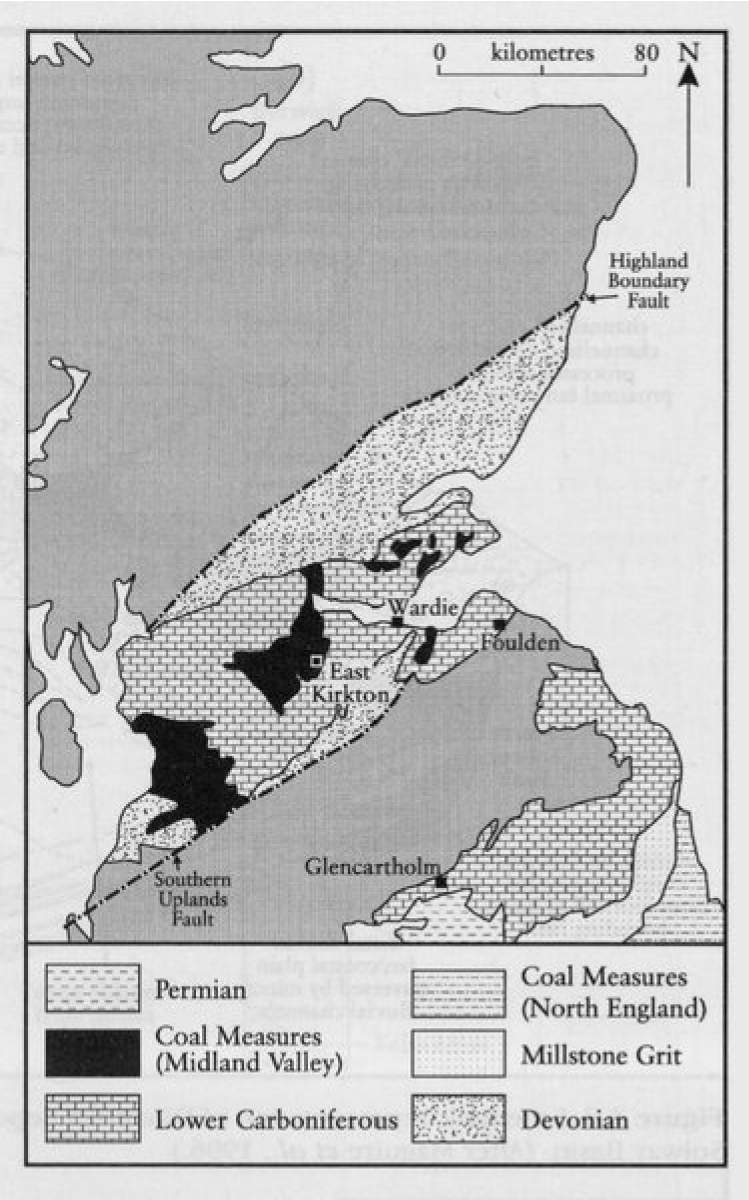
Conclusions

Though yielding a less diverse arthropod fauna than Glencartholm, the locality at Foulden has been recently sampled in a detailed, bed-by-bed analysis that synthesized data from sedimentology, palaeoecology and all groups of plant and animal palaeontology. To some extent, therefore, the importance of the locality lies in the tremendous amount of information collected about the entire fauna, of which arthropods form a vital part. In particular, the reciprocity of fishes and crustaceans (i.e. where crustaceans occur in the section, fishes are rare and *vice versa*) has provoked a number of explanatory hypotheses.

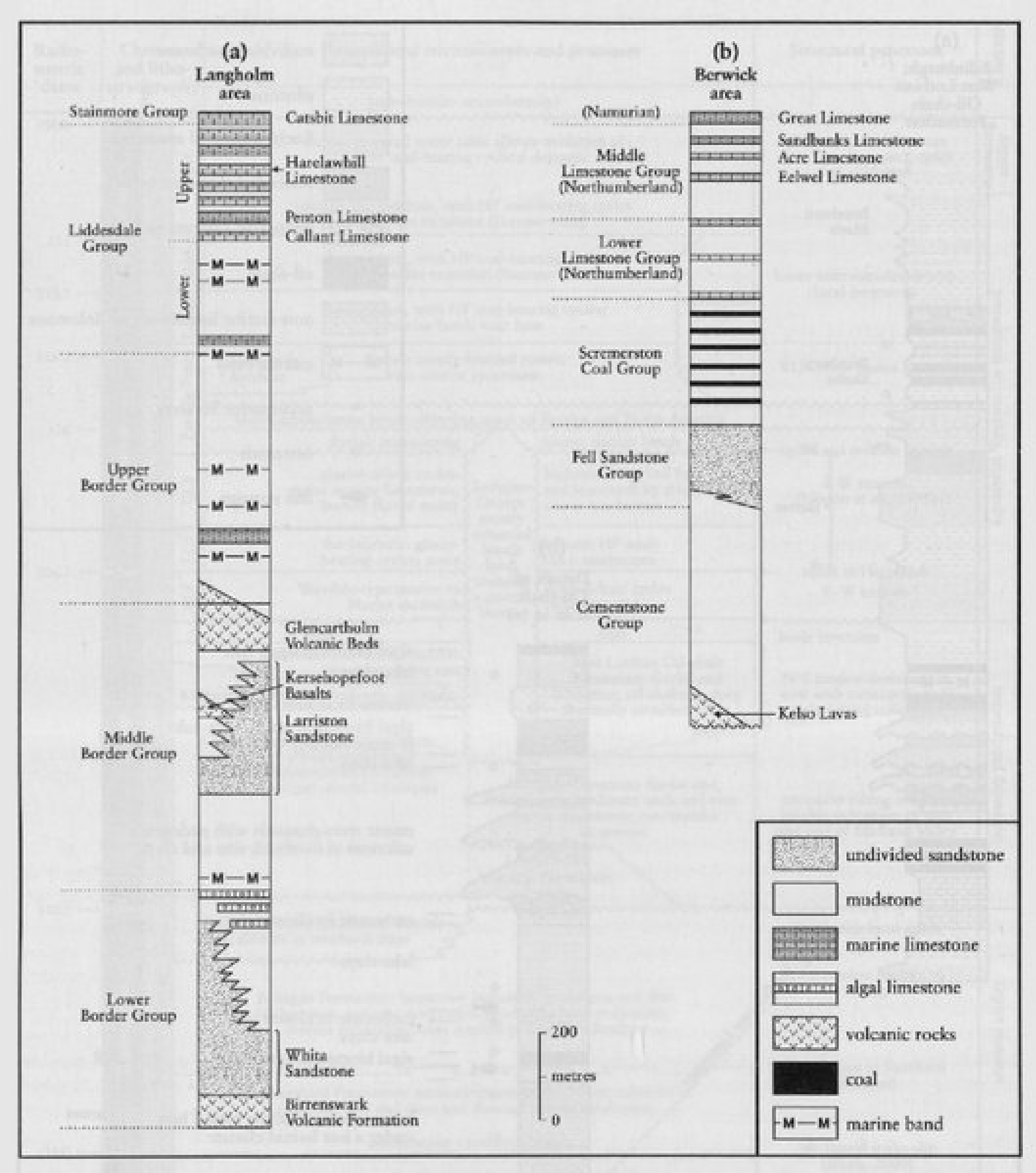
Of particular interest among the arthropods from Foulden are the unique species that have been described from there, known from nowhere else in the world. These include the earliest limuloid xiphosuran *Rolfeia,* the large, early terrestrial scorpion *Trachyscorpio,* and the enigmatic metazoan *Polylurida,* referred to here because of its original interpretation as a myriapod.

The accessibility of Foulden, and the huge database of sedimentological and stratigraphical information about the site, make it a key Scottish Lower Carboniferous locality.

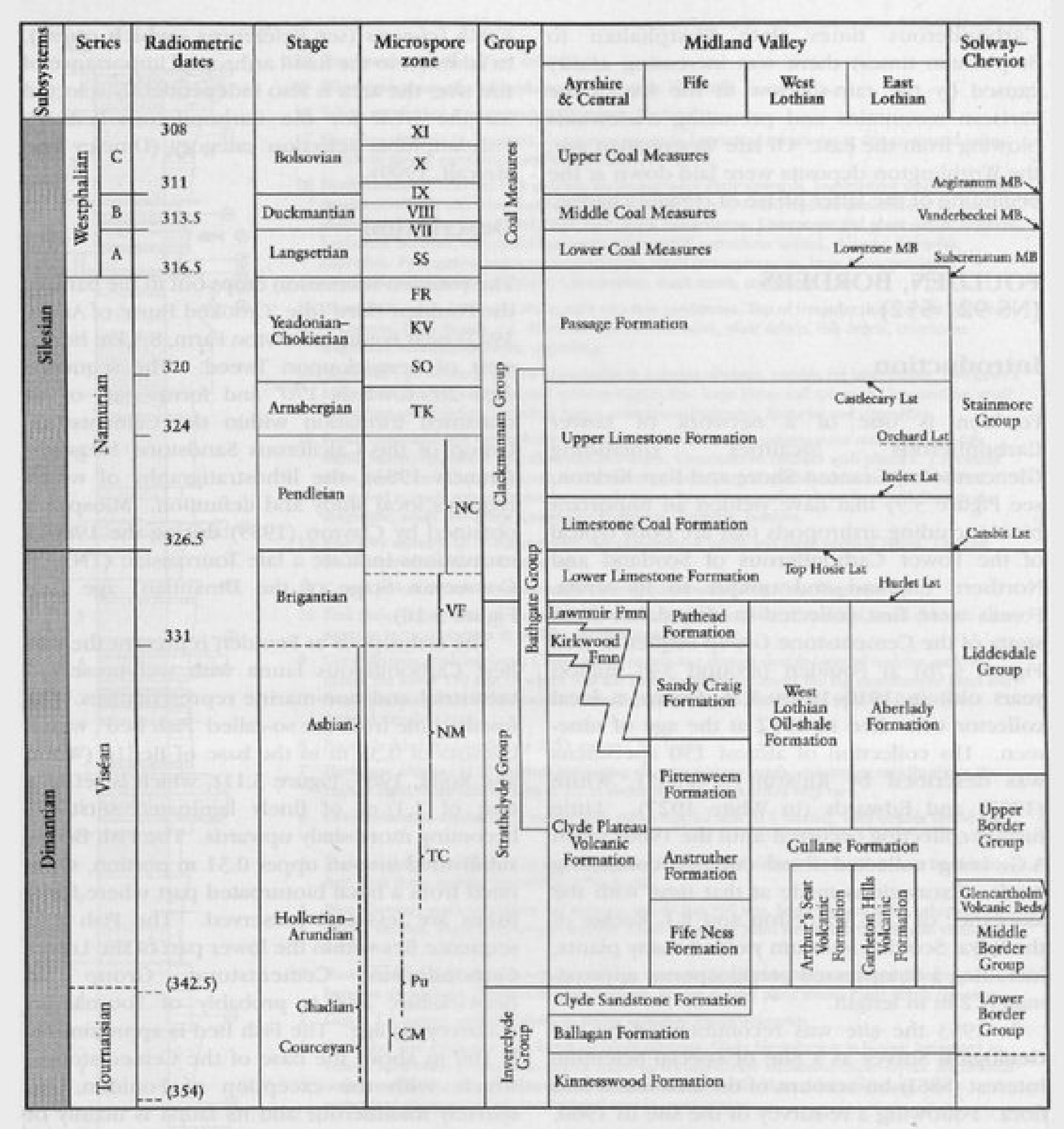
References



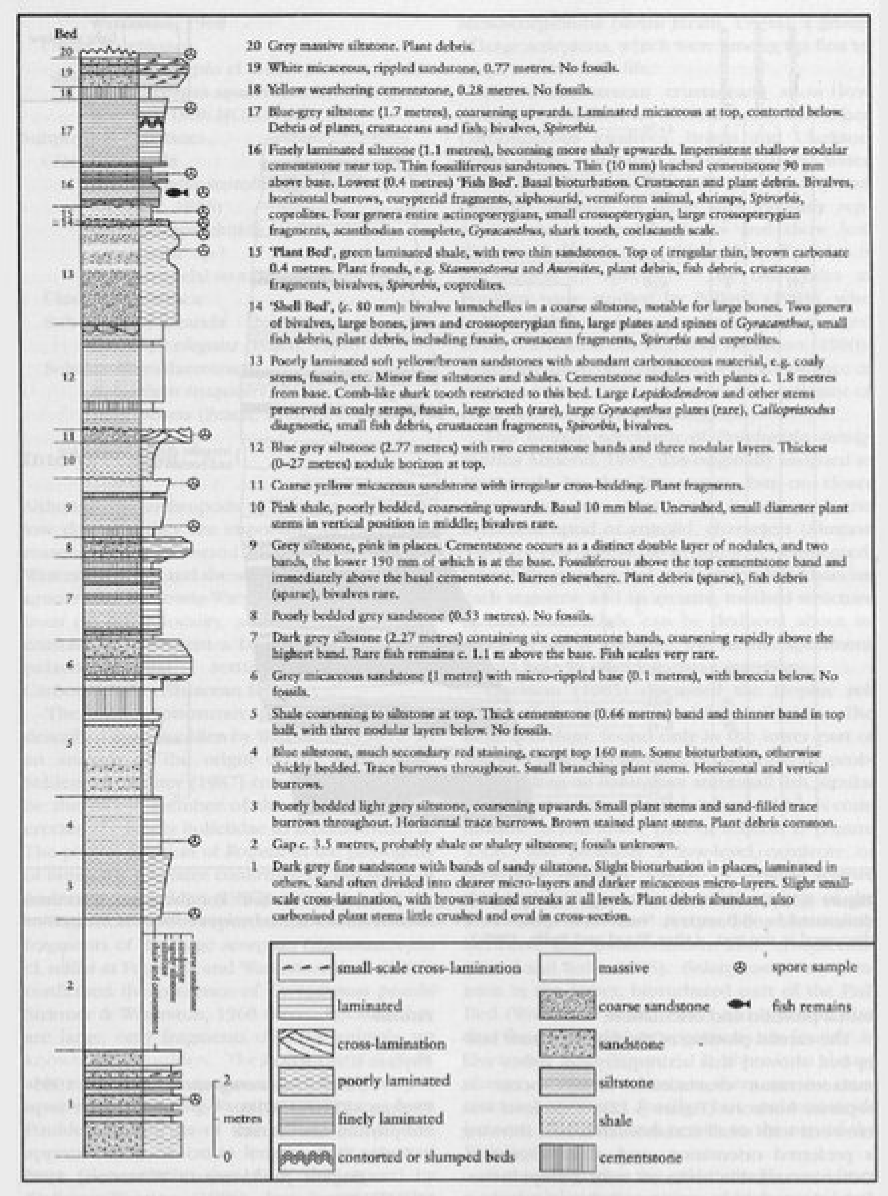
(Figure 3.9) Geological sketch map of southern Scotland and northern England with the positions of the Scottish Carboniferous GCR arthropod sites shown. Wardie is near to the Granton Shore GCR site.



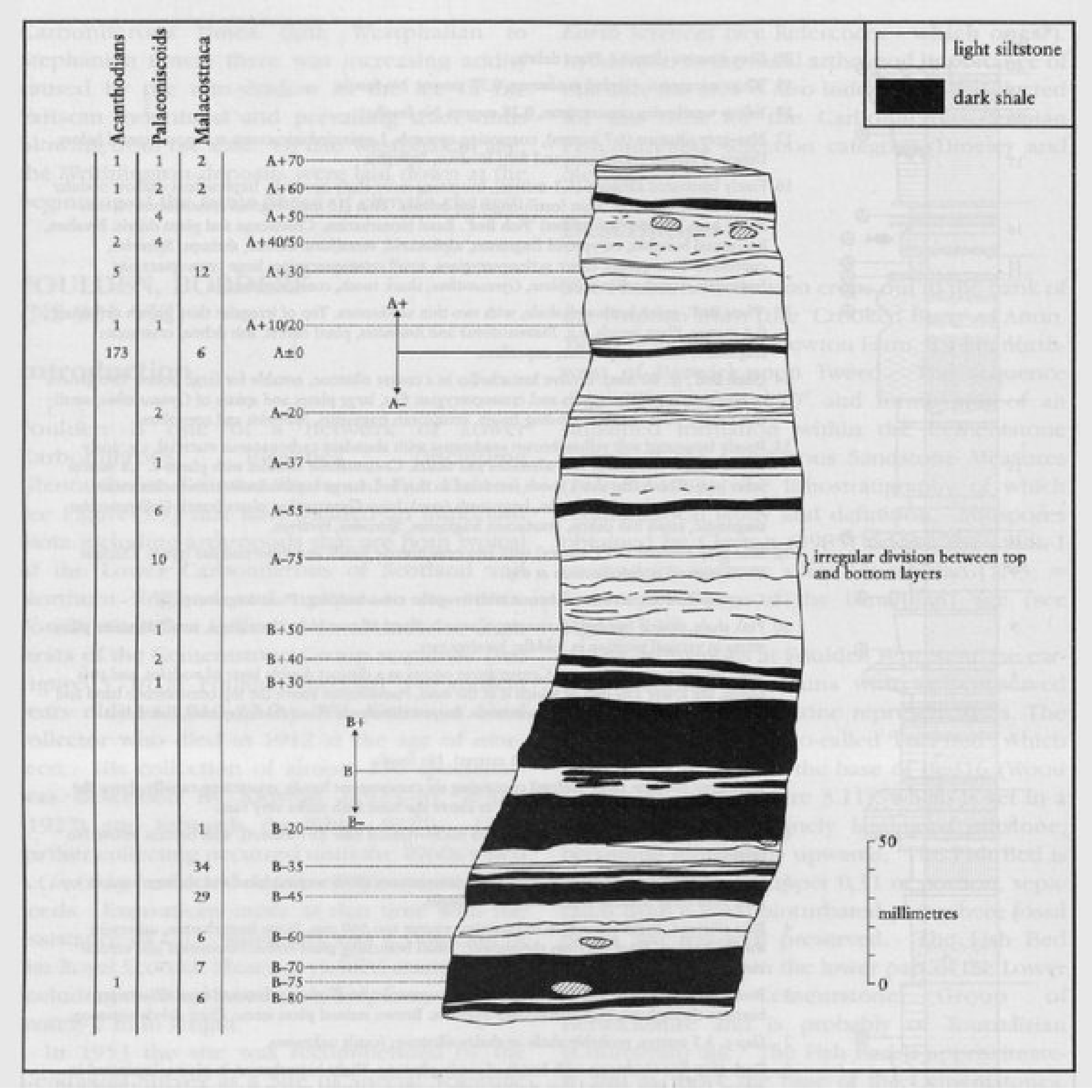
(Figure 3.7) Generalized vertical sections of the Dinantian successions in the Southern Borders (a) the Langholm area in the west and (b) the Berwick area in the east.



(Figure 3.10) Lithostratigraphical and chronostratigraphical divisions of the Carboniferous Period'in the Midland Valley and Southern Borders. Key marine bands (MB) and limestones (Lst) used in correlation are noted. No clear evidence for Chokierian or Alportian stages has been found in Scotland, possibly reflecting a mid-Carboniferous depositional break.



(Figure 3.11) Foulden stratigraphical column. (After Wood and Rolfe, 1985.)



(Figure 3.12) Detailed section through the top 0.31 m of the 9.4 m thick Fish Bed. For discussion of horizons designated A and B see text. Numbers of specimens are indicated in the left-hand columns from the section and discussed in the text. (After Wood and Rolfe, 1985.)