British Upper Carboniferous Stratigraphy

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Chapter 2

International stage stratotypes

All of the Upper Carboniferous stages in the so-called 'Heerlen Classification', from the Chokierian to the Bolsovian, have their base stratotypes in northern England (the Westphalian D base stratotype has yet to be selected, although sites in South Wales will probably be strong contenders). Because of their importance for stabilizing the definitions of the stages, these stratotypes have a rather different status from the other sites dealt with in this volume; they were automatically selected as GCR sites and did not have to go through the normal processes of critical assessment and comparison. Most also do not fit into the network of sites used to demonstrate the Upper Carboniferous stratigraphy in the main regions of Britain (River Darwen is the main exception); in fact, it is possible that some of the sites would not have been included in the GCR coverage, if it were not for their stratotype status. To reflect their distinct status, the history and description of each of the stratotypes is given separately in this chapter.

Historical background

The stages are part of what is known as the Heerlen Classification. The outlines of the scheme had been originally formulated by Munier Chalmas and de Lapparent (1893), but it was at the first two congresses on Carboniferous stratigraphy (held at Heerlen in 1927 and 1935) that it became established as a formal chronostratigraphical classification (Jongmans, 1928; Jongmans and Gothan, 1937). In its 1935 form, three stages were recognized in the Upper Carboniferous: Namurian, Westphalian, Stephanian. The Namurian and Stephanian were subdivided into three substages, and the Westphalian into four (e.g. Namurian A, Westphalian D).

During the 1960s and early 1970s, the classification underwent a number of changes. The most significant was that the three stages were upgraded to series. This was first done for the Namurian following proposals by Ramsbottom (1969b). It was also proposed that, instead of the tripartite subdivision of the Namurian, seven stages should be recognized, based on the ammonoid biostratigraphy that had been developed in Britain (Bisat, 1928; Hudson and Cotton, 1943; Hodson, 1957). The changes were formally adopted by the Subcommission on Carboniferous Stratigraphy (hereafter referred to as the SCCS) in 1967 (George and Wagner, 1969).

The Stephanian was the next to undergo revision. The boundary between the Westphalian and Stephanian had been an ongoing problem since the two intervals were proposed in 1927. The classic Westphalian sequences are in the paralic coalfields of northern Europe, while the classic Stephanian sequences are in the intra-montane basins of central and southern France; virtually nowhere (at least in western or central Europe) do they occur together. One of the few exceptions is the Saar-Lorraine coalfield. Even here the contact (at the base of the Holz Conglomerate) is unconformable, but it was widely assumed that the time gap involved was small and so it was used to define the Westphalian-Stephanian boundary (Jongmans and Gothan, 1937). However, subsequent work on the more complete sequences in northern Spain showed that this time gap was much larger than previously thought, and that there was consequently a gap in the sequence of stages (Wagner, 1969). To fill this gap, it was proposed in 1971 to introduce the Cantabrian Stage, which was to be the lowest subdivision of the Stephanian (George and Wagner, 1972). Whether the Stephanian was to be a stage or series was still a matter of disagreement in 1969 (George and Wagner, 1970). However, the acceptance of the Cantabrian Stage as the lower subdivision of the Stephanian meant that the latter had to become a series.

Details of the stratotype and definition of the Cantabrian, as now accepted by the SCCS, are given by Wagner and Winkler Prins (1985). It has altered since the original 1971 proposal, because of changes in detailed correlation between the marine and non-marine sequences in northern Spain. However, these changes have little direct bearing on the chronostratigraphy of the British sequences. Wagner and Winkler Prins (1985) also proposed that the Stephanian A should be renamed the Barruelian Stage, again with a base-stratotype in northern Spain. The Stephanian B and Stephanian C are still awaiting new names.

It has been proposed to introduce a fifth stage at the top of the Stephanian - the 'Stephanian D' (Bouroz and Doubinger, 1977). This is connected with the so-far unresolved complications concerning the recognition of the Carboniferous-Permian boundary in non-marine sequences (e.g. Kozur, 1984), and no decision has been made by the SCCS on the status of the 'Stephanian D'.

Compared with the forgoing series, the Westphalian has remained more or less stable since the 1935 definition, with four subdivisions. The bases of the lower three subdivisions were defined at prominent marine bands, while the base of the top subdivision (Westphalian D) was informally linked to the base of the range of the plant fossil *Neuropteris ovata* Hoffmann. Following on the coat-tails of the Namurian and Stephanian, the Westphalian was upgraded to a series in 1971 (George and Wagner, 1972). The subdivisions, now being stages, required formal names, and have been renamed Langsettian, Duckmantian and Bolsovian, with stratotypes designated in northern England (Owens *et al.*, 1985); the Westphalian D remains the only stage without a designated stratotype or a formal name.

Details of the historical changes to the Upper Carboniferous part of the Heerlen Classification is shown in Figure 1.2. For a more complete account, the reader is directed to Wagner (1974, 1989).

Reasons for selecting stratotypes in Britain

As the name suggests, the concept of a Namurian stage was first developed in Belgium ('étage namurien' of Purves 1883). However, there has always been a close link with the Millstone Grit sequences in northern England, initially through the work of Bisat (1924, 1928). When it proved impossible to find suitable stratotype sections in Belgium, it was thus not surprising that the SCCS decided to turn to Britain for alternative sites (George and Wagner, 1969). Particularly in the basinal sequences of northern England, extensive marine fossil assemblages can be found, which provide good biostratigraphical control. The sites also tend to be in areas of relatively low population density, thus reducing the potential conservation problems.

The Westphalian Series has its historical links with the Ruhr Coalfield in Germany (Munier Chalmas and de Lapparent 1893). This persisted until the 1960s, but during the 1965 SCCS meeting at Sheffield, it was pointed out that there were no surface exposures in the Ruhr to provide permanent stratotype sections. Initially, a possible move to the Nord-Pas-de-Calais Coalfield in northern France was considered but, again, there is an absence of permanent exposure. The obvious choice, at least in northern Europe, was South Wales, which is the only coalfield to provide both a continuous succession through the Westphalian and extensive natural outcrop. The SCCS therefore decided to look there for stratotypes (George and Wagner, 1972) but, for reasons that are far from clear, they failed to find any suitable candidates (Calver and Owens, 1977). This now seems strange in view of the fact that in the mid-1970s Cwm Gwrelych-Nant Llyn Fach provided an even more complete sequence than it does today. Whatever the reason, however, it was decided to search for sites in the Pennines Basin, and it is here that the base-stratotypes for the lower three subdivisions have been selected (Owens *et al.*, 1985).

The Westphalian D is rather different from the other Westphalian stages. It was traditionally linked with the Assise de la Houve in the intra-montane Saar-Lorraine Basin (Jongmans and Gothan, 1937), but there are no outcrops of this formation to provide a suitable stratotype. The SCCS has investigated various other areas for a suitable stratotype section, including South Wales (George and Wagner, 1972). However, the relevant working group has not yet produced any concrete proposals.

Geographical limits of the Heerlen Classification

The first Heerlen congress specifically dealt with the Carboniferous stratigraphy of Europe (Jongmans, 1928). Consequently, the classification that was first outlined there was only intended to be used in a European context. Subsequent congresses attempted to take a wider view but, by the fourth meeting, it was concluded that 'worldwide correlations are utterly impossible' (van der Heide, 1960). Thereafter, it became normal to talk in terms of regional chronostratigraphies in the Carboniferous, reflecting the palaeogeography and biogeography of the time. A scheme put forward by Bouroz *et al.* (1978) attempted to unify the classification for the palaeoequatorial belt but, particularly for the Upper Carboniferous, it was impossible to integrate the evidence from the northern temperate (Angaran) and southern temperate and boreal (Gondwanan) sequences. Recently, the SCCS has been looking again at the possibility of a global classification, the first manifestations of which have been investigations into a so-called 'Mid-Carboniferous boundary' (Lane *et al.*, 1985b). Other levels which might be capable of being identified globally are also being investigated, and these might provide the basis of a truly international chronostratigraphy (Engel, 1989). In the absence of such a scheme however, the local chronostratigraphies still provide the only practical means of classifying these strata.

The Namurian Series and its component stages are most easily identified in the siliciclastic deposits of northwestern and central Europe. Detailed correlations with some of the sequences in North America (e.g. Manger and Sutherland, 1985) suggest that the Namurian stages can also be identified there, but American workers still tend to use their local classification. In the USSR, coeval strata belong to all but the lowest Serpukhovian and the lower Bashkirian (Wagner *et al.*, 1979). Fossils indicative of the Alportian Stage have been tentatively identified from the upper Serpukhovian but until recently it has been impossible to recognize the other Namurian stages (N.J. Riley, pers. comm. now claims that the Namurian stages can be recognized in the Urals). In north Africa, the fossils are most comparable to those of the USSR, and so the Soviet classification is now normally used there (Wagner *et al.*, 1985).

The Westphalian and Stephanian series and their component stages are mostly used in the essentially non-marine sequences of western and central Europe and north Africa. Other than the lower three stages of the Westphalian, which in the paralic basin of northern Europe can be identified by marine bands and non-marine animal fossils, the boundaries between the stages of the Heerlen Classification are best identified using plant fossils (palynology is still unable to provide an accurate fix on the stage boundaries). This has proved fully successful in the intra-montane basins of Europe (e.g. Cleal, 1984b) and the mixed marine/non-marine sequences of south-western Europe (e.g. Wagner and Winkler Prins, 1985). The Heerlen Classification has also been applicable to eastern North America through plant biostratigraphy (e.g. Zodrow and Cleal, 1985). However, plant fossils are so poorly documented through much of the rest of North America that it is so far impossible to use the Heerlen Classification there with any accuracy. There are also problems with using it in the European part of the USSR, although this is more due to apparent discrepancies in the ranges of some of the plant fossil species than an absence of reliable records (Fissunenko and Laveine, 1984).

GILL BECK

Highlights

Gill Beck is the international stratotype for the boundary between the Arnsbergian and Chokierian stages, and is effectively the standard for the Mid-Carboniferous boundary in Europe (Figure 2.1).

Introduction

This is a stream section (also known as Stonehead Beck) west of Stone head Lane, 2 km west of Cowling, North Yorkshire (SD 957433). It lies in

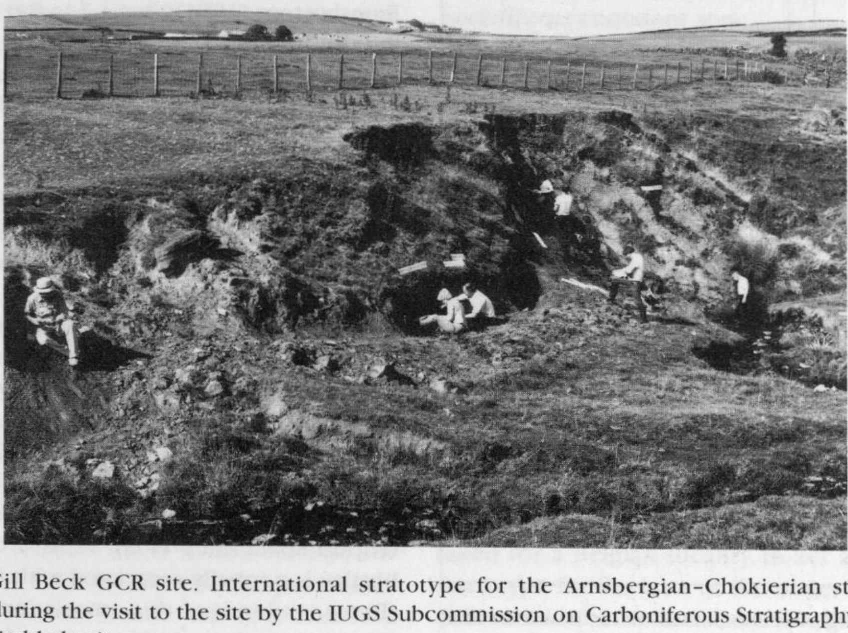

Figure 2.1 Gill Beck GCR site. International stratotype for the Arnsbergian–Chokierian stage boundary. Photographed during the visit to the site by the IUGS Subcommission on Carboniferous Stratigraphy, August 1981. (Photo: W.A. Wimbledon.)

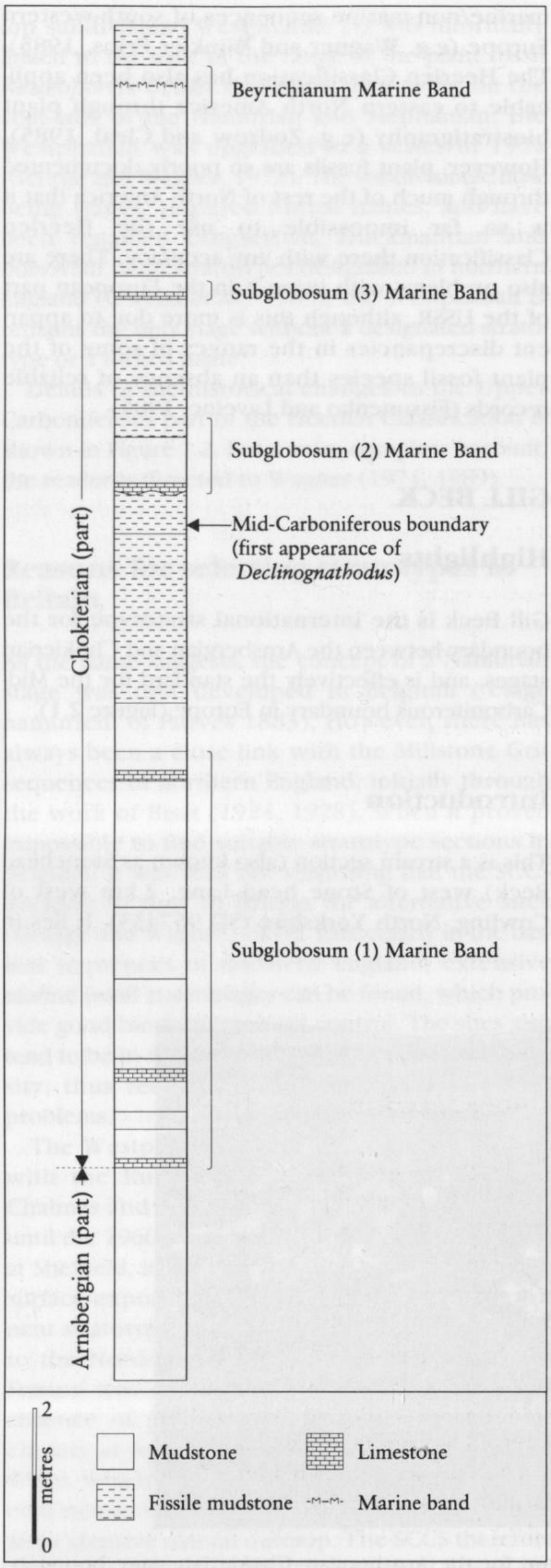

Figure 2.2 Log of section at Gill Beck. Based on Riley *et al.* (1987, fig. 2).

the southern part of the Craven Basin and is the boundary stratotype for the base of the Chokierian Stage. Exposure is generally good, although the actual level of the boundary was until recently obscured. This was remedied by the excavation of a trench for the 1981 visit by the SCCS, dug as part of the GCR Unit's site cleaning programme. Goniatites have been known from here since the early part of the century (Hind, 1918; Bisat, 1924), and the field geology described by Earp *et al.* (1961), Riley *in* Ramsbottom (1981) and Riley *et al.* (1987).

Description

Lithostratigraphy

The exposed sequence here is about 56 m of Sabden Shales, which is a mainly argillaceous formation between the Warley Wise Grit and Cobden Sandstone (Figure 2.2). The lower 20 m of the outcrop are mainly blue-grey mudstones, with occasional black mudstones containing concretions. Above this, the mudstones become more consistently black or very dark grey, with thin ribs of ferruginous limestone.

Biostratigraphy

Marine bands

Nine marine bands have been identified in this sequence, and referred to as bands 1–9 by Ramsbottom (1981); Band 4 is further subdivided into Beds T1–T13. Bands 1 and 3 contain abundant goniatites of the *Nuculoceras nuculum* Zone, including *N. nuculum* Bisat, *Kazakhoceras hawkinsi* (Moore), *Eumorphoceras beta* (Riley) and *Fayettevillea darwenensis* (Moore), which indicates that they are the Nuculum Marine Bands in the upper Arnsbergian (Riley, 1987; Riley *et al.*, 1987). The exposure of Band 1 here is the type locality for *N. nuculum*.

The lowest of the ferruginous limestones (bed T1) marks a major biostratigraphical change, with the extinction of the *N. nuculum* Zone assemblages and the appearance of goniatites belonging to the *Isohomoceras subglobosum* Zone. This lowest limestone has only yielded the bivalve *Caneyella semisulcata* (Hind) together with gastropod spat. Riley *et al.* (1987) claim that this bivalve is normally associated with *I. subglobosum* (Bisat), and indeed this association occurs in bed T5, *c.*1 m higher up the section. For this reason, they place the base of the *I. subglobosum* Zone at T1. Bed 4 of Ramsbottom (1981) evidently equated to the lower Subglobosum Marine Band. The overlying three marine bands (numbers 5-7) also include assemblages diagnostic of the *I. subglobosum* Zone; beds 5 and 7 are the Middle and Upper Subglobosum Marine Bands. This is the type locality for *I. subglobosum*, which along with *N. nuculum*, and *F.darwenensis* have recently been re-described by Riley (1987).

The upper part of the succession sees another biostratigraphical change, with the introduction of assemblages of the *Homoceras beyrichianum* Zone, indicating the Beyrichianum Marine Band in the upper Chokierian. The band 8 assemblage is particularly diagnostic, including *H. beyrichianum* (Haugh), *Metadimorphoceras* and *Caneyella*.

Conodonts

Riley *et al.* (1987) and Varker *et al.* (1991) record conodonts from 12 horizons in this section, and a number of biostratigraphically sensitive forms were noted. From the lower Nodosum Marine Band, Riley *et al.* record an assemblage of 170 specimens, which is diagnostic of the *Gnathodus bilineatus bollandensis* Zone of Higgins (1985). The Middle and Upper Nodosum Marine Bands also yield assemblages probably belonging to that zone, although they were significantly less diverse.

Two samples either side of the Lower Subglobosum Marine Band provided assemblages consisting exclusively of *Rhachistognathodus minutus* Dunn. Higgins (1975) placed such assemblages in a separate zone of the same name, but they have been subsequently included within the *G. bilineatus bollandensis* Zone (Higgins, 1985). The biostratigraphical significance of this platform conodont has been the subject of some debate (e.g. Lane and Baesemann, 1982; Baesemann and Lane, 1985; Lane *et al.*, 1985b). However, Riley *et al.* (1987) have concluded that, at least in NW Europe, its taxonomy and distribution are still inadequately understood for any emphasis yet to be placed on it.

From 0.4 m below the Middle Subglobosum Marine Band, a major change occurs in the conodonts, marking the base of the *Declinognathodus noduliferus* Zone. In particular, there is the appearance of *Declinognathodus inaequalis* (Higgins), which Higgins (1985) claims to characterize the base of the zone. A further five closely spaced samples between this level and the Beyrichianum Marine Band yielded similar assemblages (a sixth proved barren), although they also see the appearance of *Declinognathodus noduliferus* (Ellison and Graves), typical of slightly higher levels in the zone.

Palynology

Being a relatively deep water sequence, miospores are neither abundant nor diverse here. Ramsbottom (1981) and Riley *et al.* (1987) list the species found at 22 horizons in both the Arnsbergian and Chokierian parts of this section. They all belong to the *Lycospora subtriquetra–Kraeuselisporites ornatus* Zone, which ranges from mid-Arnsbergian to the top of the Alportian. The presence of *Cirratriradites rarus* (Ibrahim) Schopf *et al.* throughout the sequence suggests that it is some distance above the base of the zone. There is no marked change in the palynomorphs across the Arnsbergian-Chokierian boundary here, which is consistent with observations elsewhere in northern Britain (Owens, 1982).

Chronostratigraphy

The base of the Chokierian Stage is defined at 'the base of the first marine band above the barren beds which overlie the highest *Nuculoceras nuculum* band of Arnsbergian age' (Ramsbottom, 1981). This is the marine band no. 4. According to Riley *et al.* (1987), the Mid-Carboniferous boundary occurs (and could perhaps be defined at) just below Band 5, which sees the base of the *Declinognathodus noduliferus* conodont zone.

Interpretation

In the classification introduced by Bisat (1924), strata belonging to the E_2, H_1 and H_2 zones were referred to the Sabdenian Stage, but this proved too large an interval for detailed stratigraphical work. Hudson and Cotton (1943) proposed that the stage should be restricted to the H_1 and H_2 zones. However, Hodson (1957) argued that this did not really solve the problem and proposed a totally new classification, in which the H_1 zone was referred to the Chokierian Stage.

The stage was named after a famous ammonoid locality in Belgium, but when a search was undertaken for a Belgian locality to act as a boundary stratotype for the base of the stage, nowhere suitable could be found (van Leckwijck, 1964). Ramsbottom (1969b) proposed the River Darwen site (see below) as an alternative, but the critical part of the section there is not particularly well endowed with marine bands and is now poorly exposed. It was therefore proposed to take Gill Beck as the stratotype (Ramsbottom, 1981).

The marine band containing *Isohomoceras subglobosum*, which marks the base of the Chokierian, is not present in all of the British Namurian sequences. In the Culm Trough, it is probably present along the Crackington Coast (see Chapter 3). In South Wales, it is well developed on the south crop, such as at Barland Common (see Chapter 4), but is only patchily developed on the north crop. It is best known in the Craven and Pennine basins, where there are numerous outcrops (including the present one). On the Askrigg and Alston blocks and in Scotland, however, it appears to be totally absent.

Gill Beck has also been proposed as the stratotype for the Mid-Carboniferous boundary (Riley *et al.*, 1987), which is intended to provide a globally-applicable datum line. The main criterion to be used for placing the boundary is the level of the base of the *Declinognathodus noduliferus* conodont zone (Lane *et al.*, 1985b). On currently published evidence, therefore, the Mid-Carboniferous boundary would be located 0.4 m below Band 5, or 9.4 m above the base of the Chokierian.

The main alternative contender as stratotype for the Mid-Carboniferous boundary is at Arrow Canyon in Nevada, USA (Lane *et al.*, 1985a). This sequence is in a carbonate shelf setting and, not surprisingly perhaps, there are discrepancies in the ranges of the conodonts compared with the clastic sequences in Britain. This has led to a debate as to whether there is a significant gap in the British or the Nevada sequences at the level of the Mid-Carboniferous boundary (compare Lane and Baesemann, 1982, fig. 3 and Riley *et al.*, 1987, fig. 7), which will obviously be important when the stratotype comes to be selected. The argument essentially revolves around the reliability of the refined ammonoid biostratigraphy that has been developed for the European clastic shelf sequences, and whether it provides a robust framework against which to plot the conodont ranges. If the ammonoid scheme is deemed robust, then a gap in the British sequences is difficult to accept, since a similar gap would have to be present throughout Europe, as far east as the Urals. On the other hand, there is little palaeontological or sedimentological evidence of a major gap in the Arrow Canyon sequence. The SCCS working group on the boundary is still investigating the matter but, whatever the outcome, Gill Beck will be an important site for identifying the boundary, if only in a regional context.

Conclusions

Gill Beck is an internationally recognized standard for defining a time plane 322 million years before the present, and which is taken as the start of the Chokierian Age. It is also taken as the start of the Late Carboniferous Subperiod.

BLAKE BROOK

Highlights

Blake Brook is the international stratotype for the Alportian Stage.

Introduction

This is a small stream section in Lumpool Plantation, 3.5 km SSW of Longnor, Staffordshire (SK 063612), and lies in the Staffordshire Basin, adjacent to the Wales-Brabant Barrier. It was discovered in the late 1970s, during the search for a stratotype for the base of the Alportian Stage. The only published account of the geology is in the field-guide for the 1981 meeting of the SCCS (Ramsbottom, 1981).

Description

Lithostratigraphy

The exposed sequence here is 48 m thick (Figure 2.3). The lower 29 m belong to the Lum Edge Sandstone Formation, an interval of quartzitic sandstones and mudstones typical of the upper Chokierian of north Staffordshire. This is overlain (with a small stratigraphical gap) by 19 m of dark mudstones with thin limestone bands. It is within this mudstone/limestone interval that the Alportian occurs.

Biostratigraphy

Marine bands

Within the mudstone-dominated upper part of the sequence, ammonoids are extremely common. The lowest horizon to yield them is the thin limestone

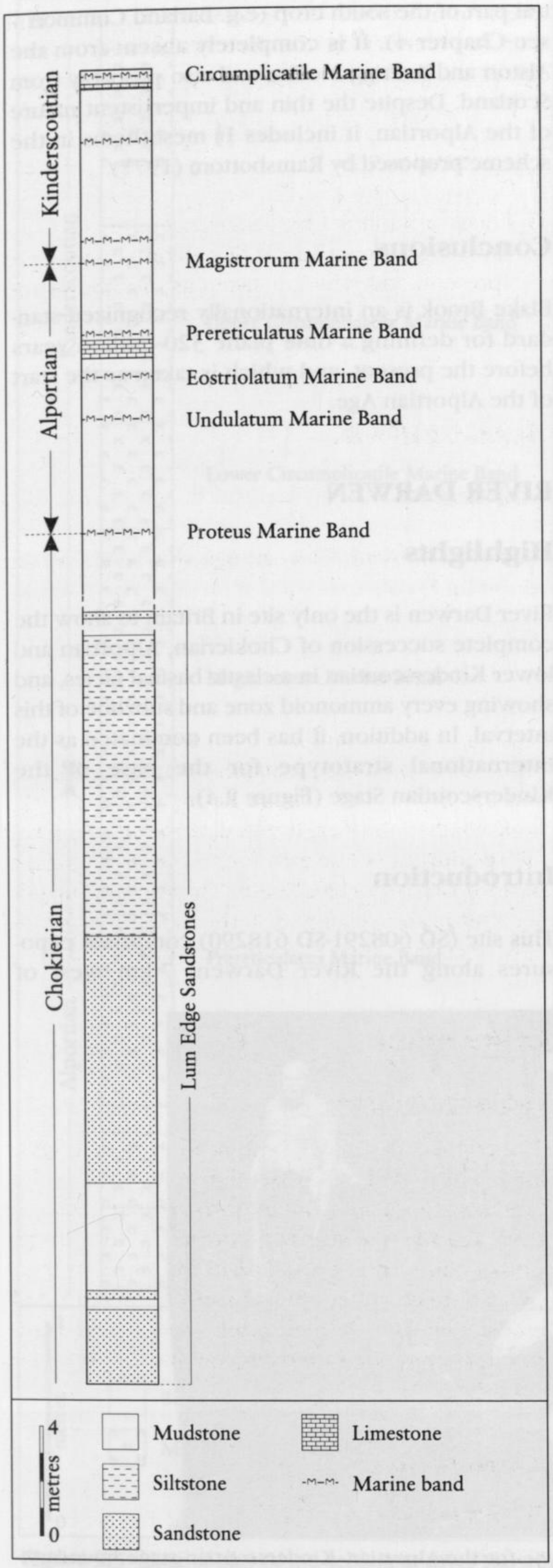

Figure 2.3 Log of section at Blake Brook. Based on Ramsbottom (1981, p. 8.3).

3 m above the Lum Edge Sandstones, and containing *Hudsonoceras proteus* (Brown). In the overlying 9.5 m, it is possible to identify the other three biostratigraphical units that typically occur in the Alportian, viz. the *Homoceras undulatum* Zone, and the *Vallites eostriolatum* and *Homoceratoides prereticulatus* subzones (of the *H. prereticulatus* Zone). The fossils here are almost exclusively ammonoids, although one band of mudstone yields bivalves (*Dunbarella*, *Myalina*).

The topmost 7.5 m of strata have yielded ammonoids of the *Reticuloceras circumplicatile* Zone, indicating the lower Kinderscoutian Stage. This includes a mudstone with *Hodsonites magistrorum* (Hodson), taken as the index horizon for the Alportian-Kinderscoutian boundary.

Palynology

Ramsbottom (1981) provides a detailed listing of palynomorphs prepared from 32 horizons in the Blake Brook section. However, the accompanying stratigraphical log does not show where each of the samples originated. A detailed assessment of the palynological evidence is therefore difficult.

According to the data provided by Owens (1982, 1984), the Chokierian-Alportian boundary is virtually impossible to recognize on a palynological basis; both stages belong to the *Lycospora subtriquetra-Kraeuselisporites ornatus* Zone. The Alportian-Kinderscoutian is better delineated, coinciding with the base of the *Crassispora kossankei-Grumosisporites varioreticulatus* Zone. However, none of the index species for the zonal boundary were listed in Ramsbottom's report, except for a single occurrence of *Remysporites magnificus* (Horst) Butterworth and Williams in the lower part of the section (the extinction of this species occurs at the boundary).

Conodonts

Ramsbottom (1981) records conodonts only from the Proteus Marine Band. The quoted assemblage includes the *noduliferus*, *japonicus*, *lateralis* and *inaequalis* varieties of *Declinognathodus noduliferus* (Ellison and Graves), together with *Ozarkodina delicatula* (Stauffer and Plummer). Significant here is the *D. noduliferous* var. *japonicus*, the base of whose range in Britain coincides with the base of the Alportian (Higgins, 1975, 1982).

Chronostratigraphy

The base of the Alportian Stage is defined in this section at the base of the thin limestone containing *Hudsonoceras proteus* Zone, 3 m above the Lum Edge Sandstones.

Interpretation

The Alportian Stage was first proposed by Hodson (1957), as part of his dismemberment of the Sabdenian Stage. He defined it in the Alport Borehole in Derbyshire, described by Hudson and Cotton (1943). However, so as to provide a permanent stratotype, Ramsbottom (1969b) proposed that the base of the stage should be defined in the River Darwen section at Samlesbury Bottoms (see below). This in turn was superseded by the present site, following proposals by Ramsbottom (1981), since it yielded better palynological evidence, and provided a complete section of all the marine bands in the stage (albeit in a highly condensed sequence). Subsequently it has been established that all the marine bands are present at Samlesbury Bottoms (Riley, pers. comm.).

At most, the Alportian is only represented by a thin sequence of mudstones in Britain. The most complete sequences through the stage are in northern England, such as here. It is poorly developed in the Culm Trough, except in the deeper-water sequences (e.g. Bonhay Road Cutting – see Chapter 3), while in South Wales it only occurs in the central part of the south crop (e.g. Barland Common – see Chapter 4). It is completely absent from the Alston and Askrigg blocks, and also probably from Scotland. Despite the thin and impersistent nature of the Alportian, it includes $1\frac{1}{2}$ mesothems in the scheme proposed by Ramsbottom (1977).

Conclusions

Blake Brook is an internationally recognized standard for defining a time plane 320 million years before the present, and which is taken as the start of the Alportian Age.

RIVER DARWEN

Highlights

River Darwen is the only site in Britain to show the complete succession of Chokierian, Alportian and lower Kinderscoutian in a clastic basinal facies, and showing every ammonoid zone and subzone of this interval. In addition, it has been nominated as the international stratotype for the base of the Kinderscoutian Stage (Figure 2.4).

Introduction

This site (SD 608291-SD 618290) comprises exposures along the River Darwen, 7 km west of

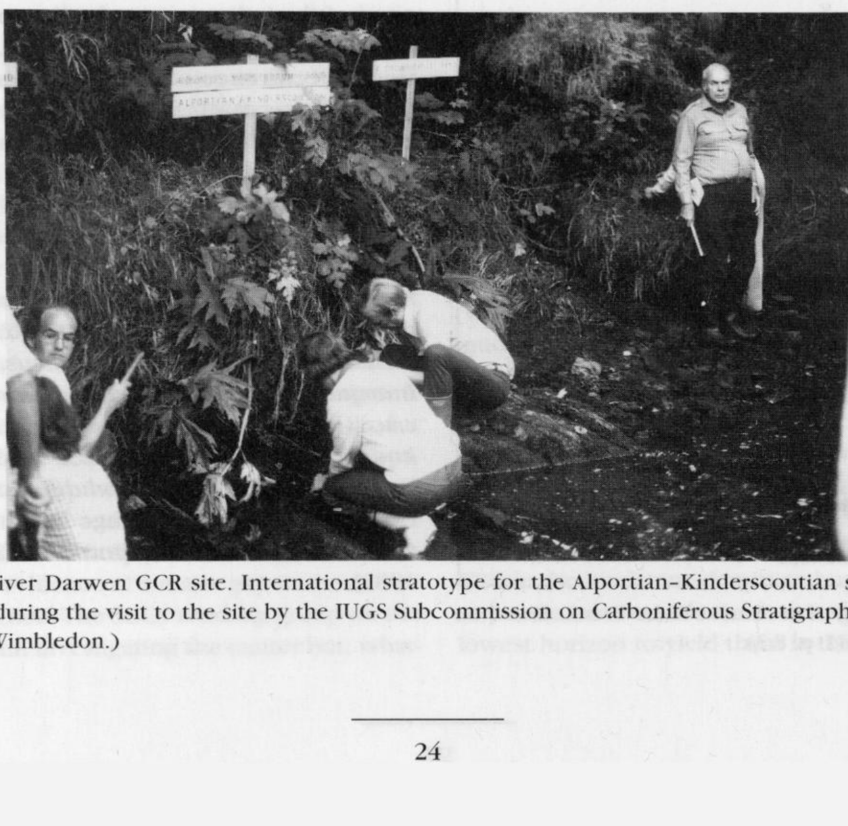

Figure 2.4 River Darwen GCR site. International stratotype for the Alportian–Kinderscoutian stage boundary. Photographed during the visit to the site by the IUGS Subcommission on Carboniferous Stratigraphy, August 1981. (Photo: W. A. Wimbledon.)

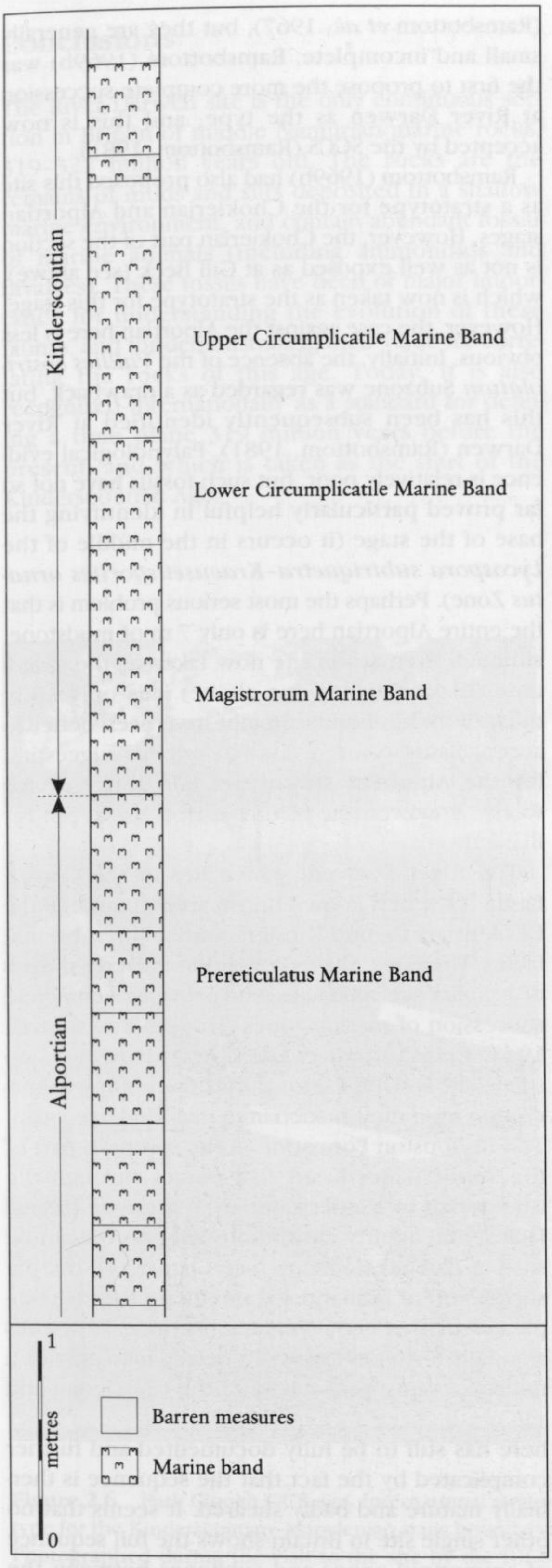

Figure 2.5 Log of part of the section at River Darwen straddling the Alportian–Kinderscoutian boundary. Based on Ramsbottom (1981, pp. 4.5–4.8).

Blackburn, Lancashire (the site is sometimes referred to as Samlesbury Bottoms). It has a dual significance. It is the best exposed mid-Namurian fossil-bearing sequence in Britain, but perhaps more importantly, it has been designated as the international boundary stratotype for the base of the Kinderscoutian Stage. The geology was first discussed by Moore (1930) and Hodson (1957), but the most complete account is in Price *et al.* (1963). A detailed log of the Alportian and Kinderscoutian parts of the section is given in Ramsbottom (1981).

Description

Lithostratigraphy

The Upper Carboniferous strata exposed here underlie the Parsonage Sandstone and comprise 100 m of mudstone with nodular limestone of the Sabden Shales Formation (Figure 2.5).

Biostratigraphy

Marine bands

The lower *Homoceras* Superzone (i.e. H_1) is represented by just two marine bands, 35 m apart, containing *H. beyrichianum* (Haugh) and *Isohomoceras subglobosum* (Bisat) respectively. These are taken as marking the bases of the zones of these species, although the biostratigraphical control here is not good.

The remainder of the sequence consists of *c.*65 m of marine mudstones. Based mainly on palaeontological evidence, Riley, Owens and Swann (*in* Ramsbottom, 1981) have been able to recognize 19 discrete cycles within this interval, which they term beds A–S. At the base of each cycle, fossils indicate deepest-water conditions, and often include abundant ammonoids. Higher in the cycles, however, the ammonoids decline and then disappear, and bivalves (e.g. *Dunbarella*, *Caneyella*, *Posidonia*) become proportionally more important; at the top of some of the cycles, drifted plant debris can be found. It is possible to identify in these strata all of the standard zones and subzones of the upper *Homoceras* (H_2) and lower *Reticuloceras* (R_1) superzones, up to and including the *Reticuloceras nodosum* Zone. Ramsbottom (1969b) was initially unable to identify the *Vallites eostriolatus* Subzone here, but Riley, Owens and Swann (*in* Ramsbottom, 1981) subsequently recognized it in their Bed D.

Palynology

Ramsbottom (1981) only lists miospores from the upper part of the sequence here (beds belonging to the upper *Homoceras* and *Reticuloceras* ammonoid (superzones). The presence of *Grumosporites varioreticulatus* (Neves) Smith and Butterworth in the mudstone G_1, which immediately overlies the lowest bed containing ammonoids of the *Reticuloceras circumplicatile* Zone, supports the correlation of the base of the *Crassispora kosankei-G. varioreticulatus* palynological zone with the base of the *Reticuloceras* ammonoid superzone (Owens, 1982, 1984). Unfortunately, none of the other index species for this palynological zone have been identified from here.

Chronostratigraphy

The base of the Kinderscoutian Stage is defined 'at the base of the marine band containing the goniatite *Hodsonites magistrorum*' (Ramsbottom, 1981). This is Bed G in the section by Riley *et al. in* Ramsbottom (1981), i.e. the Magistrorum Marine Band. The base of the Chokierian Stage is placed at the base of the bed containing *Isohomoceras subglobosum* (Bisat) (presumed to be the Lower Subglobosum Marine Band), and the base of the Alportian Stage at the base of Bed A (the Proteum Marine Band) in the log by Riley *et al.*

Interpretation

The name Kinderscoutian was first introduced by Bisat (1928) for strata containing what he referred to as the R_1 goniatite zone. A more formal definition was provided by Bisat and Hudson (1943), who placed the base of the stage at the marine band containing what is now known as *Hodsonites magistrorum* (Hodson). Ramsbottom (1977) proposed that the base should be lowered to the base of the *Homoceratoides prereticulatus* Zone, as this represented a more significant change in the ammonoid fossils, but this has not been adopted by the SCCS.

Bisat (1924) used a section at Roughlee, near Barley, Lancashire as the standard for the R_1 zone, but it is disrupted by faulting and exposure is now poor. His use four years later of the name Kinderscoutian implies that sections in the Kinderscout area of Derbyshire should be taken as the type. There are a number of exposures in this area, such as in Grinds Brook near Edale (Ramsbottom *et al.*, 1967), but they are generally small and incomplete. Ramsbottom (1969b) was the first to propose the more complete succession at River Darwen as the type, and this is now accepted by the SCCS (Ramsbottom, 1981).

Ramsbottom (1969b) had also proposed this site as a stratotype for the Chokierian and Alportian stages. However, the Chokierian part of the section is not as well exposed as at Gill Beck (see above), which is now taken as the stratotype for this stage. However, the case against the Alportian here is less obvious. Initially, the absence of the *Vallites eostriolatum* Subzone was regarded as a drawback, but this has been subsequently identified at River Darwen (Ramsbottom, 1981). Palynological evidence is relatively poor, but such fossils have not so far proved particularly helpful in identifying the base of the stage (it occurs in the middle of the *Lycospora subtriquetra–Kraeuselisporites ornatus* Zone). Perhaps the most serious problem is that the entire Alportian here is only 7 m of mudstone, although even at the site now taken as the stratotype (Blake Brook – see above) it is only 10 m thick. With hindsight, it might have been better to accept Ramsbottom's (1969b) original suggestion for the Alportian stratotype. For better or for worse, however, the SCCS has decided to opt for Blake Brook.

The River Darwen, which lies in the Craven Basin, is the best known British section through the Chokierian to mid-Kinderscoutian in a basinal facies. The Edale Shales Formation of Derbyshire is of a similar age and facies, and provides a complete succession of marine zones (Hudson and Cotton, 1945; Ramsbottom *et al.*, 1967). However, no single site in Derbyshire shows the complete succession from the Chokierian to mid-Kinderscoutian. The Bishopston Formation in the southern part of the South Wales basin also ranges through the Chokierian to Kinderscoutian in a clastic basinal facies, and a fairly continuous succession can be seen at Barland Common (see Chapter 4), but the succession of goniatites is nowhere near as complete as in the Central Pennine Province. Exposures along the Shannon Estuary in Ireland may provide a full succession, particularly of the Chokierian and Alportian (Ramsbottom, 1969b), but the geology here has still to be fully documented and further complicated by the fact that the sequence is thermally mature and badly sheared. It seems that no other single site in Britain shows the full sequence of ammonoid zones and subzones between the *Isohomoceras subglobosum* and *Reticuloceras nodosum* zones.

Conclusions

The River Darwen site is the only continuous section in Britain of middle Namurian marine rocks, 319–322 million years old. The rocks are the remains of muds and silts deposited in a shallow marine environment, and contain abundant fossils of marine animals (including ammonoids and bivalves). These fossils have been of major importance for understanding the evolution of these faunas, and for demonstrating their value for correlating the rocks of this age. Today, it is also recognized internationally as a standard for defining a time plane 319 million years before the present, and which is taken as the start of the Kinderscoutian Age.

Figure 2.6 Park Clough GCR site. International stratotype for the Kinderscoutian–Marsdenian stage boundary. Photographed during the visit to the site by the IUGS Subcommission on Carboniferous Stratigraphy, August 1981. (Photo: W.A. Wimbledon.)

PARK CLOUGH

Highlights

Park Clough is the proposed international stratotype for the base of the Marsdenian Stage (Figure 2.6).

Introduction

This site, in the middle of the Pennine Basin, is a stream section 250 m NNW of Hey Green, near Marsden, West Yorkshire (SE 030125). Its geology was briefly mentioned by Bromehead *et al.* (1933), but otherwise received little attention in the literature until it was proposed as the international stratotype for the base of the Marsdenian Stage (Ramsbottom, 1981).

Description

Lithostratigraphy

The exposed sequence here is about 35 m thick (Figure 2.7). The lower 15 m consists of flaggy or cross-bedded sandstones, belonging to the Kinderscout Grit Subgroup. These are succeeded by 20 m of mudstones, which represent the basal part of the Middle Grit Subgroup.

Biostratigraphy

Marine bands

In the detailed log provided by Ramsbottom (1981, p. 10.3), two mudstone intervals are shown to contain marine fossils. The lowest, *c.*1 m above the Kinderscout Grit, yielded *Bilinguites gracilis* Bisat and *Anthracoceratites* sp. This clearly belongs to the *B. gracilis* Zone.

Some 12 m higher, a second mudstone interval yielded crushed examples of the goniatites *Bilinguites bilinguis* (Salter) and *Bashkirites* sp. This is taken to mark the base of the *B. bilinguis* Zone. A second mudstone containing the same assemblage occurs 2 m higher, but details of this were not given.

Palynology

Ramsbottom (1981) records that 10 palynology samples were taken from this section. However, no

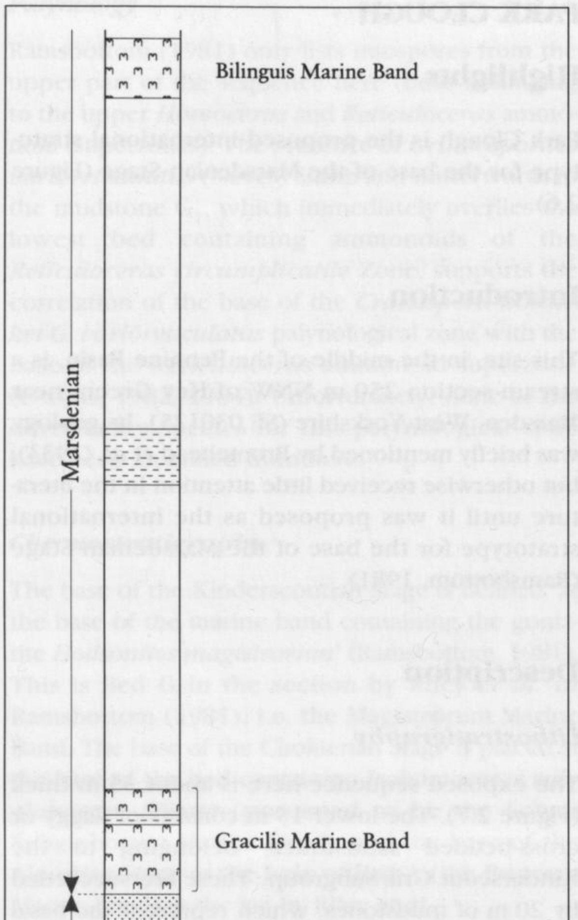

Figure 2.7 Log of section at Park Clough. Based on Ramsbottom (1981, p. 10.3).

details of the pollen and spores were given. According to Owens (1982, 1984), the Kinderscoutian–Marsdenian boundary is poorly demarcated on palynological criteria.

Chronostratigraphy

The base of the Marsdenian Stage is defined at 'the base of the marine horizon containing *Reticuloceras gracile*' (Ramsbottom, 1981).

Interpretation

The Marsdenian Stage was proposed by Bisat (1928), for the interval of strata containing the R_2 goniatite zone in his classification. He took exposures in the region between Manchester and Leeds, in particular that near Marsden, as typical. According to Ramsbottom (1981), however, the sequences there do not show the marine band containing *B. gracilis* Bisat in its fullest development. It was therefore proposed that Park Clough should be taken as the formal stratotype. However, according to Riley (pers. comm.), this is because Ramsbottom erroneously followed Bisat in thinking that the evolute, strongly plicate variety of *B. gracilis* was a late mutation and that the involute, more feebly ornamented form was an early form. The section at Sabden Brook, (Cockwood) is much better and has both forms in the marine band, with the supposed early form commonest in the upper part.

According to Ramsbottom (1981), the Gracilis Marine Band occurs extensively in Britain in the basinal areas, but is absent from the more stable blocks. This was interpreted as being a consequence of it being the basal marine horizon of a mesothem (in this case N_9) although Holdsworth and Collinson (1988) have challenged this view.

Conclusion

Park Clough is an internationally recognized standard for defining a time plane, 317 million years before the present, and marking the start of the Marsdenian Age.

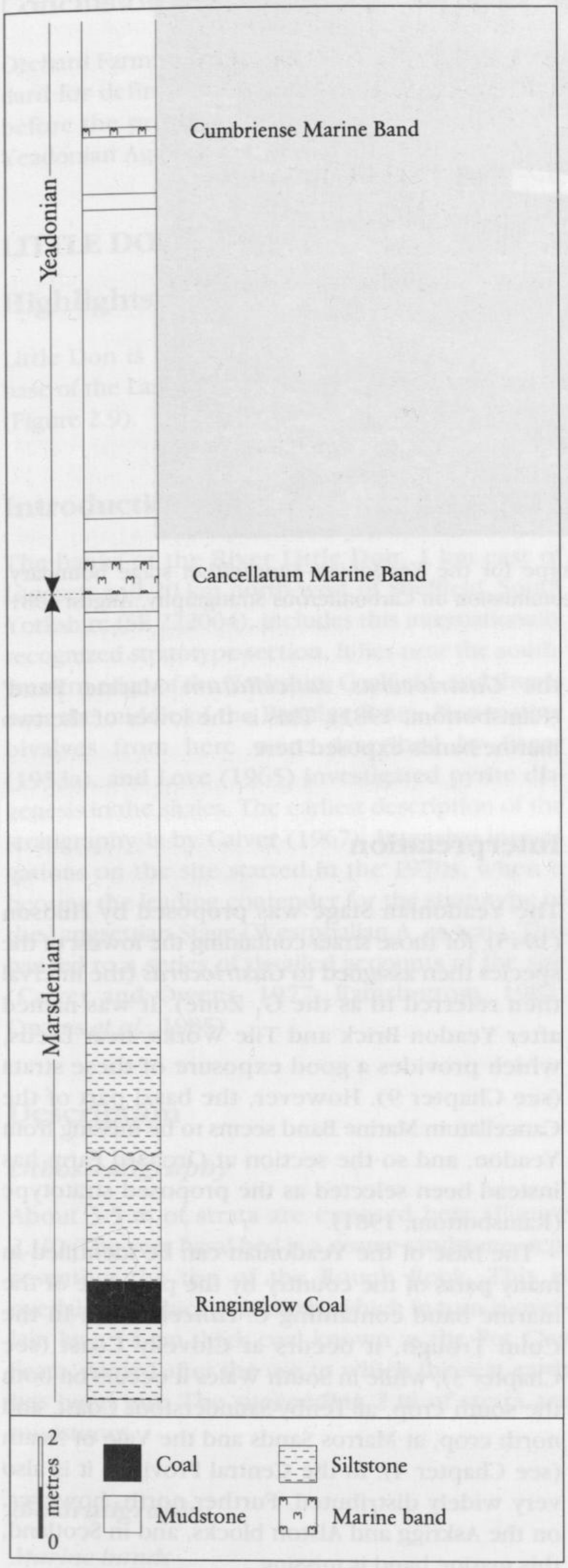

Figure 2.8 Log of section at Orchard Farm. Based on Ramsbottom (1981, p. 9.3).

ORCHARD FARM

Highlights

Orchard Farm is the proposed international stratotype for the base of the Yeadonian Stage.

Introduction

This site, in the southern part of the Pennines Basin, is along a small stream on Orchard Common, 8 km WNW of Longnor, Staffordshire (SK 023691). It was mentioned by Cope (1946), as showing an example of contorted beds in the Millstone Grit of the north Midlands. The stratigraphical significance of the section did not come to light, however, until it was proposed as the stratotype for the base of the Yeadonian Stage.

Description

Lithostratigraphy

About 30 m of strata are exposed here (Figure 2.8). The lowest 4 m is a pink sandstone, belonging to the top of the Chatsworth Grit, which is in the upper part of the Middle Grit Subgroup. This is overlain by a 90 cm thick dirty coal known as the Ringinglow Seam. The remaining 25 m are mainly mudstones, which mark the base of the Rough Rock Subgroup. Within this part of the section, there are two beds of contorted mudstone, showing prominent slickensiding. Cope (1946) interpreted this as bedding-plane slip, resulting from tectonic folding.

Biostratigraphy

Marine bands

Two bands of mudstone within the Rough Rock Formation here have yielded marine fossils. The lowest occurs 13.5 m above the Ringinglow Seam, and contains the ammonoid *Cancelloceras cancellatum* (Bisat). According to Ramsbottom (1981), three successive assemblages can be recognized within this mudstone: 1 – at the base, containing only *Cancelloceras branneroides* (Bisat); 2 – in the middle, a mixture of *C. cancellatum* and *Bilinguites superbilinguis* Bisat; 3 – at the top, a mixture of *C. cancellatum* and *Agastrioceras carinatum* (Frech). This is the classic succession of ammonoids within this marine band, as outlined by

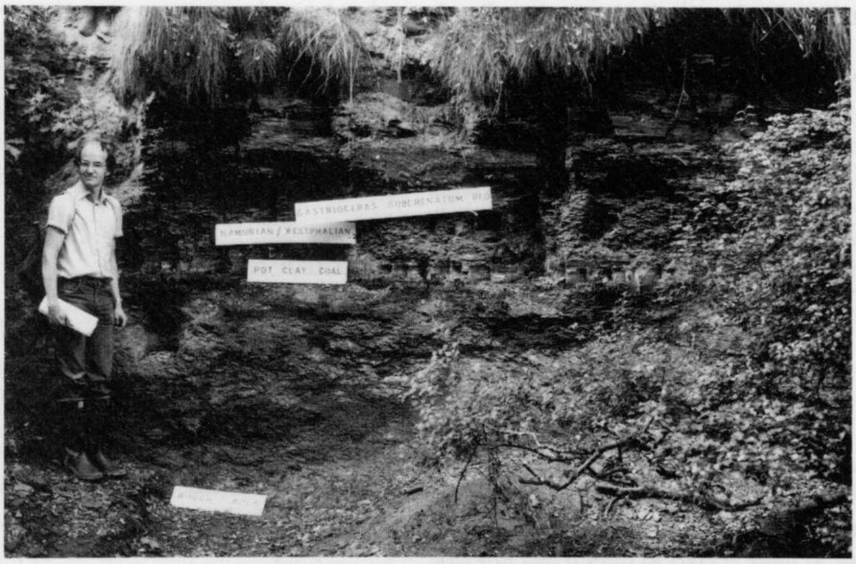

Figure 2.9 Little Don GCR site. International stratotype for the Yeadonian–Langsettian stage boundary. Photographed during the visit to the site by the IUGS Subcommission on Carboniferous Stratigraphy, August 1981. (Photo: W.A. Wimbledon.)

Ramsbottom (1969b). It marks the base of the *C. cancellatum* Zone in the European biostratigraphy, and the base of the *Cancelloceras–Branneroceras* Superzone.

About 8 m above this, a second band of mudstones has yielded ammonoids. Ramsbottom (1981) does not record identifications, although it is claimed that it is the Cumbriense Marine Band.

Palynology

Ramsbottom (1981) details pollen and spores derived from 28 levels within this section. The abundant occurrence of *Ahrenisporites beeleyensis* Neves and *Raistrickia fulva* Artüz suggests that the sequence belongs to the *Raistrickia fulva–Reticulatisporites reticulatus* Zone (Owens *in* Ramsbottom *et al.*, 1979). No major change can be recognized through the sequence exposed here. This is not surprising, as the base of the *fulva-reticulatus* Zone is in the middle Marsdenian (Owens *et al.*, 1977), at a rather lower stratigraphical level than is represented here. Perhaps significantly, however, *Florinites antiquus* Schopf comes in at a short distance below the Cancellatum Marine Band, as its lowest occurrence is usually at about the base of the Yeadonian Stage (Owens, 1982).

Chronostratigraphy

The base of the Yeadonian Stage is defined at 'the base of the marine band containing the faunas of the *Gastrioceras cancellatum* Marine Band' (Ramsbottom, 1981). This is the lower of the two marine bands exposed here.

Interpretation

The Yeadonian Stage was proposed by Hudson (1945), for those strata containing the lowest of the species then assigned to *Gastrioceras* (the interval then referred to as the G_1 Zone). It was named after Yeadon Brick and Tile Works, near Leeds, which provides a good exposure of these strata (see Chapter 9). However, the basal part of the Cancellatum Marine Band seems to be missing from Yeadon, and so the section at Orchard Farm has instead been selected as the proposed stratotype (Ramsbottom, 1981).

The base of the Yeadonian can be identified in many parts of the country by the presence of the marine band containing *C. cancellatum*. In the Culm Trough, it occurs at Clovelly Coast (see Chapter 3), while in South Wales it occurs on both the south crop, at Tenby-Saundersfoot Coast, and north crop, at Marros Sands and the Vale of Neath (see Chapter 4). In the Central Province it is also very widely distributed. Further north, however, on the Askrigg and Alston blocks, and in Scotland, this marine band is missing.

Conclusion

Orchard Farm is an internationally recognized standard for defining a time plane, 316 million years before the present, and marking the start of the Yeadonian Age.

LITTLE DON

Highlights

Little Don is the international stratotype for the base of the Langsettian (Westphalian A *auct.*) Stage (Figure 2.9).

Introduction

The banks of the River Little Don, 1 km east of Langsett and 20 km north-west of Sheffield, South Yorkshire (SE 222004), includes this internationally recognized stratotype-section. It lies near the south-western edge of the Yorkshire Coalfield, and thus is near the middle of the Pennine Basin. Non-marine bivalves from here were described by Eagar (1953a), and Love (1965) investigated pyrite diagenesis in the shales. The earliest description of the stratigraphy is by Calver (1967). Intensive investigations on the site started in the 1970s, when it became the leading contender for the stratotype of the Langsettian Stage (Westphalian A, as was). This has led to a series of detailed accounts of the site (Calver and Owens, 1977; Ramsbottom, 1981; Owens *et al.*, 1985).

Description

Lithostratigraphy

About 3.5 m of strata are exposed here (Figure 2.10). The very basal bed is a coarse sandstone, representing the top of the Rough Rock. This is overlain by a thick seat earth, which in turn is overlain by a 14 cm thick coal known as the Pot Clay Seam, named after the use to which the seat earth has been put. The succeeding 2 m of strata are mudstones.

Biostratigraphy

Marine bands

Marine fossils occur in a 66 cm thick interval of mudstones, which lies 24 cm above the Pot Clay

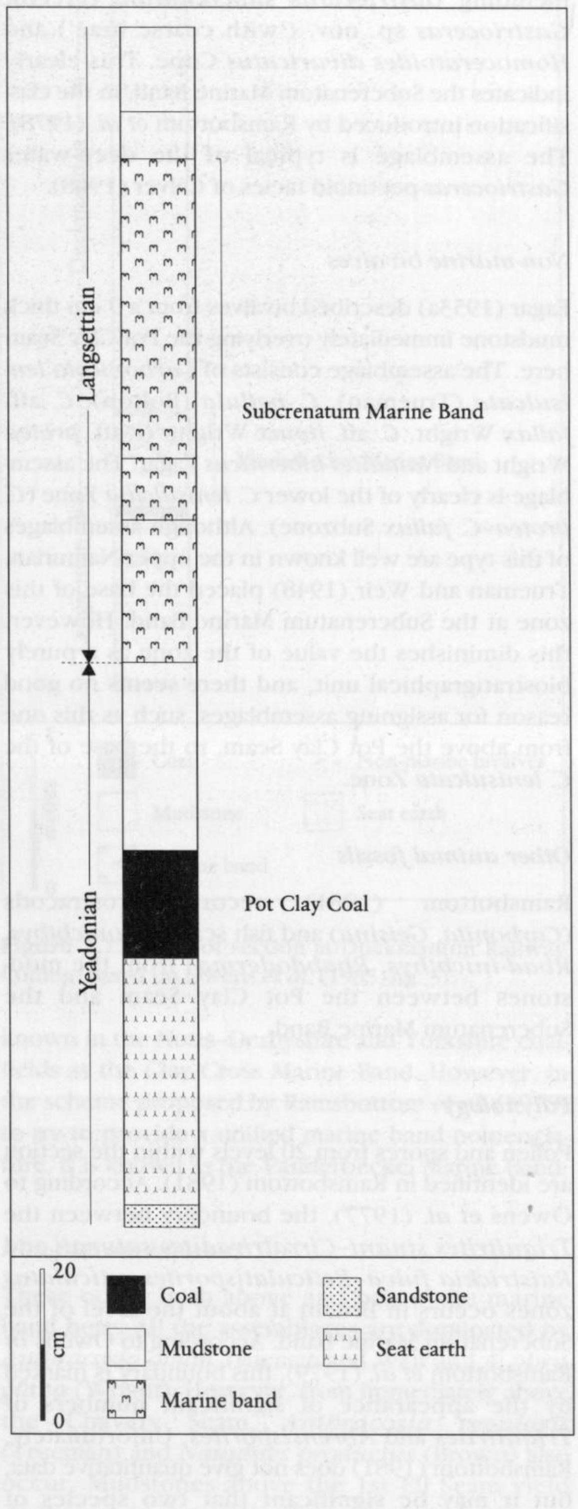

Figure 2.10 Log of section at Little Don. Based on Owens *et al.* (1985, fig. 2).

Seam (locally known as the Pot Clay Marine Band). According to Owens *et al.* (1985), the marine band has yielded a rich assemblage of ammonoids, including *Gastrioceras subcrenatum* (Frech), *Gastrioceras* sp. nov. ('with coarse lirae') and *Homoceratoides divaricatus* Cope. This clearly indicates the Subcrenatum Marine Band, in the classification introduced by Ramsbottom *et al.* (1978). The assemblage is typical of the deep-water *Gastrioceras*-pectinoid facies of Calver (1968).

Non-marine bivalves

Eagar (1953a) described bivalves from a 9 cm thick mudstone immediately overlying the Pot Clay Seam here. The assemblage consists of *Carbonicola lenisulcata* (Trueman), *C. bellula* (Bolton), *C.* aff. *fallax* Wright, *C.* aff. *limax* Wright, *C.* aff. *protea* Wright and *Naiadites hibernicus* Eagar. The assemblage is clearly of the lower *C. lenisulcata* Zone (*C. protea–C. fallax* Subzone). Although assemblages of this type are well known in the upper Namurian, Trueman and Weir (1948) placed the base of this zone at the Subcrenatum Marine Band. However, this diminishes the value of the zone as a purely biostratigraphical unit, and there seems no good reason for assigning assemblages, such as this one from above the Pot Clay Seam, to the base of the *C. lenisulcata* Zone.

Other animal fossils

Ramsbottom (1981) recorded ostracods (*Carbonita*, *Geisina*) and fish scales (*Elonichthys*, *Rhad-inichthys*, *Rhabdoderma*) from the mudstones between the Pot Clay Seam and the Subcrenatum Marine Band.

Palynology

Pollen and spores from 20 levels within the section are identified in Ramsbottom (1981). According to Owens *et al.* (1977), the boundary between the *Triquitrites sinani–Cirratriradites saturnii* and *Raistrickia fulva–Reticulatisporites reticulatus* zones occurs in Britain at about the level of the Subcrenatum Marine Band. According to Owens *in* Ramsbottom *et al.* (1979), this boundary is marked by the appearance of significant numbers of *Triquitrites* and *Ahrensisporites*. Unfortunately, Ramsbottom (1981) does not give quantitative data, but it may be significant that two species of *Ahrensisporites* appear in the seat earth below the Pot Clay Seam. One of the other indices for the zonal boundary is the base of the range of *Florinites mediapudens* (Loose) Potonié, and this was found in most samples from the seat earth upwards. It would seem, therefore, that the base of the *T. sinani-C. saturnii* Zone here occurs a little way below the Subcrenatum Marine Band.

Chronostratigraphy

The base of the Langsettian Stage is defined 'at the base of the Subcrenatum Marine Band, which overlies the Pot Clay Coal' (Ramsbottom, 1981).

Interpretation

The Westphalian A was proposed as a substage in 1927 (Jongmans, 1928), and was only later upgraded to a stage (George and Wagner, 1972). This promotion also required a change of name for the interval, which is now called the Langsettian, following Owens *et al.* (1985). In its 1927 form, the effective stratotype was the Sarnsbank Marine Band in the Ruhr Coalfield. This is only seen in underground workings, however, and so it was decided to find an alternative surface exposure in another coalfield. After investigating a number of sites in Britain (Calver and Owens, 1977), the SCCS Westphalian A, B and C Working Group proposed the Little Don as the stratotype (Owens *et al.*, 1985). Both the name Langsettian and the stratotype were ratified by the SCCS in 1989, although they have yet to be ratified by the IUGS.

The Subcrenatum Marine Band is one of the most widely occurring marine bands in Britain; only in Scotland has it not been identified. According to Calver (1968), it is most fully developed in Lancashire and Yorkshire, at least in the areas north of St. George's Land. However, it has not been subject to the same sort of detailed investigation as has been done in South Wales, such as at the Vale of Neath (see Chapter 4), and so a detailed comparison with the areas north and south of St George's Land is impossible.

Conclusion

Little Don is an internationally recognized standard for defining a time plane, 315 million years before the present, and marking the start of what has become known as the Langsettian Age (and thereby the Westphalian Epoch).

DUCKMANTON RAILWAY CUTTING

Highlights

Duckmanton Railway Cutting is the international stratotype for the base of the Duckmantian (Westphalian B *auct.*) Stage.

Introduction

This is a cutting on the disused Bolsover to Chesterfield railway line near Arkwright Town, 4 km east of Chesterfield, Derbyshire (SK 424704). It is in the middle of the Notts-Derbyshire Coalfield, and is thus near the centre of the Pennine Basin. The geology was first described by Smith *et al.* (1967). It was proposed as the stratotype for the base of the Duckmantian Stage by Calver and Owens (1977), and as a result there have been detailed biostratigraphical analyses of the interval near the boundary by Ramsbottom (1981) and Owens *et al.* (1985). The exposure here has become largely grassed over, but rock can easily be revealed by trenching, and the key parts of the section can be seen in permanently protected enclosures. The site was purchased by the Derbyshire Naturalists' Trust in 1976, and is now known as the W.H. Wilkinson Nature Reserve.

Description

Lithostratigraphy

The sequence originally exposed along this cutting was *c.*150 m thick (Figure 2.11). It consists mostly of mudstones, but also includes four coal seams: in ascending order, the Chavery, Joan, 2nd Ell and 1st Ell seams.

Biostratigraphy

Marine bands

The 3 m of mudstone overlying the Joan Seam have yielded a restricted marine assemblage, including *Dunbarella*, *Myalina*, *Lingula*, and the ostracods *Geisina* and *Hollinella*. No ammonoids have been found here, but what is believed to be the same band in neighbouring sites has yielded *Anthracoceratites vanderbeckei* (Ludwig) (Owens *et al.*, 1985). Traditionally, this marine band, which is the only one normally occurring between the basal Langsettian and the middle Duckmantian, was

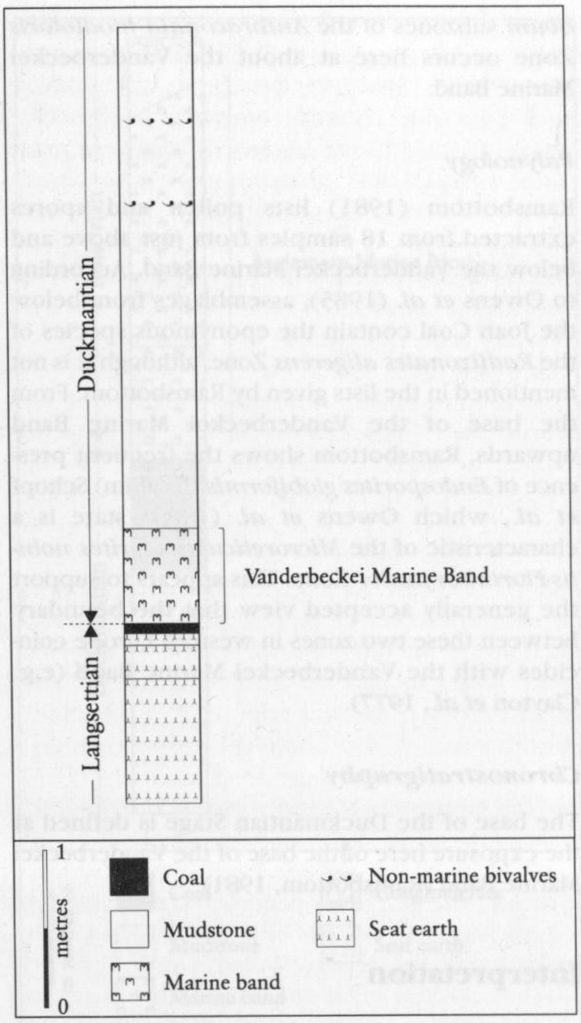

Figure 2.11 Log of section at Duckmanton Railway Cutting. Based on Owens *et al.* (1985, fig. 3).

known in the Notts–Derbyshire and Yorkshire coalfields as the Clay Cross Marine Band. However, in the scheme proposed by Ramsbottom *et al.* (1978) to try to provide a unified marine band nomenclature, it is known as the Vanderbeckei Marine Band.

Non-marine bivalves

These occur both above and below the marine band here. All the assemblages are dominated by *Anthracosia ovum* Trueman and Weir and *A. phrygiana* (Wright). However, from immediately above the Chavery Seam, *Anthracosia regularis* (Trueman) and *Naiadites productus* (Brown) also occur. Mudstones above the 1st Ell Seam yield *Anthracosia lateralis* (Brown) and *Anthracosphaerium* aff. *turgidum* (Brown). This suggests that the junction between the *A. lateralis* and *A.*

ovum subzones of the *Anthraconaia modiolaris* Zone occurs here at about the Vanderbeckei Marine Band.

Palynology

Ramsbottom (1981) lists pollen and spores extracted from 18 samples from just above and below the Vanderbeckei Marine Band. According to Owens *et al.* (1985), assemblages from below the Joan Coal contain the eponymous species of the *Radiizonates aligerens* Zone, although it is not mentioned in the lists given by Ramsbottom. From the base of the Vanderbeckei Marine Band upwards, Ramsbottom shows the frequent presence of *Endosporites globiformis* (Ibrahim) Schopf *et al.*, which Owens *et al.* (1985) state is a characteristic of the *Microreticulatisporites nobilis-Florinites junior* Zone. This appears to support the generally accepted view that the boundary between these two zones in western Europe coincides with the Vanderbeckei Marine Band (e.g. Clayton *et al.*, 1977).

Chronostratigraphy

The base of the Duckmantian Stage is defined at the exposure here of the base of the Vanderbeckei Marine Band (Ramsbottom, 1981).

Interpretation

The Westphalian B was part of the original 1927 tripartite division of the Westphalian Stage (Jongmans, 1928). It was later upgraded to a stage (George and Wagner, 1972) and renamed the Duckmantian (Owens *et al.*, 1985). The type horizon denoting the base of the stage was originally taken at the Katharina Marine Band in the Ruhr, but there are no surface outcrops in this coalfield. It was therefore decided to define the stage boundary at a site in Britain (George and Wagner, 1972) and, after a number of candidates were considered, Duckmanton was selected (Calver and Owens, 1977; Ramsbottom, 1981; Owens *et al.*, 1985). Both the name Duckmantian and the location of the stratotype were ratified by the SCCS in 1989, although they have not yet been ratified by the IUGS.

A weakness of the site as a stratotype is the relatively restricted assemblage of fossils present in the marine band. However, it makes up for this by the excellent non-marine bivalve and palynology record that it provides across the boundary (plant macrofossils are to all intents absent, but this is also the case in all of the other Upper Carboniferous stage stratotypes).

The Vanderbeckei Marine Band is the only fully marine band between the lower Langsettian and topmost Duckmantian; the only possible exceptions are some thin bands with estheriids in the middle Langsettian of the Notts-Derbyshire Coalfield. Nevertheless, it is an extremely widespread marine band, having been identified in every British coalfield with lower Westphalian strata. It is also widely found in northern Europe, having been identified as far east as the Lublin Coalfield in Poland, where it is known as the *Dunbarella* Marine Band (Musia *et al.*, 1983). According to Calver (1968), it ranges over an area 960 km by 650 km, and is one of the most reliable horizons for establishing inter-coalfield correlations.

Conclusion

Duckmanton Railway Cutting is an internationally recognized standard for defining a time plane, 313 million years before the present, and marking the start of what has become known as the Duckmantian Age.

DOE LEA

Highlights

Doe Lea is the international stratotype for the base of the Bolsovian (Westphalian C *auct.*) Stage.

Introduction

This small exposure (SK 460692) lies below a weir on the River Doe Lea, 2 km south-west of Bolsover, Derbyshire. It is in the northern part of the Notts-Derbyshire Coalfield, and is thus in the middle of the Pennine Basin. The only published descriptions of the geology are by Owens *et al.* (1985) and Riley *et al.* (1985), when it was being proposed as the stratotype for the Duckmantian-Bolsovian boundary.

Description

Lithostratigraphy

The exposed sequence here is less than 2 m thick (Figure 2.12). It consists of 55 cm of seat earth overlain by a 25 cm thick coal, which in turn is overlain by about 1 m of mudstones. Part of the mudstone has been replaced by ankerite (a calcium/ferrous/manganese carbonate) known locally as 'cank'.

Biostratigraphy

Marine band

A diverse assemblage of marine fossils occurs in the mudstones overlying the coal. Ammonoids are particularly abundant, and Owens *et al.* (1985) have recorded *Donetzoceras aegiranum* (Schmidt), *Metacoceras costatum* (Hind) and cf.*Peripetoceras dubium* (Hind). In addition, there are bivalves (*Dunbarella*, *Pterinopecten*, *Aviculopecten*, *Posidonia*), inarticulate brachiopods and ostracods. This is clearly indicative of the Aegiranum Marine Band in the classification introduced by Ramsbottom *et al.* (1978).

Conodonts

Owens *et al.* (1985) and Riley *et al.* (1985) list a number of species from this exposure of the Aegiranum Marine Band, belonging to the genera *Idiognathoides*, *Declinognathodus*, *Hindeodella* and *Ligonodina*. Of interest is the presence of *Neognathodus kanumai* (Igo), previously described from beds thought to be equivalent to the lower Westphalian of Japan. Otherwise, however, the rest of the assemblage consists of elements described by Higgins (1975) from lower stratigraphical levels in Britain.

Palynology

Riley *et al.* (1985) record numerous palynomorphs from eleven levels within the section. In most biostratigraphical schemes (e.g. Smith and Butterworth, 1967; Clayton *et al.*, 1977; Owens, 1984), the Duckmantian-Bolsovian boundary does not coincide with a biozonal boundary. The evidence from Doe Lea seems to corroborate this; what changes that can be seen seem to be controlled by the ecological changes between swamp and marine conditions.

Chronostratigraphy

The base of the Bolsovian Stage is defined at this site at the base of the Aegiranum Marine Band, which is 3 cm above the coal seam exposed here (Owens *et al.*, 1985).

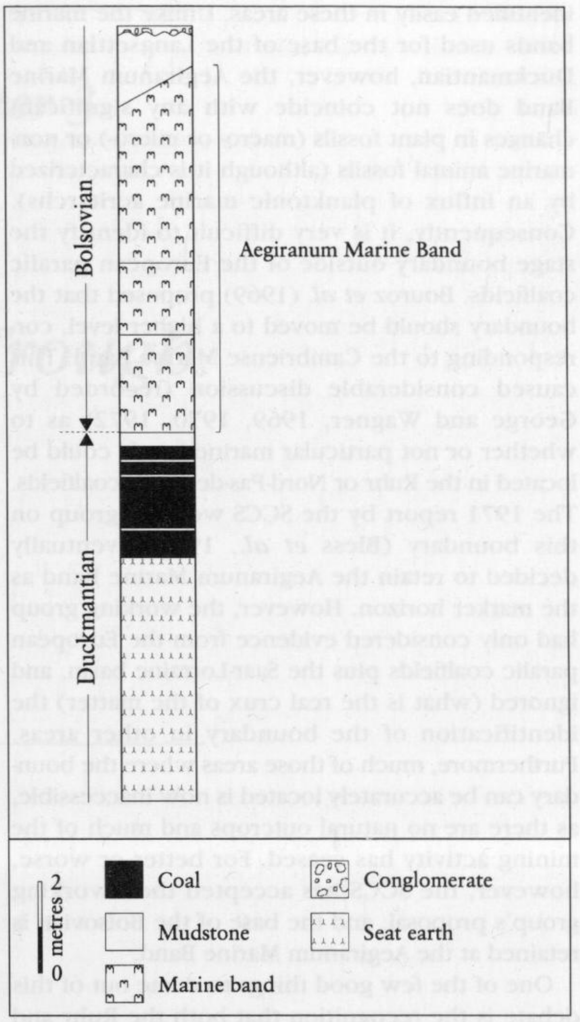

Figure 2.12 Log of section at Doe Lea. Based on Owens *et al.* (1985, fig. 4).

Interpretation

The Westphalian C was originally the top unit in the tripartite division of the Westphalian Stage, as outlined by Jongmans (1928). Shortly after, its range was restricted by the recognition of a fourth substage (Westphalian D). This was for the upper part of the original Westphalian C, and representing strata thought not to be well developed in the classic paralic coalfields (e.g. Notts–Derbyshire, Nord-Pas-de-Calais, Ruhr). The redefined Westphalian C was subsequently raised in rank to a stage (George and Wagner, 1972) and renamed the Bolsovian (Owens *et al.*, 1985).

The Aegiranum Marine Band marks the base of the Bolsovian. The marine band is widespread and readily identified in the classic European paralic coalfields, and so the stage boundary can usually be identified easily in these areas. Unlike the marine bands used for the base of the Langsettian and Duckmantian, however, the Aegiranum Marine Band does not coincide with any significant changes in plant fossils (macro- or micro-) or non-marine animal fossils (although it is characterized by an influx of planktonic marine acritarchs). Consequently, it is very difficult to identify the stage boundary outside of the European paralic coalfields. Bouroz *et al.* (1969) proposed that the boundary should be moved to a higher level, corresponding to the Cambriense Marine Band. This caused considerable discussion (recorded by George and Wagner, 1969, 1970, 1972) as to whether or not particular marine bands could be located in the Ruhr or Nord-Pas-de-Calais coalfields. The 1971 report by the SCCS working group on this boundary (Bless *et al.*, 1972) eventually decided to retain the Aegiranum Marine Band as the marker horizon. However, the working group had only considered evidence from the European paralic coalfields plus the Saar-Lorraine basin, and ignored (what is the real crux of the matter) the identification of the boundary in other areas. Furthermore, much of those areas where the boundary can be accurately located is now inaccessible, as there are no natural outcrops and much of the mining activity has ceased. For better or worse, however, the SCCS has accepted their working group's proposal, and the base of the Bolsovian is retained at the Aegiranum Marine Band.

One of the few good things to come out of this debate is the recognition that both the Ruhr and Nord-Pas-de-Calais coalfields were totally unsuitable to act as a stratotype for the base of the Bolsovian. A search for a candidate site was first made in South Wales, but was soon after switched to the Pennine Basin. At the 1971 SCCS meeting, two candidates were put forward: Wales Railway Cutting in Derbyshire and Stairfoot Brickpit in South Yorkshire (George and Wagner, 1972). Despite being designated an SSSI, the railway cutting was shortly afterwards infilled and so, by default, the brickworks became the nominated site (Calver and Owens, 1977). This was far from satisfactory, however, as there were conservation problems (it was still being actively worked for brick-clay) and it did not yield a particularly diverse marine fossil assemblage (Ramsbottom, 1981). In the early 1980s, a previously unknown exposure at Doe Lea seemed to offer a solution to these problems; although it was only a small outcrop, it yielded a much more diverse fossil assemblage and should have been much easier to conserve. However, a matter of only a few weeks after the SCCS 1983 decision to accept it as the stratotype (Manger, 1985), the Doe Lea exposure was covered by a new weir, constructed to control erosion. Fortunately, the weir only just extended over the outcrop and it proved possible to excavate a new exposure a few metres downstream from the original site (Anon. 1987).

The Aegiranum Marine Band is very widely distributed, having been identified in most coalfields in Britain (Ramsbottom *et al.*, 1978). The similarity between the fossils found in the band in South Wales and the Pennine Basin suggests that the St George's Landmass was not a major obstacle to faunal migration by this time and may have been at least two separate islands (Bless and Winkler Prins, 1972). One of the best British exposures was at Aberbaiden in South Wales (Ramsbottom, 1952), but the site has unfortunately been destroyed. Otherwise, the known exposures of this marine band in southern Britain have yielded assemblages of relatively low diversity. In the Pennine Basin, more diverse assemblages have been reported (Calver, 1968), but mainly from underground workings or temporary exposures; the Doe Lea site is one of the few to provide permanent outcrop and diversity of assemblage (see also Eyemore Railway Cutting – Chapter 7). In Scotland, where it is known as the Skipsey's Marine Band, there are a number of exposures, but they have less diverse assemblages (Currie *et al.*, 1937; Bless and Winkler Prins, 1972).

In northern Europe, this marine band is widely known in the paralic coalfields between the Pas-de-Calais and the Ruhr (Bless and Winkler Prins, 1972), although always in underground or temporary workings. Unlike the Vanderbeckei Marine Band, however, it has not yet been identified further east in Poland (Musia *et al.*, 1983). The hope that similar assemblages might be identifiable in the fully marine sequences in Russia (Bless *et al.*, 1972) has not been fulfilled (see Wagner and Bowman, 1983 for an account of some of the problems involved).

Conclusion

Doe Lea is an internationally recognized standard for defining a time plane, 311 million years before the present, and marking the start of the Bolsovian Age.