British Upper Carboniferous Stratigraphy

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Chapter 7

English Midlands

This chapter covers sites in the southern-marginal parts of the Pennine Basin, as it laps up against the Wales-Brabant Barrier. There are five main areas of outcrop, which are known, from west to east, as the Shrewsbury, Coalbrookdale, Wyre Forest, South Staffordshire and Warwickshire coalfields; there are also small areas of outcrop in the Clee Hills of Shropshire (Figure 7.1). The coalfields of North Wales (Denbigh and Flint) and a small outcrop in Anglesey, are also in a marginal part of the Pennine Basin, but they contain no sites that merited inclusion in the GCR coverage, and so will only be touched on in passing in this chapter.

A little to the north of this belt of Midlands coalfields showing marginal sequences are two other areas of Coal Measures known as the Leicester-South Derbyshire and the North Staffordshire coalfields. They show sequences which are intermediate in character between those of Warwickshire and South Staffordshire, and the more fully developed, basinal sequences of Yorkshire and Lancashire (e.g. Earp, 1961; Spink and Ford, 1968; Worssam and Old, 1988). However, exposure here is very limited and only one site was selected during the GCR survey, in the North Staffordshire Coalfield (Metallic Tileries).

As they occupied a marginal position in the basin, the sequences here are relatively condensed and show frequent evidence of emergent conditions (e.g. red beds). Nevertheless, there are some grey measures of the Productive Coal Formation, with commercially exploitable coals, particularly in the Leicester-South Derbyshire and North Staffordshire coalfields. In the 1930s, the coalfields on the southern margins of the Pennine Basin had a combined annual output of up to about 12 million tons, while the intermediate Leicester-South Derbyshire and North Staffordshire coalfields produced up to about 10 million tons (Bone and Himus, 1936). This has remained more or less constant up to the present (Hains and Horton, 1969; British Coal Corporation Annual Report, 1990/91). The marginal position of these deposits also resulted in the development of other economically significant resources. Iron ore deposits, particularly in South Staffordshire, were extensively worked during the 19th and early 20th centuries, and mudstones suitable for brick and earthenware manufacture have been an important industrial resource in north Staffordshire, hence this area being referred to as 'the Potteries'.

History of research

The following will only deal with those areas in which sites have been selected. For historical details of work on the North Wales coalfields, the reader is directed to Calver and Smith (1974), while the Leicestershire Coalfield is discussed by Spink and Ford (1968) and Worssam and Old (1988).

Shrewsbury Coalfield

This area, which is also sometimes referred to as the Hanwood Coalfield, consists mainly of upper Westphalian red beds with only very limited coal development. The latter factor, together with the limited natural exposure, has meant that there has been relatively little interest in the geology of the area. The earliest study seems to have been by Murchison (1839), and a brief summary was provided some years later by Davies (1885). A memoir on the coalfield was published by the Geological Survey (Pocock *et al.*, 1938). Otherwise, however, the only geological work seems to have been part of studies on the Etruria Formation, by Robertson (1931) and Besly (1983, 1988).

Coalbrookdale Coalfield

The Productive Coal Formation is more extensively developed here than in the Shrewsbury Coalfield, and so the area received rather more attention from geologists. The earliest accounts were by Aiken (1811), Murchison (1839) and Prestwich (1840), who provide general descriptions of the stratigraphy. The so-called 'Symon Fault' (in fact, an unconformity below the Halesowen Formation) was described by Scott (1861) and Clarke (1901), whilst Woodward (1867) described a limulid arthropod from a lower Westphalian horizon. However, the economically viable seams had been worked out by the end of the 19th century and, as natural exposure is limited, interest from geologists waned. A general description was provided by Watts (1925) as an introduction to a Geologists' Association excursion to the area, but otherwise investigations have been mainly restricted to the Etruria Formation, where workings for brick-clays provided some exposure (Robertson, 1931; Besly, 1983, 1988).

Wyre Forest

The earliest account of the Upper Carboniferous geology of this area is by England (1834), but this was soon over-shadowed by Murchison's (1839)

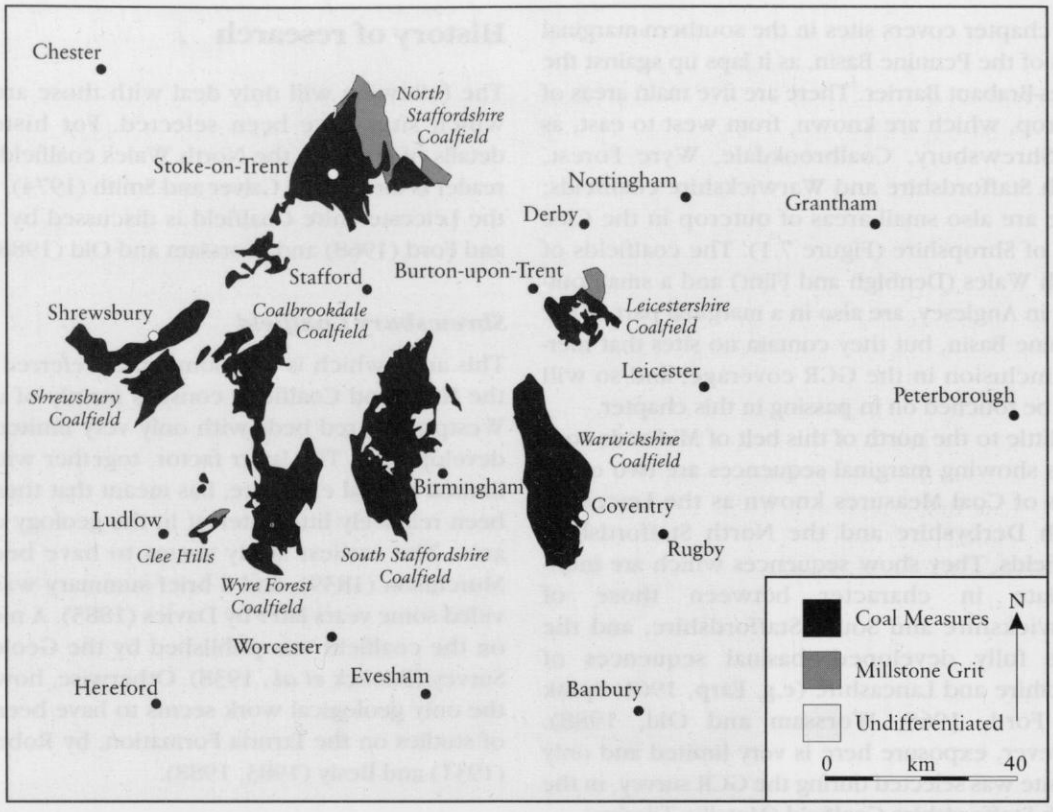

Figure 7.1 Upper Carboniferous outcrops in the English Midlands and northern Welsh Borders. Based on Hains and Horton (1969, pl. II), and Earp and Hains (1971, fig. 2).

now classic account of the Palaeozoic of the English Midlands. There followed numerous papers dealing with this area, but those of two people, both amateurs for at least part of the time, are worth special mention (a full list is provided by Arber (1914) and Kidston *et al.* (1917)). G.E. Roberts, perhaps better known for his work on the Old Red Sandstone of this area, published a number of short contributions on fossils from the Wyre Forest Coalfield (Roberts, 1858, 1860, 1861a, 1861b), whilst Thomas Cantrill worked on the stratigraphy of the coalfield (Cantrill, 1895). Also of considerable significance was a borehole drilled near Claverley by the Geological Survey, which provided an almost complete sequence through the Upper Carboniferous of this area (Gibson, 1913).

This work culminated in the second decade of the 20th century. At this time, two projects analysing the plant fossils from here were instigated by Arber and Kidston. The problem they encountered was the absence of a Geological Survey memoir on the area to provide a stratigraphical background to their work, and so they themselves provided detailed accounts of the geology (Arber, 1914; Kidston *et al.*, 1917).

Thereafter, interest in the geology of the area declined. The long-awaited Survey Memoir was published (Whitehead and Pocock, 1947), and it is mentioned in some more general accounts, such as Robertson's (1931) study of the Etruria Formation. Otherwise, however, little of note has been published. The reason for this is far from clear; coal was still being extracted from at least one colliery up until the 1960s, and there is a certain amount of natural outcrop, although no GCR site has been selected. There is certainly considerable potential for further work here.

Clee Hills

Although only of small extent, and never providing coal in any quantity, the Upper Carboniferous outcrops of Titterstone Clee and Brown Clee have been the subject of a number of geological studies. They are referred to briefly by Murchison (1839), and described in more detail in his classic 1839 book *The Silurian System*. Other brief accounts are provided by Jones (1871, 1873) and Piper (1884). The most detailed account is probably that of Dixon *in* Kidston *et al.* (1917), whilst some of the outcrops are admirably described in a Geological Survey memoir (Greig *et al.*, 1968).

Jones and Owen (1961) provide a detailed discussion on the lower beds and their relationship to the underlying strata. The palynology of some of the deposits has been discussed by Turner and Spinner (1990) and Turner and Owens (1993).

South Staffordshire Coalfield

This has yielded considerable quantities of iron-ore and coal, and resulted in the development of the Birmingham-Wolverhampton area as a major industrial centre. However, there was relatively little interest in the coalfield among early geologists, the only published accounts of interest being of *in situ* tree stumps (Beckett, 1845; Dawes, 1845; Ick, 1845). The first coherent account did not appear until the publication of the Geological Survey memoir (Jukes, 1859). Later memoirs (Whitehead and Eastwood, 1927; Mitchell *et al.*, 1945; Whitehead and Pocock, 1947) provide a comprehensive guide to the geology of the coalfield and its outcrops. Otherwise, the only studies of note were by Kidston (1888b, 1914) and Arber (1916) on the plant fossils and their biostratigraphical significance.

Warwickshire Coalfield

A number of early works deal with the red beds in the upper part of the coalfield (e.g. Conybeare and Phillips, 1822). These strata were assigned to the New Red Sandstone and thought to be Triassic in age, but they were subsequently assigned to the Permian (Ramsay, 1855; Howell, 1859). The age of these beds remains problematic. Some authors suggest they are mid-Stephanian to Autunian (e.g. Haubold and Sarjeant, 1973). However, Crookall *in* Mitchell *et al.* (1942) argued that there was no unequivocal evidence that they are younger than Westphalian D, and this is the position still generally held today.

The geology of the productive part of this coalfield attracted relatively little attention, beyond the publication of survey memoirs (Howell, 1859; Mitchell *et al.*, 1942), together with an important paper by Vernon (1912). Most recent data are reviewed by Fulton and Williams (1988), Old *et al.* (1987, 1991) and Worssman and Old (1988).

North Staffordshire Coalfield

Geological interest in this coalfield has a venerable history, going back to Plott (1686), who first delineated the main divisions of the Carboniferous of the area, including the 'Coal-measures' and the 'Gritstone' (i.e. Millstone Grit). More detailed and 'modern' accounts followed some time later by Conybeare and Phillips (1822). The Geological Survey took an early interest in the coalfield, producing a number of maps, and eventually memoirs (Gibson, 1905, 1925), which provided a firm lithostratigraphical framework for subsequent work. Recently, the Survey have produced an additional memoir relevant to the area (Evans *et al.*, 1968), and also a report on borehole investigations (Earp, 1961).

Based on observations in North Staffordshire, Stobbs (1905a) provided one of the first detailed analyses of marine band biostratigraphy in this country. On the whole, however, the marine bands are not as well developed here as in the more basinal sequences further north (see Chapter 10). This necessitated the development of alternative biostratigraphical tools in the Potteries, and seems to have generally encouraged work on other groups of fossils. The early work, particularly on fossil fish, is summarized by Ward (1890). Subsequently, interest concentrated mainly on non-marine bivalves (e.g. Hind, 1893; Hind and Stobbs, 1903; Stobbs, 1906; Melville, 1945), plants (Kidston, 1891, 1897, 1905; Dix, 1931b) and palynology (Millott, 1939, 1946; see Smith and Butterworth (1967) for a review of the subsequent palynological studies in this coalfield). Of particular interest is the role that North Staffordshire played in the development of Kidston's (1923) stratigraphical classification, with many of the units (essentially equivalent to stages) being named after formations here (e.g. Blackband 'Group', Newcastle-under-Lyme 'Group', Keele 'Group'). Although Kidston's scheme has now fallen into disuse, being replaced by the Heerlen Classification, for many years it was the standard classification for British Coal Measures strata.

Lithostratigraphy

The marginal sequences dealt with in this chapter differ from those of the central parts of the Pennine Basin in two main ways. Firstly, for the most part the Millstone Grit Group is poorly developed. In most areas immediately adjacent to the Wales-Brabant Barrier (e.g. the southern parts of the South Staffordshire Coalfield – see Brewin's Canal Cutting), Westphalian strata lie unconformably on Lower Carboniferous or older beds. About 10 km further north, condensed Millstone Grit sequences have been proved in boreholes (Mitchell, 1954; Taylor and Rushton, 1971), and only when north Staffordshire and south Nottinghamshire are

reached can fully basinal sequences be seen (Falcon and Kent, 1960; Trewin and Holdsworth, 1973).

Secondly, red beds occur more commonly and the Productive Coal Formation is correspondingly restricted. Such beds are often barren of fossils, which has caused problems of correlation, and thus of establishing a coherent stratigraphical classification. Recent work (Besly, 1988; Besly and Turner, 1983) is starting to unravel the problems, but much of the results are as yet unpublished. Consequently, the following classification is only provisional, and will need to be revised in the light of new work.

Millstone Grit Group (not subdivided into formations)

Cornbrook Sandstone Formation
- Stratotype: Cornbrook Dingle
- Base defined: base of Upper Carboniferous in Clee Hills.
- Characteristic facies: massive, pebbly sandstone, sometimes stained red.
- Chronostratigraphical range: Duckmantian.

Productive Coal Formation
- Defined in South Wales (see Chapter 4)

Blackband Formation
- Stratotype: North Staffordshire Coalfield
- Base defined: the coal seam known as the Bassey Mine.
- Characteristic facies: grey or very rarely red mudstones, with coals, carbonaceous clay-ironstones, and non-marine limestones.
- Chronostratigraphical range: upper Bolsovian.

Etruria Formation
- Stratotype: North Staffordshire Coalfield
- Synonyms: Hadley Formation (Shrewsbury Coalfield), Old Hill Marls (South Staffordshire Coalfield).
- Base defined: the lowest primary red beds in the Langsettian to Bolsovian interval; the formation is often transitional with the Productive Coal Formation.
- Characteristic facies: red mudstones, with fluvial-channel sandstones and alluvial-fan conglomerates; the mudstones frequently show evidence of palaeosols.
- Chronostratigraphical range: Langsettian to Duckmantian in the south of the area, changing gradationally to Bolsovian and Westphalian D in the north.

The overlying strata have been traditionally assigned to five formations (Halesowen, Newcastle, Keele, and Enville Beds, and the Clent Conglomerates), but this scheme is currently being reviewed by B. Besly.

Geological setting

The Late Carboniferous geological evolution of this area is summarized by Besly (1988) and Fulton and Williams (1988). Being near the margins of the Pennine Basin, the Wales-Brabant Barrier caused a significant reduction in subsidence rates. At times between the late Namurian and Bolsovian, subsidence was enough to allow a condensed sequence of Productive Coal Formation to develop. More often, however, the reduced subsidence caused emergent conditions with a lower water-table. This resulted in the development of red mudstones with frequent palaeosols but few coals, known as the Etruria Formation. In areas adjacent to uplifting parts of the Wales-Brabant Barrier, (e.g. Northeast Shropshire and West Warwickshire blocks) proximal alluvial fan deposits occur. In all cases, the sediment seems to have been derived from the south.

In the middle Westphalian D, there appears to have been some tectonic activity and, as a consequence, the Etruria Formation is overlain unconformably by upper Westphalian D and possibly lower Stephanian strata. This unconformity is referred to locally in the Coalbrookdale Coalfield as the Symon 'Fault'. The beds above the unconformity have been assigned to a variety of lithostratigraphical units (e.g. Halesowen Beds, Keele Beds). As pointed out in the previous section, however, their inter-relationships are far from clear and it is impossible at present to establish a detailed geological history. The only point which now seems evident is that the beds immediately overlying the unconformity were derived from two discrete sources: from the south, which produced the 'Pennant-like' sandstones known as the Halesowen Beds; and from the north, which produced the red sandstones known as the Keele Beds. The timing of this tectonic activity, and the petrography and provenance of the Halesowen Beds, suggests strongly a link with developments in southern Britain that resulted in the development of the Forest of Dean Coalfield and the unconformity in the eastern part of the South Wales Coalfield. These developments in southern Britain have in turn been correlated with the

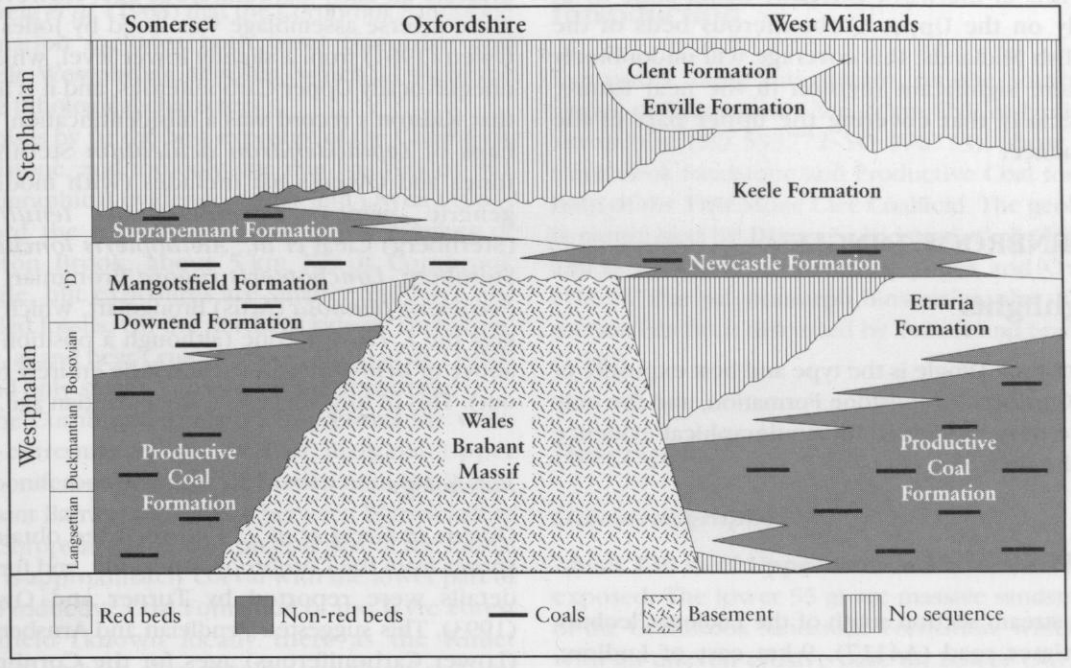

Figure 7.2 Relationship of Upper Carboniferous lithostratigraphical units in the English Midlands. Based on Besly (1988, fig. 15.2).

Leonian phase of tectonic activity, which has been identified over large areas of Europe (see Chapters 4 and 5).

GCR site coverage

This has attempted to show the main facies of the Westphalian formations in this part of the Pennine Basin; unfortunately, no suitable sites showing the condensed Namurian sequences were identified. The GCR site coverage may be summarized as follows:

1. Cornbrook Sandstone Formation
   (a) Cornbrook Dingle (type section)
   (b) Benson's Brook (basal unconformity and relationship with Productive Coal Formation)
2. Productive Coal Formation
   (a) Benson's Brook (development of formation in Clee Hills, and its relationship with the Cornbrook Sandstone Formation)
   (b) Brewin's Canal Cutting (basal part of formation in South Staffordshire Coalfield)
   (c) Doulton's Claypit (middle part of formation in South Staffordshire Coalfield)
   (d) Eyemore Railway Cutting (Aegiranum Marine Band in Wyre Forest)
3. Etruria Formation
   (a) Ketley Claypit (alluvial plain facies)
   (b) New Hadley Brickworks (alluvial fan facies)
4. 'Halesowen and Newcastle Beds'
   (a) Halesowen Road Cutting (best exposure of Halesowen Beds in type area)
   (b) Kingsbury Brickworks (best exposure of unconformity between Halesowen and Etruria formations)
   (c) Metallic Tileries (best exposure of unconformity between Newcastle and Etruria formations)
5. 'Keele Beds'
   (a) Cheswardine Canal Cutting (the formation near its type area)
   (b) Alveley Grindstone Quarry (Alveley Grindstone facies)
6. 'Enville Beds'
   (a) Gospel End Cutting (alluvial fan association)
   (b) Webster's Claypit (ephemeral fluvial association)

In view of the work currently being done by B. Besly on the Upper Carboniferous beds of the English Midlands, this coverage will undoubtedly require significant revision in the near future, especially that covering the upper part of the sequence.

CORNBROOK DINGLE

Highlights

Cornbrook Dingle is the type and best exposure of the Cornbrook Sandstone Formation, and the only place to have yielded biostratigraphical evidence for the unit.

Introduction

This stream section south of the Ludlow-Cleobury Mortimer road (A4117), 9 km east of Ludlow, Shropshire (SO 602758–SO 604755) is the type section for the Cornbrook Sandstone Formation in the Titterstone Clee Coalfield. The geology is mentioned by Dixon *in* Kidston *et al.* (1917), and a more complete account provided by Jones and Owen (1961).

Description

Lithostratigraphy

According to Dixon *in* Kidston *et al.* (1917), the Cornbrook Sandstone here is about 300 m thick, but Jones and Owen (1961) claimed that this was an over-estimate due to repetition of the sequence by faulting and that it was probably nearer to 215 m. The sequence is thought to lie unconformably on Lower Carboniferous limestones, although the exposed contact is faulted. The formation consists mainly of thick, pebbly sandstones, some of which are stained red, orange or brown. There are also clay bands, which according to Jones and Owen are often seat earths with thin coals, but exposure of these emergent layers is poor.

Biostratigraphy

Plant fossils

Kidston *in* Kidston *et al.* (1917) recorded *Lepidodendron veltheimianum* Sternberg from near the top of the formation, which seemed to indicate an Early Carboniferous age. However, a more diverse assemblage was listed by Jones and Owen (1961) from a slightly lower level, which is unequivocally Upper Carboniferous, and it is likely that Kidston's record was a misidentification, perhaps of *Lepidodendron aculeatum* Sternberg. Jones and Owen's list includes (with modified generic names) *Laveineopteris tenuifolia* (Sternberg) Cleal *et al.*, *Alethopteris lonchitica* Sternberg, *Lonchopteris rugosa* Brongniart and *Pecopteris plumosa* (Artis) Brongniart, which suggest the *L. rugosa* Zone (although a position just above or below that zone cannot be entirely ruled out). This in turn suggests a Duckmantian age.

Palynology

Owens *in* Greig *et al.* (1968) reported obtaining spores from the Cornbrook Sandstone, and further details were reported by Turner and Owens (1993). This suggested Pendleian and Arnsbergian (Lower Carboniferous) ages for the Cornbrook Sandstone, in obvious conflict with the macropalaeobotanical evidence mentioned above.

Interpretation

The Cornbrook Sandstone was referred to by early authors as the Millstone Grit of this area (Prestwich, 1840; Jones, 1871). Dixon's downwards revision of the age, based on the erroneous palaeobotanical evidence, appeared to support the ideas put forward by Vaughan (1905), that the Cornbrook Sandstone was a lateral equivalent of the Drybrook Sandstone of the Forest of Dean. As pointed out by George (1956), however, this does not agree with the field evidence, as there is a clear unconformity between the Cornbrook Sandstone and the Lower Carboniferous limestones. George reverted to the original view that it was Millstone Grit (i.e. Namurian). The most recent biostratigraphical evidence has produced conflicting ages, a middle Westphalian, probably Duckmantian age from the plant macrofossils (Jones and Owen, 1961) and a basal Namurian (Pendleian-Arnsbergian) from the palynomorphs (Turner and Owens, 1993). Turner and Owens dismiss the macropalaeobotanical evidence as having originated probably from sandstones overlying the true Cornbrook Sandstone. However, the lithostratigraphical argument for this is not clearly presented. It is perhaps more reasonable to accept the view

of Greig *et al.* (1968) that the Cornbrook Sandstone Formation includes both basal Namurian and middle Westphalian deposits, which all share the same lithological characters.

This is by far the best exposure of the Cornbrook Sandstone, and the only one that has yielded biostratigraphical evidence. Jones and Owen (1961) record the formation in the upper reaches of Hopton Brook, about 5 km NE of Cornbrook Dingle, but exposures are smaller and have not yielded fossils. On the northern side of Titterstone Clee, at and near Crumps Brook, Greig *et al.* (1968) found only small exposures of this formation.

The Cornbrook Sandstone represents the western extremity of the belt of marginal Upper Carboniferous deposits, that onlap onto the Wales-Brabant Barrier, and extend between Warwickshire and Shropshire. The Westphalian part of the formation is approximately coeval with the lower part of the Productive Coal Formation of the Wyre Forest Coalfield (known locally there as the Kinlet Group), which also consists mainly of red and brown sandstones. However, it is slightly younger than the lowest beds of the South Staffordshire Coalfield, such as seen at Doulton's Claypit (upper Langsettian), which in turn is younger than the base of the Warwickshire Coalfield (lower Langsettian - Ramsbottom *et al.*, 1978). The reason for this apparent westerly younging of the base of the Upper Carboniferous along the northern margins of the Wales-Brabant Barrier is at present unclear.

Conclusions

Cornbrook Dingle is the most important locality for rocks of the Cornbrook Sandstone Formation, the upper part of which is nearly 312 million years old. It is the only place where fossils have been found in these rocks, allowing their stratigraphical age to be accurately determined.

BENSON'S BROOK

Highlights

Benson's Brook is the only good exposure of the Productive Coal Formation in the Titterstone Clee Coalfield, and provides important information concerning the northern margins of the Wales-Brabant Barrier.

Introduction

Exposures along this stream, on the southern slopes of Titterstone Clee, 8 km ENE of Ludlow, Shropshire (SO 593772-SO 596773), show the Cornbrook Sandstone and Productive Coal formations of the Titterstone Clee Coalfield. The geology is mentioned by Dixon *in* Kidston *et al.* (1917), and is described in detail by Jones and Owen (1961). The palynomorph biostratigraphy of the section has been discussed by Turner and Spinner (1990).

Description

Lithostratigraphy

About 130 m of Upper Carboniferous strata are exposed. The lower 55 m are massive sandstones of the Cornbrook Sandstone Formation, which lie with an uneven erosive base on Lower Old Red Sandstone. The basal beds are thick conglomerates, but the formation fines upwards into pebbly yellow sandstones. Palaeocurrent directions suggest that the sediments were derived from the WNW.

Above the Cornbrook Sandstone are beds of the Productive Coal Formation. The contact between the formations was described by Dixon *in* Kidston *et al.* (1917) as unconformable, but Jones and Owen (1961) argued that the apparent angular discordance was due to faulting. The 75 m of Productive Coal Formation consists mainly of thick seat earths and 'espley' type sandstones, i.e. lenticular bodies of coarse green or white sandstones with conglomerate bands (Hains and Horton, 1969), although there is also a grey mudstone with ironstone nodules. There are a number of coaly smuts, and near the eastern end of the site are the remains of a bell-pit which used to work the Great Coal, although the seam does not crop out in the stream.

Biostratigraphy

The only biostratigraphical evidence found here are plant macrofossils and palynomorphs. From the mudstone with ironstone nodules in the lower part of the Productive Coal Formation, Jones and Owen (1961) record *Neuropteris gigantea* Sternberg and *Cyclopteris* sp. The former species, which in fact belongs to the form-genus *Paripteris*, occurs mainly in the Langsettian and Duckmantian. However, it is frequently confused with *Paripteris pseudogigantea* (Potonié) Laveine, which does not

occur below the Duckmantian. The material in question clearly needs to be revised.

From just below the Great Seam, near the top of the section, Jones and Owen list a more diverse assemblage, including *Sphenophyllum myriophyllum* Crépin, *Fortopteris latifolia* (Brongniart) Boersma and *Neuropteris* cf. *subplicata* Kidston (probably a synonym of the better documented *Neuropteris chalardii* Laveine). Particularly if the identity of the neuropterid were confirmed, the assemblage strongly points to the lower *Paripteris linguaefolia* Zone, indicative of the lower Bolsovian (or very possibly topmost Duckmantian).

Turner and Spinner (1990) have reported palynomorph assemblages of both Langsettian and early Duckmantian age.

Interpretation

This is the only good exposure of the Productive Coal Formation in the Titterstone Clee Coalfield. The presence of Upper Carboniferous strata in the Clee Hills, which Dixon *in* Kidston *et al.* (1917) claimed to be over 400 m thick, has been used as evidence of the existence in the early Westphalian of the Herefordshire Straits – a narrow area of deposition crossing the Wales-Brabant Barrier (Wills, 1956). However, Dixon has probably overestimated the thickness of these strata. For instance, he claimed that there is 531 feet (162 m) between the thick sandstones and conglomerates, which probably belong to the Cornbrook Sandstone, and the Great Coal. At Benson's Brook, however, this interval is only 75 m thick; thicknesses of a similar order also occur on the northern side of Titterstone Clee (Greig *et al.*, 1967). Dixon also claimed that 750 feet (229 m) of 'Coal Measures' overlay the Great Coal, but it is far from clear on what evidence he based this. If instead, the 130 m of Cornbrook Sandstone and Productive Coal formations, as seen at Benson's Brook, is taken as nearer to the true thickness for the coalfield, then there is no great discrepancy from what is seen in the nearby Wyre Forest Coalfield (Whitehead and Pocock, 1947). Although there is evidence of a Herefordshire Straits in the very late Westphalian (Cleal, 1987), its existence prior to this is unlikely.

This site also provides important exposures of the Cornbrook Sandstone. Unlike Cornbrook Dingle, no fossils have been found here. However, it clearly shows the erosive base of the formation, and sedimentary structures allow palaeocurrent directions to be determined.

Conclusions

Benson's Brook is the only good exposure of rocks of the Productive Coal Formation in the Titterstone Clee Coalfield. These rocks are about 310 million years old, and represent the deposits formed near the southern edge of the area of deposition known as the Pennine Basin. They are thus much thinner than successions of similar age found further north in the Yorkshire and Lancashire coalfields.

EYEMORE RAILWAY CUTTING

Highlights

Eyemore Railway Cutting (Figure 7.3) shows the only marine band known from the Wyre Forest Coalfield, and provides important evidence for the palaeogeography of this part of Britain during the Westphalian.

Introduction

A cutting (SO 767792) on the Severn Valley Railway Line, about 1 km south of Arley station, Hereford and Worcester, provides the only known exposure of the Aegiranum Marine Band in the Wyre Forest Coalfield. Part of the exposure has been covered by brick facing, to prevent collapse of the cutting, but enough remains visible to establish the stratigraphical sequence. The site was first described by Whitehead and Pocock (1947) and further details were supplied by Poole (1966).

Description

Lithostratigraphy

A log of the sequence is given by Whitehead and Pocock (1947, pp. 54–5). The sequence now exposed consists of 3.2 m of sandstones overlain by about 2.4 m of shales and siltstones. The marine band, which is 30 cm thick, occurs about 1.5 m above the top of the sandstones. Whitehead and Pocock mention a further 10 m of sandstones and coloured mudstones at the top of the sequence, but these are no longer exposed.

The mudstones associated with the marine band are purple, red and brown, and are of the Etruria facies. This can be just about made out in the railway cutting, but was more clearly demonstrated by

Figure 7.3 Eyemore Railway Cutting GCR site. Exposures are above the protective casing at the far end of the cutting as shown in the photograph. (Photo: C.J. Cleal.)

Poole (1966) in nearby boreholes. Whitehead and Pocock assigned all of the lower and middle Westphalian strata to the Kinlet Group. As pointed out by Besly (1983), however, this classification does not reflect the true nature of the sequence in the Wyre Forest. In the northern part of the coalfield, most of the sequence consists of red beds, of the type referred to elsewhere as the Etruria Formation. The only exception is a *c.* 20 m thick grey interval (Productive Coal Formation) associated with the Highley-Brooch, Half Yard, Four Foot and Two Foot seams (cf. Besly and Turner, 1983, fig. 2). In the south, such as at Eyemore, even this thin Productive Coal Formation disappears, and the entire lower and middle Westphalian belongs to the Etruria Formation.

Biostratigraphy

The marine band here has yielded the ammonoid *Donetzoceras* cf. *aegiranum* (Schmidt), together with brachiopods *Lingula* and *Levipustula*. The marine band was given the local name of the Eyemore Marine Band by Mitchell *in* Trueman (1954), but the fossils clearly indicate that it is the Aegiranum Marine Band in the standard classification of Ramsbottom *et al.* (1978) (Figure 7.4). From the same bed found in nearby boreholes (Eyemore Farm Nos 7 and 14 boreholes), Calver *in* Poole (1966) reported diverse assemblages of calcareous brachiopods, including *Crurithyris*, *Levipustula*, *Linoproductus*, *Productus*, *Rhipidomella*, *Rugosochonetes* and *Schuchertella* (see also Calver, 1968, p. 51).

Interpretation

This is the only well-developed marine band identified so far in the Wyre Forest Coalfield, and thus the only level in the sequence where a stage boundary can be unequivocally fixed (i.e. between the Duckmantian and Bolsovian stages). There are records of the Vanderbeckei Marine Band in boreholes at Kinlet and Alveley (Stubblefield *in* Whitehead and Pocock, 1947; Poole, 1970) but only very restricted fossil assemblages have been found. The poor or non- development of marine bands other than the Aegiranum in the Wyre Forest is probably a consequence of its marginal position in the Pennine Basin. It confirms that the Aegiranum Marine Band represents the most widespread of the marine transgressions in the middle Westphalian, and why it was selected to define the boundary between the Duckmantian and Bolsovian stages.

The most characteristic feature of the Aegiranum Marine Band in the Wyre Forest is the diversity of the calcareous brachiopods. Calver (1968) has observed that similar assemblages are also typical of the Vanderbeckei and Haughton marine bands near the northern margins of the Wales-Brabant Barrier. This, he suggested, reflects the repetition of comparable conditions and facies in each of these transgressions.

Calver *in* Poole (1966) also noted that a similar, brachiopod-rich assemblage has been described from the Aegiranum Marine Band of South Wales (Ramsbottom, 1952). This provides possible

Figure 7.4 The Aegiranum Marine Band (Duckmantian–Bolsovian boundary) exposed on the Severn Valley Railway Line at Eyemore. (Photo: C.J. Cleal.)

support for the Herefordshire Straits hypothesis of Wills (1956), in which a narrow channel linked the South Wales and Pennine basins across the Wales-Brabant Barrier, thus allowing the migration of the brachiopod faunas. As pointed out by Bless and Winkler Prins (1972), however, the distribution of the 'microfaunas' (i.e. conodonts, foraminifera, ostracods) does not support this idea, nor is there any direct geological evidence for it (see discussion on Benson's Brook).

Conclusions

Eyemore Railway Cutting is the only place in the Wyre Forest Coalfield where marine rocks can be seen. These rocks are about 311 million years old, and were formed when the area was flooded by a raising of the sea level, possibly due to a partial melting of the polar ice cap.

BREWIN'S CANAL CUTTING

Highlights

Brewin's Canal Cutting is the best exposure of the unconformable base of the Productive Coal Formation in the southern part of the South Staffordshire Coalfield, and helps demonstrate the onlap of the Upper Carboniferous of the Pennine Basin onto the Wales-Brabant Barrier.

Introduction

A cutting (SO 937877) on the south side of the Dudley Canal, just east of High (or Brewin's) Bridge, Brierley Hill, West Midlands shows the lowest preserved Carboniferous strata in the southern part of the South Staffordshire Coalfield. The outcrop is described by Whitehead and Eastwood (1927), Hardie *in* Hardie *et al.* (1971) and Cutler (1981). Whitehead and Pocock (1947, pp. 18-20, pl. 3 fig. A) provide a drawing of the exposure and a detailed lithostratigraphical log. The site forms part of the Saltwells Local Nature Reserve, established by the Black Country Geological Society, in conjunction with the former NCC (West Midlands Region).

Description

Most of the strata exposed here are Upper Silurian shales and sandstones of the Temeside Shales and

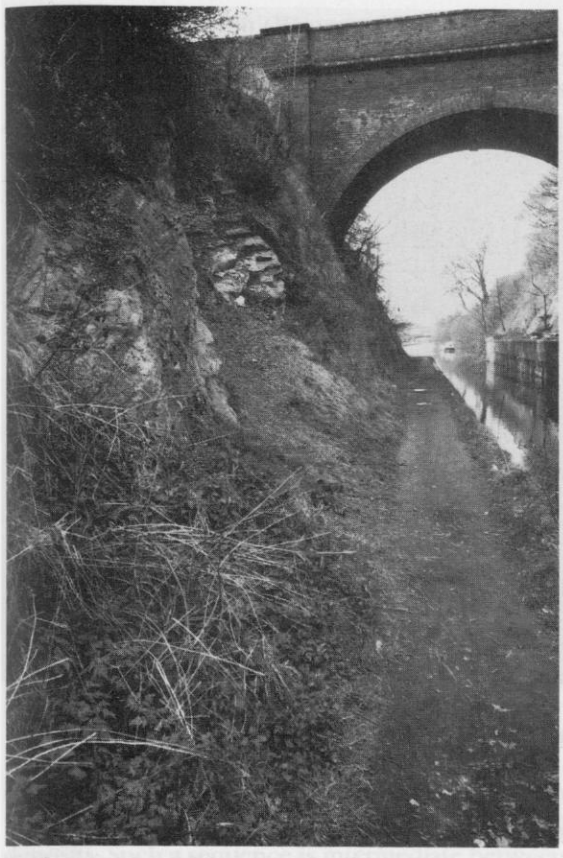

Figure 7.5 Base of the Coal Measures lying unconformably on Upper Silurian beds at Brewin's Canal Cutting. (Photo: C.J. Cleal.)

Red Downton formations. Overlying these beds with a low angle unconformity are 4 m of buff-yellow sandstone, the upper part of which becomes conglomeratic. They represent the basal part of the Productive Coal Formation in this part of the coalfield (Figure 7.5). Structural complications make it difficult to establish an exact lithostratigraphical position for these beds, but they probably lie not far below the New Mine Coal.

Interpretation

This site shows the unconformity between the Productive Coal Formation and the underlying strata in the southern part of this coalfield. The absence of Namurian and basal Westphalian strata is particularly significant. In the northern part of the coalfield, boreholes have proved thin Millstone Grit sequences underlying the Productive Coal Formation – reportedly 60 m thick near Lichfield and 23 m near Rugeley (Mitchell, 1954; Stevenson and Mitchell, 1955) although these sequences may have suffered from faulting (N.J. Riley, pers. comm.). Underlying the North Staffordshire Coalfield, only about 25 km further north, there is 1250 m of Millstone Grit. This clearly demonstrates the onlap relationship of the Upper Carboniferous of the Pennine Basin onto the Wales-Brabant Barrier. A similar relationship can also be seen a little to the east, in the Warwickshire Coalfield, but this is based exclusively on evidence from boreholes and underground workings (Fulton and Williams, 1988).

Whitehead and Eastwood (1927) mention a number of other exposures of this unconformity, perhaps most significantly the Hayes Road Cutting at Lye, which until recently was designated an SSSI. However, Brewin's Canal Cutting is by far the best exposed and easily accessed of these sites.

Conclusions

Brewin's Canal Cutting shows the relationship between the Productive Coal Formation in the southern part of the South Staffordshire Coalfield (310 million years old), and the underlying older rocks. This is important for understanding the evolution of this part of the Pennine Basin at this time.

DOULTON'S CLAYPIT

Highlights

Doulton's Claypit provides the best exposure of lower Westphalian coal-bearing strata in the southern-marginal part of the Pennine Basin. It clearly shows a typical marginal-type facies representing continuous emergent conditions (Figure 7.6).

Introduction

This exposure (SO 936871) near Lodge Farm Reservoir, Brierley Hill, West Midlands is the remains of a disused quarry in the southern part of the South Staffordshire Coalfield. It is part of what used to be called the Saltwells Clay-field, which was worked for the extensive fireclays developed in this part of the coalfield, and here used for the production of sanitary ware. The geology of the pit, when it was still being worked, was summarized by Whitehead and Eastwood (1927). By the late 1940s, the clays were worked out here and the pit abandoned. However, unlike so many of such disused workings in this part of the Midlands, it was

Figure 7.6 Lower Westphalian rocks exposed at the now disused Doulton's Claypit, Brierley Hill. (Photo: C.J. Cleal.)

not reclaimed and built on. Instead, it became incorporated into the Saltwells Local Nature Reserve, established to preserve the wildlife habitat that had developed there, as well as conserving part of the geological exposure. The geology of the nature reserve is summarized by Cutler (1981).

Description

Lithostratigraphy

It is impossible to establish a coherent sequence from the available exposures, due to tectonic disturbance and weathering, but there are probably about 150 m of strata represented. The bulk of the sequence consists of grey palaeosols, some iron-rich mudstones, and cross-bedded sandstones. Three coals can still be seen in ascending stratigraphical order, the New Mine, Stinking and Lower Heathen seams. None of these were thick enough to justify commercial working. However, in the eastern part of the quarry, burnt shales mark the position of the commercially important South Staffordshire Thick Coal, which was about 10 m thick.

Biostratigraphy

Marine bands

Elsewhere in the coalfield, a marine band occurs just above the Stinking Seam, and hence is known locally as the Stinking Marine Band. This is generally identified with the Vanderbeckei Marine Band, and thus marks the Langsettian-Duckmantian stage boundary.

Plant macrofossils

Kidston (1914) described the plant fossils from several horizons in this claypit, as originally exposed. The most diverse assemblages were associated with the Bottom and Fireclay coals, not now exposed. From the roof of the New Mine Coal, he listed *Neuropteris heterophylla* Brongniart (probably a misidentification of *Laveineopteris loshii* (Brongniart) Cleal *et al.* - see comments by Cleal and Shute, 1991), *Mariopteris muricata* (Brongniart) Zeiller, *Eusphenopteris obtusiloba* (Brongniart) Novik and *Sigillaria elegans* Brongniart. A specimen identified by Kidston as *Alethopteris integra* (Gothan) Kidston was figured by Crookall (1955, pl. 5 fig. 3), but it is a lobing fragment of a frond, which is virtually impossible

to identify in isolation (Wagner, 1968). However, the rest of the assemblage can be assigned to the *Laveineopteris loshii* Subzone (upper *Lyginopteris hoeninghausii* Zone), and is thus indicative of the upper Langsettian.

The only fossils recorded by Kidston from the exposed part of the sequence here are from just below the Thick Coal. He identified them as *N. heterophylla* (again, probably a misidentification of *L. loshii*) and the fructification *Whittleseya elegans* Newberry, from the Ten-foot Ironstone. This assemblage is not biostratigraphically diagnostic.

Interpretation

This is the only remaining exposure of coal-bearing strata in the southern part of the South Staffordshire Coalfield. It demonstrates the characteristic sedimentology in this marginal part of the Pennine Basin in the upper Langsettian and Duckmantian, which is referred to by Besly (1988) as the Alluvial Coal-Bearing Facies Association. According to Besly, this association represents deposition in continuously emergent conditions, allowing the extensive development of swamp soils, while the sandstones are fluvial channel deposits. Such a sequence is intermediate between typical Productive Coal Formation and the more consistently red deposits of the Etruria Formation; however, as grey strata seem to predominate (at least here) they are probably best assigned to the Productive Coal Formation.

Another feature of this type of basin-margin deposit is that each of the coal seams divides into more than one seam in the more central parts of the basin. Of the seams still represented at Doulton's Claypit, the New Mine divides into the Yard and Bass coals in the northern part of the coalfield, the Heathen divides into an upper and a lower seam, and the Thick Coal divides into the Park, Eight Feet and Benches coals (Hains and Horton, 1969).

Extensive ironstone development is associated with this type of sedimentary regime. This had important consequences for the industrial development of this part of the English Midlands, since it provided the combination of fuel (coal) and raw material (iron ore) that was necessary for the development of this area.

Conclusions

Doulton's Claypit is the best exposure of rocks of early Westphalian age (310 million years old) in the southern-marginal part of the Pennine Basin. It clearly shows features that are typcial of such rocks formed in a marginal setting, characterized by a slow rate of sedimentation, and where flooding was a relatively rare event.

KETLEY CLAYPIT

Highlights

Ketley Claypit shows one of the best exposures of red beds of the Upper Carboniferous Etruria Formation (Figure 7.7).

Figure 7.7 Etruria Formation exposed at Ketley Claypit. (Photo: C.J. Cleal.)

Introduction

This claypit (SO 897887) east of Standhills Road, between Kingswinford and Bromley, Staffordshire, shows a large exposure of Etruria Formation in the South Staffordshire Coalfield. It is part of a quarry which is still intermittently active, and the extent of the exposure depends on how recently it was worked. At its best, however, it is the most extensive available exposure of this formation. The site was briefly described by Whitehead and Eastwood (1927), and a fuller account given in an unpublished thesis by Besly (1983).

Description

The main face at this claypit shows a thick sequence of red and purple mudstones, with occasional beds of sandstone. They represent the upper part of the Etruria Formation, and are overlain at the top of the face by sandstones of the Halesowen Formation.

Interpretation

The Etruria Formation is an interval of red beds in the English Midlands, that occurs between the Productive Coal and Halesowen formations. Biostratigraphical control on the interval is extremely poor, but it seems to be diachronous, becoming younger away from the Wales-Brabant Barrier (Besly, 1983, 1988; Besly and Turner, 1983). There seem to be two main facies-associations in the formation, which Besly refers to as alluvial plain and alluvial fan associations; the Ketley sequence represents the former, whilst New Hadley Brickworks represents the latter. The alluvial plain association consists mainly of fluvial channel, overbank and crevasse-splay deposits, and thus does not differ significantly from deposits of the Productive Coal Formation, except in being red and having a greater development of palaeosols.

The mechanism for generating the red coloration has been a matter of some dispute, but Besly has shown that it was produced during and immediately after deposition of the sediment. It seems to reflect substraits that were better drained than present during the formation of the grey Productive Coal Formation, which in turn reflects reduced rates of subsidence; this is also supported by the increased abundance of palaeosols. The reduction in subsidence rates probably reflects the stabilizing effect of the Wales-Brabant Barrier, and possibly some topographic changes produced by Variscan tectonics. There is no support for the view that the red Etruria Formation reflects climatic aridification (e.g. Hedemann and Teichmüller, 1971; Bless *et al.*, 1984).

Conclusions

Ketley Quarry shows one of the best exposures of red beds of the Upper Carboniferous Etruria Formation, about 310 million years old. The red coloration was probably a product of a relatively low water-table at that time, reflecting the marginal position of these sediments in the Pennine depositional basin.

NEW HADLEY BRICKWORKS

Highlights

New Hadley Brickworks is the best available site for showing the Etruria Formation in a high-energy, alluvial fan setting, and clearly demonstrates a number of key sedimentological characters (Figure 7.8).

Introduction

This claypit (SJ 683118), on the eastern side of Hadley, Telford, Shropshire, is an exposure of the Etruria Formation in the Coalbrookdale Coalfield. Although in a working claypit, the face in question has not been worked for some time. Exposure is not exceptional, but is enough to demonstrate the characteristic features of the formation in this coalfield. The stratigraphical sequence here is summarized in a log shown by Besly (1988, fig. 15.7), and further details are given in the unpublished thesis by Besly (1983).

Description

The exposed sequence here is 30 m thick, and consists mainly of red mudstones and siltstones, and includes some palaeosol development (Figure 7.9). There are also numerous channels, filled with coarse sandstones and matrix-supported conglomerates. Many of the clasts in the conglomerates have a weathered ferruginous crust. Channel forms vary from steep- to shallow-sided, and seem to represent debris-flows in an alluvial-fan setting.

Figure 7.8 Etruria Formation exposed at New Hadley Brickworks. (Photo: C.J. Cleal.)

Some fine neptunian dykes, no more than 1 cm or so wide, can be seen at numerous places in the sequence. They are sand-filled, and can be observed cutting both the palaeosol and channel deposits.

Interpretation

This sequence shows the Etruria Formation in the alluvial fan association of Besly (1983), and clearly represents a high-energy, almost catastrophic depositional environment. It was probably in the proximal part of an alluvial fan running off from the nearby Northeast Shropshire High, which was a horst undergoing active uplift during the mid-Westphalian. The small neptunian dykes present may have been formed by seismic activity causing cracks to form in the sediment.

A significant feature of this facies-association in the Etruria Formation is that, despite it being an alluvial fan deposit, up to 50% of the sequence is mudstone and siltstone. Besly (1983) interpreted this as being due to the tropical weathering of the source area producing high proportions of fine sediment. In support of this, he compared them with similar, mud-dominated fans in present-day Papua New Guinea.

The type of sedimentary regime shown at New Hadley Brickworks contrasts strongly with that seen at Ketley Claypit, where deposition seems to have been in a much quieter, alluvial plain setting. This clearly shows that the traditional concept of the Etruria Formation covers more than one type of sedimentary facies-association, albeit producing strata of superficially similar appearance.

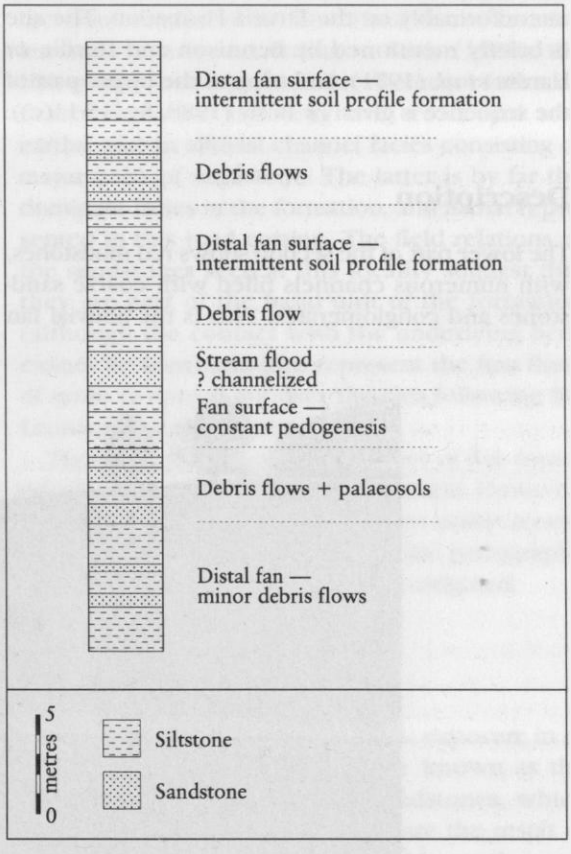

Figure 7.9 Vertical sequence through part of the Etruria Formation at New Hadley Brickworks. After Besly (1988, fig. 15.7c).

Conclusions

New Hadley Brickworks shows the best available example of rocks of the Etruria Formation (about 310 million years old), representing high-energy, alluvial fan deposits.

KINGSBURY BRICKWORKS

Highlights

Kingsbury Brickworks provides the best exposure of the Halesowen Formation, lying unconformably on alluvial fan deposits of the Etruria Formation (Figure 7.10).

Introduction

This claypit (SP 220987) on the east side of the Birmingham-Sheffield main railway line, 2.5 km north of Kingsbury, Warwickshire shows an excellent exposure of the Halesowen Formation lying unconformably on the Etruria Formation. The site is briefly mentioned by Bennison and Hardie *in* Hardie *et al.* (1971), and a log of the upper part of the sequence is given by Besly (1988, fig. 15.11(c)).

Description

The lower part of the section shows red mudstones, with numerous channels filled with coarse sandstones and conglomerates. This is the alluvial fan association of the Etruria Formation. These beds are overlain by massive, buff sandstones of the Halesowen Formation (Figure 7.11). Besly (1988) interpreted the latter as alluvial channel and overbank deposits. Palaeocurrent evidence suggests a southerly source for the Halesowen Formation here.

Interpretation

The development of the alluvial fan association in the Etruria Formation here is due to the Western Boundary Fault, which lies only 2 km to the west, and which marks the western margin of the Warwickshire Coalfield. The fault was active during the Westphalian, with a horst lying to the east providing the source for the Etruria Formation sediments. The situation was thus similar to that seen at New Hadley Brickworks, where the alluvial fan association can also be seen.

More significant at this site, however, is the excellent exposure of sandstones of the Halesowen Formation. No biostratigraphical control is available here, but evidence from elsewhere suggests they are late Westphalian D in age (Cleal, 1987). They are thus coeval with the Pennant Formation of the Forest of Dean, and probably with strata of the Oxfordshire Coalfield (Cleal, 1986a). The southern provenance of the Halesowen Formation and its petrological similarity to the Pennant Formation suggests that it is all part of a major belt of sandstones that spread out from the south during the very late Westphalian, perhaps as a response to nappe-loading along the Variscan Front.

Figure 7.10 Halesowen Formation lying unconformably on Etruria Formation, as seen at Kingsbury Brickworks. (Photo: C.J. Cleal.)

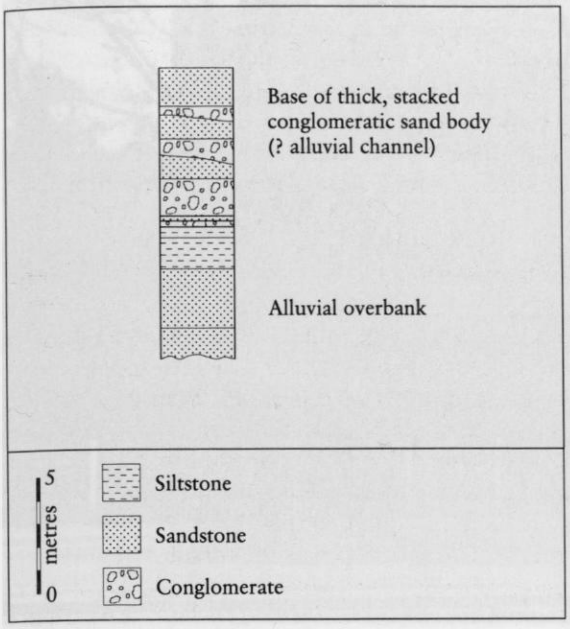

Figure 7.11 Halesowen Formation exposed at Kingsbury Brickworks. Based on Besly (1988, fig. 15.11c).

Conclusions

Kingsbury Brickworks is the best exposure of rocks known as the Halesowen Formation, which are about 306 million years old. They are probably a lateral equivalent of similar-aged rocks in the Forest of Dean and Oxfordshire coalfields, and represent a belt of river deposits that spread northwards from the growing uplands in southern Britain.

HALESOWEN ROAD CUTTING

Highlights

Halesowen Road Cutting is the best exposure of the Halesowen Formation in its type area (Figure 7.12).

Introduction

This cutting (SO 971836) on the west side of the Bromsgrove Road (A459) in Halesowen shows sandstones of the Halesowen Formation. There is no published description of the geology here, although the site is mentioned by Whitehead and Eastwood (1927).

Description

This exposure shows about a 3 m thick sequence of coarse, buff sandstones. They probably belong to the basal part of the Halesowen Formation, although the contact with the underlying Etruria Formation cannot be seen here. Some cross-bedding can be seen and, following Besly (1988), the unit probably represents alluvial channel deposits. There is no biostratigraphical control at this site, but evidence from elsewhere in the area (reviewed by Cleal, 1987) indicates that they belong to the *Dicksonites plueckenetii* plant subzone (upper Westphalian D).

Interpretation

The Halesowen Formation represents an interval of upper Westphalian D sandstones, most typically developed in the southern part of the South Staffordshire Coalfield. They correlate with the Forest of Dean Pennant Formation in the southern Midlands (Cleal, 1986a), and were the product of increased erosion of the hinterland due to Leonian tectonic activity. According to Besly (1988), the Halesowen Formation includes two major facies, an overbank facies including thin coals and seat earths, and an alluvial channel facies consisting of major units of sandstone. The latter is by far the dominant facies in the formation, and is that represented in this road cutting. The field relations of the sandstones seen at this locality suggest that they are part of the basal unit of the formation (although the contact with the underlying beds cannot be seen) and thus represent the first flood of sands to spread out over the area following the Leonian tectonic movement.

There are several other exposures of this formation in the South Staffordshire Coalfield. However, this is the most extensive and most easily accessible exposure, allowing details of the petrography and of the sedimentology to be investigated.

Conclusions

Halesowen Road Cutting is the best exposure in its type area of a unit of sandstone known as the Halesowen Formation. These sandstones, which are about 306 million years old, are the result of increased erosional activity caused by earth movements at this time.

Figure 7.12 Halesowen Road Cutting GCR site. Halesowen Formation exposed in type area. (Photo: C.J. Cleal.)

METALLIC TILERIES

Highlights

Metallic Tileries is the best exposure of the contact between the Newcastle and Etruria formations, where the nature of the important palaeoenvironmental change can be studied (Figure 7.13).

Introduction

This disused and partly infilled quarry (SJ 840498) on the east side of the A34(T) road, 4.5 km north of Newcastle-under-Lyme, Staffordshire shows the unconformable contact between the Etruria and Newcastle formations in the North Staffordshire Coalfield. The site was mentioned by Gibson (1905, 1925), Williamson (1946) and Besly (1988), and non-marine bivalves were described by Myers (1954). The most detailed geological description is by Pollard and Wiseman (1971).

Description

Lithostratigraphy

The lower 30 m of the sequence belong to the Etruria Formation, and are red mudstones with a lenticular sandstone body. The sandstone is very similar to lenticular bodies found in the Etruria Formation further south in the Midlands, and known as espley sandstones (Hains and Horton, 1969).

These red beds are overlain by 10 m of grey to black strata of the Newcastle Formation (Figure 7.14). The lower 2.5 m are black laminated shales and siltstones, belonging to the Lacustrine Facies Association defined by Besly (1988). Two beds within this interval have traditionally been known as 'limestones' (e.g. Gibson, 1925), although the lower one is in fact a calcareous mudstone, and the upper one a sideritic or ankeritic siltstone (Williamson, 1946). At the contact between the Newcastle and Etruria formations, however, there are lenses of true limestone, containing calcareous algae (*Garwoodia*, *Girvanella*, *Bevocastria*, *Ortonella*).

The remainder of the succession is a coarsening upwards unit of siltstones passing into cross-bedded sandstones, representing the progressive infill of the lake by deltaic deposits.

Biostratigraphy

Non-marine bivalves

Shells have been reported by Myers (1954) from the shales between the two 'limestone' beds in the basal Newcastle Formation. Species identified include *Anthraconauta* cf. *tenuis* (Davies and Trueman), *A.* aff. *phillipsi* (Williamson) and *A. calcifera* (Hind). The assemblage is generally agreed

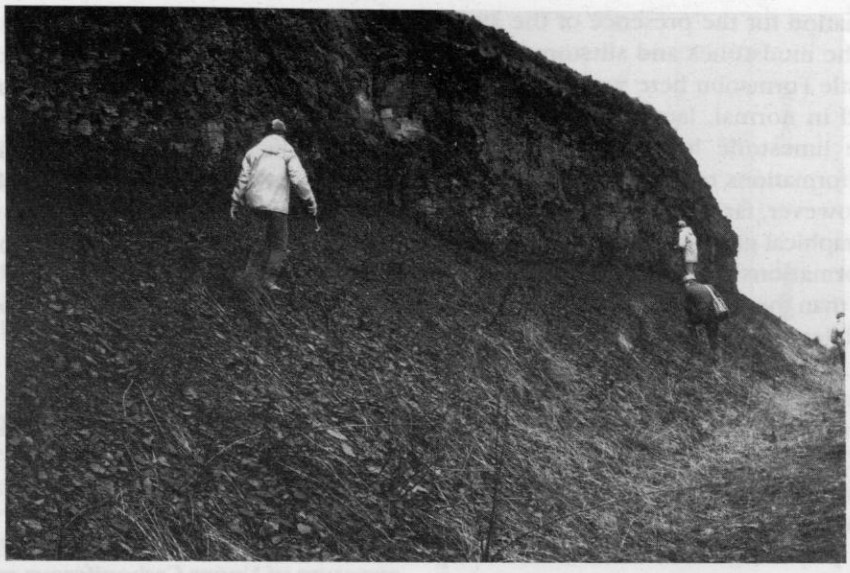

Figure 7.13 Contact between Newcastle and Etruria formations at Metallic Tileries. (Photo: C.J. Cleal.)

to belong to the *A. tenuis* Zone, indicating upper Bolsovian to Cantabrian (see Cleal, 1984a).

Shells have not been found in the Etruria Formation exposed here. However, Besly (1988) reports the presence of *A. phillipsi* in the formation elsewhere in the North Staffordshire Coalfield.

Palynology

No palynomorphs have been reported from this locality. However, from the nearby Downing Marl Pit (now inaccessible) Smith and Butterworth (1967) reported an assemblage of the *Thymospora obscura* Zone, indicating upper Bolsovian to Cantabrian (see Cleal, 1984a).

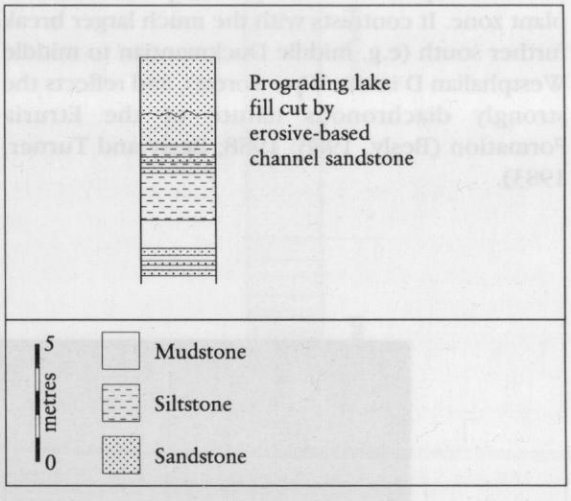

Figure 7.14 Newcastle Formation exposed at Metallic Tileries. Based on Besly (1988, fig. 15.11b).

Interpretation

This is the only site where the contact between the Etruria and Newcastle formations in the North Staffordshire Coalfield can be examined in detail. The evidence described by Pollard and Wiseman (1971) suggests that there was at least a temporary break in sedimentation between the two units. The limestone lenses at the contact are thought to have formed in small, shallow pools on the top of what was presumably an already lithified Etruria Formation. The stromatolite-like algae found here are unique in the Upper Carboniferous of Britain, and are among the best known non-marine algae of this age from anywhere in the world. The only other well documented examples are from Nova Scotia and Newfoundland in Canada (Bell, 1940; Belt, 1968), but these represent a significantly less diverse flora to that present at Metallic Tileries. However, Pollard and Wiseman (1971) implied that the presence of such algae reflects an indirect marine influence, but this was based on the incorrect assumption that the Newcastle Formation was lagoonal (a view they later withdrew). Besly (1988) dismisses the likelihood of a marine influence as there is no supporting evidence, but gives no alter-

native explanation for the presence of the algae. The rest of the mudstones and siltstones in the basal Newcastle Formation here were almost certainly formed in normal, lacustrine conditions. Whether the limestone lenses at the contact between the formations represent the same environment is, however, far from certain.

The stratigraphical gap between the Etruria and Newcastle formations in North Staffordshire is much smaller than the equivalent gap (between the Etruria and Halesowen formations) in the South Staffordshire, Warwickshire and Wyre Forest coalfields. The plant fossils listed by Dix (1931b) for the Newcastle Formation suggest the middle or upper Westphalian D, and are thus of about the same age as the Halesowen Formation. Virtually no plant fossils have been reported from the Etruria Formation here, but the palynological evidence outlined by Smith and Butterworth (1967; see also Butterworth and Smith, 1976) suggests that at least the upper Etruria Formation in north Staffordshire is Westphalian D. The gap between the formations is thus extremely small, representing only a small part of the Westphalian D and probably less than one plant zone. It contrasts with the much larger break further south (e.g. middle Duckmantian to middle Westphalian D in the Wyre Forest), and reflects the strongly diachronous nature of the Etruria Formation (Besly, 1983, 1988; Besly and Turner, 1983).

Conclusions

Metallic Tileries is the best exposure of the contact between units of rock known as the Newcastle and Etruria formations, which are about 306 and 308 million years old respectively. At the contact are lenses of limestone containing the fossilized remains of algae, which are thought to have formed in shallow pools of water. This has been given as evidence of a time gap between the deposition of the two rock units.

CHESWARDINE CANAL CUTTING

Highlights

Cheswardine Canal Cutting provides the best exposure of Upper Carboniferous red beds known as the 'Keele Beds' near its type area, and demonstrates the typical lithology of these strata (Figure 7.15).

Introduction

This cutting on the west side of the Shropshire Union Canal, 2 km WNW of Cheswardine, and 4.5 km SE of Market Drayton, Shropshire (SJ 697307) is one of the few exposures of the red 'Keele Beds' near its type area in the North Staffordshire Coalfield; this particular exposure is in an area of 'Keele Beds' lying between the Shrewsbury and North Staffordshire coalfields. There is no

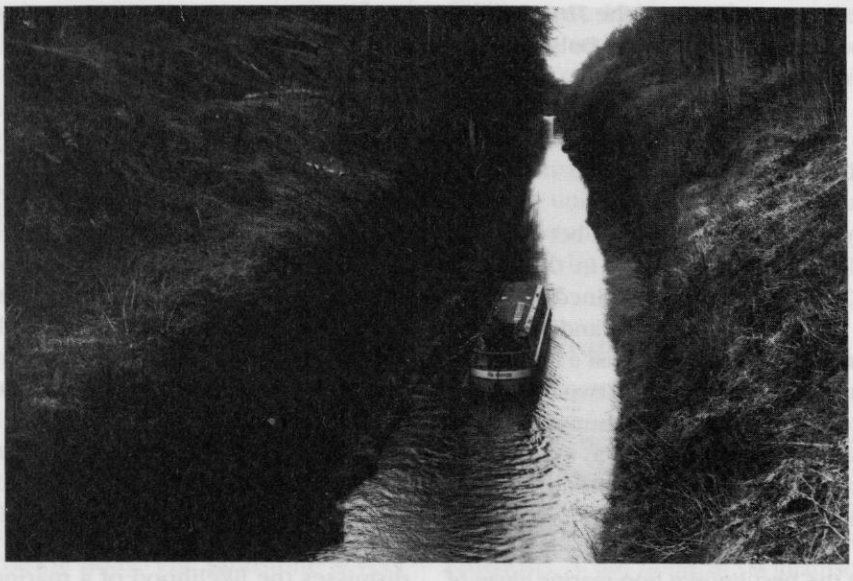

Figure 7.15 Keele Beds exposed at Cheswardine Canal Cutting. (Photo: C.J. Cleal.)

published account of the geology here, but a log was given by Besly in an unpublished excursion guide to the West Midlands (British Sedimentological Research Group, Upper Carboniferous Meeting – April 1986), and which is the basis of Figure 7.16 in the present volume.

Description

The 'Keele Beds' here are overlain unconformably by the Triassic Bunter Pebble beds. The most prominent feature is a sandstone unit with an erosive base, which may be a meandering channel-deposit, and can be seen on both sides of the canal. There are also thinner sandstones, which are probably crevasse-splay deposits. Overbank deposits are poorly exposed, but can sometimes be seen in minor landslips, and consist of laminated, micaceous shales.

Interpretation

The term 'Keele Beds' has traditionally been used for the red measures thought to overlie the Halesowen and Newcastle formations in the English Midlands. They are on the whole poorly exposed, and have only recently been investigated in any detail. Unpublished work by Besly (pers. comm., 1990), based mainly on borehole evidence, has shown that the situation is in fact far more complex than previously thought, and that there are no such things as lithostratigraphically homogeneous 'Keele Beds'. It is as yet unclear how the Cheswardine Canal Cutting section fits into the more refined model being established by Besly.

There are superficial resemblances between these red beds and the stratigraphically lower red beds known as the Etruria Formation. However, the overbank shales exposed at Cheswardine Canal Cutting are significantly more micaceous and laminated than overbank mudstones of the Etruria Formation, and this is typical for the strata traditionally referred to as 'Keele Beds'.

Conclusions

Cheswardine Canal Cutting provides the best exposure of Upper Carboniferous red beds known as the 'Keele Beds' near its type area. The red coloration is thought to have been due to a low water table at that time, reflecting the general uplift of the English Midlands about 300 million years ago.

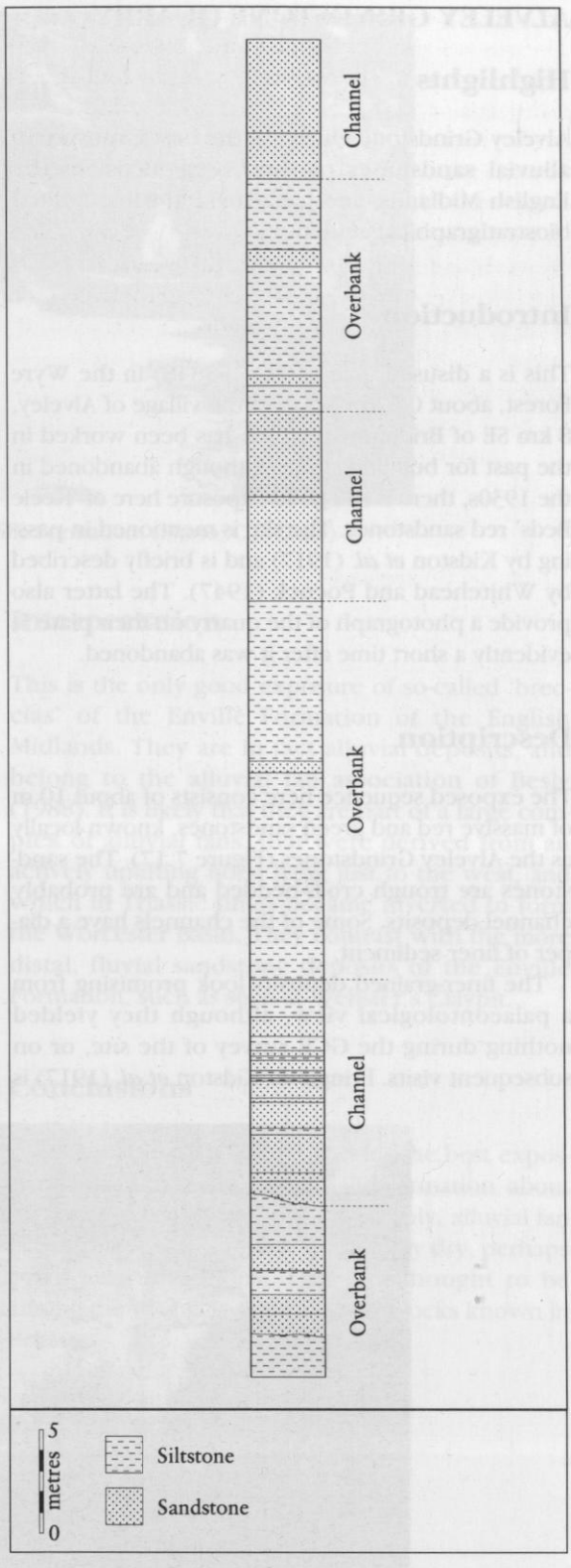

Figure 7.16 Keele Beds exposed at Cheswardine Canal Cutting. Based on information supplied by B. Besly (pers. comm.).

ALVELEY GRINDSTONE QUARRY

Highlights

Alveley Grindstone Quarry is the best exposure of alluvial sandstones of the 'Keele Beds' in the English Midlands, and has provided some limited biostratigraphical evidence.

Introduction

This is a disused quarry (SO 758848) in the Wyre Forest, about 0.5 km NNW of the village of Alveley, 8 km SE of Bridgnorth, which has been worked in the past for building stone. Although abandoned in the 1930s, there is still good exposure here of 'Keele Beds' red sandstones. The site is mentioned in passing by Kidston *et al.* (1917) and is briefly described by Whitehead and Pocock (1947). The latter also provide a photograph of the quarry on their plate 5, evidently a short time after it was abandoned.

Description

The exposed sequence here consists of about 10 m of massive red and green sandstones, known locally as the Alveley Grindstones (Figure 7.17). The sandstones are trough cross-bedded and are probably channel deposits. Some of the channels have a diaper of finer sediment.

The finer-grained deposits look promising from a palaeontological view, although they yielded nothing during the GCR survey of the site, or on subsequent visits. Pringle *in* Kidston *et al.* (1917) is reported to have found a *Sigillaria* here, but this is of little biostratigraphical significance.

At nearby Butts Quarry, sandstones from a slightly lower stratigraphical level, towards the base of the 'Keele Beds', yielded a number of amphibian footprints (Raw *in* Whitehead and Pocock, 1947). These have been taken to indicate a mid-Stephanian age for these beds (Haubold and Sarjeant, 1973). As pointed out by Besly (1988), however, the biostratigraphical worth of such trace fossils is far from proved. Work currently in progress by Besly and Cleal is indicating a late Westphalian D or Cantabrian age.

Interpretation

This is the best of the quarries in the Alveley district, exposing the so-called 'Keele Beds' of the Wyre Forest Coalfield (see report on Cheswardine Canal Cutting for brief comments on the nomenclatural problems surrounding this formation). The exposed beds are part of an extensive fluvial system, that extended southwards across central and northern England from positive areas such as the Mid-North Sea High, Southern Uplands and Grampian Uplands (Besly, 1988). It contrasts with the underlying Halesowen Formation, which has a southern provenance, and which seems to be a northern extension of the Forest of Dean Pennant Formation.

Conclusions

Alveley Grindstone Quarry is the best exposure of red sandstones known as the 'Keele Beds', which

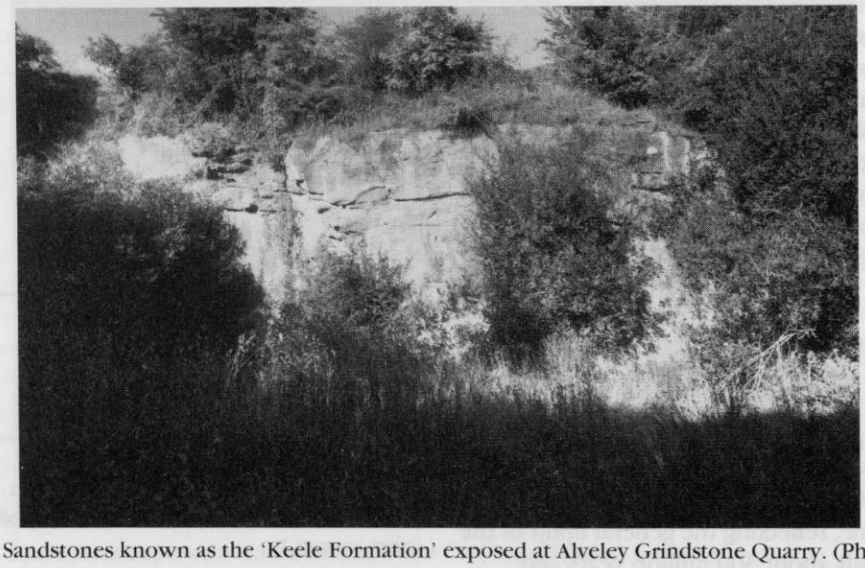

Figure 7.17 Sandstones known as the 'Keele Formation' exposed at Alveley Grindstone Quarry. (Photo: C.J. Cleal.)

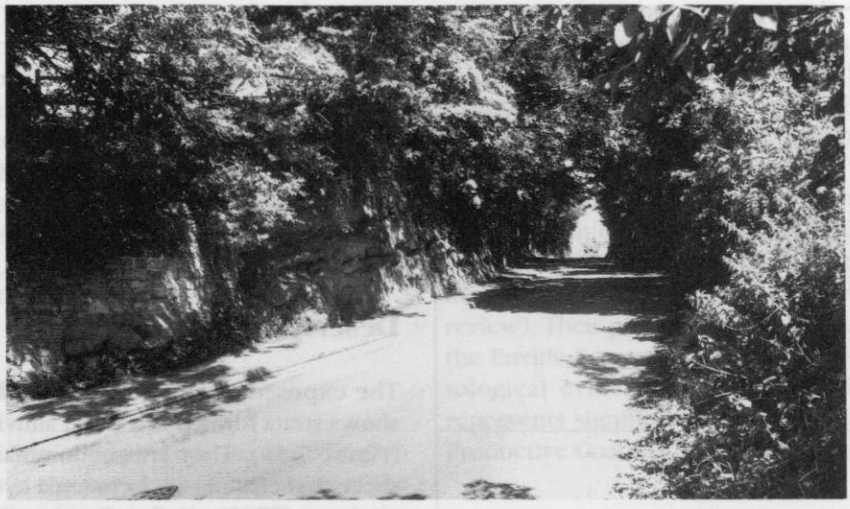

Figure 7.18 Gospel End Road Cutting. Exposures of Enville Formation. (Photo: C.J. Cleal.)

are about 300 million years old. The red coloration is thought to have been due to a low water table at that time, reflecting the general uplift of the English Midlands at this time.

GOSPEL END ROAD CUTTING

Highlights

Gospel End Road Cutting provides the best exposure of alluvial fan deposits of the Enville Formation.

Introduction

This exposure (SO 905936) along the Gospel End Road, 1 km west of Sedgley, West Midlands shows part of the Enville Formation of the western part of the South Staffordshire Coalfield. It is briefly mentioned by Whitehead and Eastwood (1927), and was included in an unpublished excursion guide to the West Midlands by Besly (British Sedimentological Research Group, Upper Carboniferous Meeting - April 1986).

Description

The exposure shows 11 m of fluvial sandstones with pebbly lags and some trough cross-bedding. There are also some red mudstones, which although partially obscured by brick facing, are still visible on the west side of the wall (Figure 7.18).

Interpretation

This is the only good exposure of so-called 'breccias' of the Enville Formation of the English Midlands. They are in fact alluvial deposits, and belong to the alluvial fan association of Besly (1988). It is likely that they are part of a large complex of alluvial fans, that were derived from an actively uplifting horst lying just to the west, and which in Triassic times became inverted to form the Worcester Basin. They contrast with the more distal, fluvial sandstone deposits of the Enville Formation, such as seen at Webster's Claypit.

Conclusions

Gospel End Road Cutting provides the best exposure of rocks known as the Enville Formation, about 300 million years old. They are pebbly, alluvial fan deposits, probably formed under very dry, perhaps sub-desert conditions. They are thought to be among the youngest Carboniferous rocks known in Britain.

WEBSTER'S CLAYPIT

Highlights

Webster's Claypit is the only available exposure of alluvial plain deposits of the Enville Formation, and is the best British site for Upper Palaeozoic *Walchia*-like conifers remains.

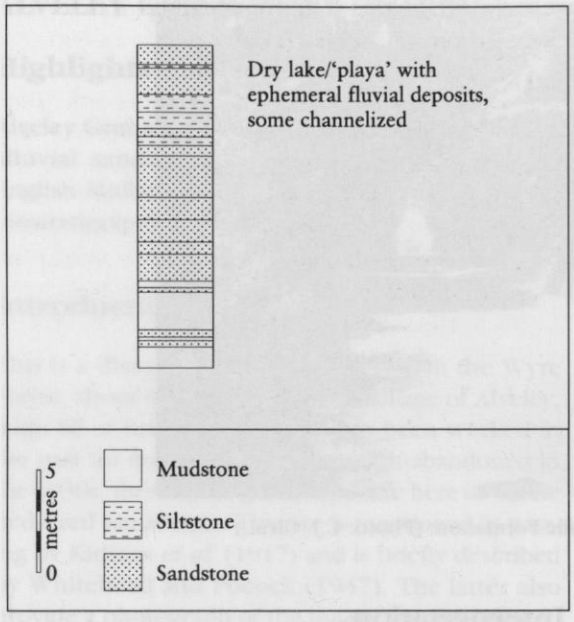

Figure 7.19 Enville Formation (distal alluvial facies association) exposed at Webster's Claypit. Based on Besly (1988, fig. 15.13b).

Introduction

This is an extensive exposure of part of the Enville Formation in the Warwickshire Coalfield, on the west side (SP 341806) of Stoney Stanton Road, Great Heath, Coventry, West Midlands. A brief description of the geology here, together with a lithostratigraphical log, is given by Besly (1988).

Description

The exposed sequence is about 28 m thick, and shows strata formed in a distal alluvial plain setting (Figure 7.19). They are predominantly sandstone sheets and channel-fills, separated by intervals of red mudstone. The sandstones have well developed primary current lineations and sole structures, with very little cross-lamination. Emergent conditions can be identified at several levels in the section, through the presence of rain-drop pits, desiccation cracks and rill marks. The sandstones would thus seem to represent intermittent and short-lived bouts of sedimentation, in what Besly (1988) interprets as an ephemeral fluvial setting.

The only fossils reported from here are branches of conifers, preserved on the weathered surfaces of the sandstones (Vernon, 1912, pl. 59, fig. 10; see

Figure 7.20 Alluvial plain deposits of the Enville Formation, as exposed at Webster's Claypit in the early 1980s. (Photo: C.J. Cleal.)

also Dix, 1935). Vernon identified them as *Walchia imbricata* Schimper, but as pointed out by Visscher *et al.* (1986) this is a poorly defined taxon. The Coventry material is in clear need of revision. For many years, no new specimens had been reported. Recently, however, H. Williams (pers. comm., 1989) found some further conifer remains at this site on large blocks of sandstone. Unfortunately, the blocks were too large to move and, on his return, they had been destroyed.

Interpretation

Although widely distributed in the English Midlands, this is the only known exposure of the Enville Formation in what Besly (1988) terms the ephemeral fluvial association. The sedimentology suggests that this association was formed in an alluvial-plain setting, in which most of the discharge was concentrated in large flood-events. It contrasts with the more conglomeratic facies of the alluvial fan association, such as seen at Gospel End Road Cutting, which is normally associated with the Enville Formation. The latter association is more localized and represents a more proximal position within the delta system, but is less vulnerable to erosion and thus tends to outcrop more often.

This is also the best known British site for Upper Palaeozoic *Walchia*-like conifers. At one time, such fossils were thought to be strong evidence of a Permian age for the beds (e.g. Dix, 1935). However, it is now accepted that they are merely an indication of drier substrates, and that conifers are now well documented from strata as low as the mid-Westphalian (see Lyons and Darrah, 1989, for a review). Their presence in the alluvial sediments of the Enville Formation thus supports the sedimentological evidence, that the Enville Formation represents significantly drier conditions than the Productive Coal and Halesowen formations.

Conclusions

Webster's Claypit is the only available exposure of sandstones of the Enville Formation, about 305 million years old. They are probably the remains of alluvial plain deposits laid down in relatively dry, possibly sub-desert conditions. This is also the best site in Britain for fossils of Late Palaeozoic *Walchia*-like conifers.