Chapter 10 Coal Measures of the Pennine Basin

This chapter covers the classic areas of Coal Measures of the Lancashire, Yorkshire and East Midlands coalfields (Figure 10.1). They are the thickest and most fully developed coalfields north of the Wales–Brabant Barrier, with up to 2000 m of Westphalian strata being present. They have also yielded abundant and diverse assemblages of non-marine bivalves (e.g. Eagar, 1946, 1947, 1951, 1952b, 1956), marine band faunas (e.g. Calver, 1968) and plant microfossils (e.g. Smith and Butterworth, 1967). The main drawback from a field geology standpoint is the very poor exposure, due to a combination of thick glacial deposits, and the extensive urbanization of the area. Despite this, the area has played a central role in the study of the Westphalian of Britain, and is generally regarded as the type-area for the Coal Measures Group. Furthermore, the area, particularly around Sheffield and Chesterfield, has been used by the IUGS Subcommission on Carboniferous Stratigraphy as the basis for defining the Langsettian, Duckmantian and Bolsovian stages (see Chapter 2).

Economically, these coalfields are among the most important in Britain, and were the driving-force behind the Industrial Revolution, at least in its middle and later phases. In 1857, they had a combined annual production of 21 million tons, representing virtually one-third of the entire UK production, and over 20% of that of the whole world (Hull, 1861). By the mid-1930s, it had gone up to 82 million tons per year, or 39% of the UK production (Bone and Himus, 1936), and by the 1950s it was over 100 million tons, or nearly half the UK production (Edwards and Trotter, 1954). The most recent figures (for 1990/91 — British Coal Corporation Annual Report) show a reduction in output to 48 million tons, forming 67% of the total UK production. A combination of exhaustion of the reserves and geological difficulties has seen a rapid decline in the Lancashire and South Yorkshire coalfields, but North Yorkshire and the East Midlands are the most important British coalfields.

Clay ironstones were also an important economic reserve in this area. They were worked as far back as Roman times and were a major industry in the medieval period (Edwards and Trotter, 1954). However, improved smelting technology introduced during the 19th century could not use such clay ironstones, and today all of the iron ore used in the area is imported.

Other economically important products of the Pennine Coal Measures are seat earths, particularly in the lower Westphalian where they are refractory and thus of use in the steel industry. Some of the other mudstones are also used for brickmaking.

History of research

The history of geological investigations into the Pennine coalfields started in earnest in the early 19th century, and coincided with the rapid growth in the commercial exploitation of the coalfields. The work was initiated by William Smith, who prepared some of the earliest geological maps of the area (Edwards and Trotter, 1954), but the earliest published descriptions were by his colleagues and pupils, such as Farey (1811), Phillips (1832) and Looney (*in* Hall, 1836).

In contrast to South Wales, where the Geological Survey was active from a very early time through the activities of Henry De la Beche (see Chapter 4), the government's geological agency was relatively slow to take an interest in the Pennine coalfields; mapping did not start until 1850, 15 years after the Survey had been established. Eventually, however, a memoir for the entire Yorkshire Coalfield was produced by Green *et al.* (1878). During the 20th century, the Survey's work expanded considerably in the Pennine coalfields, involving re-mapping and the publication of descriptive memoirs, reflecting the wider significance of this area for Westphalian stratigraphy. A full list of the published memoirs is beyond the scope of this review, but it is worth mentioning some of the most recent which reflect much of the Survey's current thinking on the stratigraphy of these coalfields (Earp *et al.,* 1961; Smith *et al.,* 1967; Frost and Smart, 1979; for a more complete list, see Edwards and Trotter, 1954).

During the mid-19th century, the main interest was in establishing correlations between coal seams in different parts of the coalfields. Although a seam might be laterally persistent within a particular colliery, it soon became evident that they were not so over longer distances. It resulted in much confusion in seam nomenclature, which could often have serious economic consequences. Early efforts to resolve the problem relied on lithostratigraphical criteria (e.g. Dickinson, 1864; Aitken, 1866; De Rance, 1878), but such correlations in deltaic sequences are usually unreliable. More robust means of correlation were therefore sought.

The presence of thin, discrete marine bands in the Pennine coalfields was first recognized by Phillips (1832) and Looney *in* Hall (1836), and their potential for correlation was discussed by Binney (1841, 1860). The Geological Survey subsequently used them in their memoirs, and helped to confirm them as one of the most useful stratigraphical tools, in the lower and middle Westphalian. Further significant records by Culpin (1909, 1910), Edwards and Stubblefield (1948) and Goossens (1952) culminated in the major studies by Calver (1968, 1969a, 1969h), which brought together all of the distributional and faunal data available to establish a stratigraphically coherent palaeoecological and biostratigraphical model for these marine bands. There has also been some interest in the geochemistry of these bands, especially in the Yorkshire and East Midlands coalfields (e.g. Curtis, 1964; Spears, 1964).

Marine bands have been supplemented for stratigraphical work by non-marine bivalves. Although such bivalves are known throughout the Upper Carboniferous paralic belt of northern Europe, their stratigraphical role was pioneered in the Pennines coalfields. Their potential was first recognized by Binney (1860), and the first significant zonation proposed by Hind (1894–1905). As with the marine bands, progress with the non-marine bivalves was helped significantly by the work of the Geological Survey, who used them in their mapping of the coalfields. The most extensive documentation of these bivalves was by Trueman and Weir (1946–1968), who also established the currently accepted biozonal scheme. Most recently, there have been attempts to further refine the biostratigraphy by introducing what are in effect subzones ('faunal belts' — Calver, 1956; Eagar, 1956), and to examine the environmental effects on the morphological variation of these shells (e.g. Eagar, 1947, 1952a, 1956, 1960, 1987).

In contrast, plant macrofossils have been relatively little used for biostratigraphy here. Kidston (1890, 1892, 1893) made extensive but mostly unillustrated records of their distribution in these coalfields, and a number of specimens were figured in his 1923–1925 monograph, especially from the Barnsley Seam of Yorkshire (see also Kidston, 1888a, 1895, 1896). However, they have not been developed as stratigraphical tools in the same way as has happened in the South Wales and Bristol–Somerset coalfields.

In passing, it is worth noting the discovery by Binney (1862a, 1862b, 1866) of nodules in a Langsettian coal seam in Lancashire, which yielded exquisitely preserved plant fossils. These coal balls, as they became known, revolutionized Palaeozoic palaeobotany and resulted in numerous significant studies; however, their geological significance is limited, (see Phillips, 1980 for a review of the subject).

The coals of the Pennine coalfields are mostly of low rank, and thus are suitable for the preparation of fossil pollen and spores. The Yorkshire coalfield in particular saw some of the pioneering work on stratigraphical palynology of the British Coal Measures (e.g. Slater *et al.,* 1930; Slater and Eddy, 1932). However, major progress was not made until the 1950s and later, mainly through the work of Smith and Butterworth, whose work on these strata was incorporated in their 1967 monograph. In addition to their basic biostratigraphical work, Smith (1957, 1962) made major progress in the use of palynology for interpreting the palaeoecology of the coals. Recently, Turner and Spinner (1993) have also investigated the palynology of some of the clastic deposits, in an attempt to refine both the biostratigraphy and the palaeoecology.

Up until about the mid-1960s, most work on the Pennine coalfields was stratigraphical, in its simplest sense, i.e. trying to establish correlations. The sedimentology tended to be largely seen in terms of cyclothems, resulting from marine transgressions. While such a model works broadly for the lower Langsettian, for higher parts of the Westphalian it is less satisfactory, since they were formed in a middle to upper delta-plain setting. The first significant progress was made by Elliott (1968, 1969, 1974), who used facies analysis to interpret them in terms of switching subdeltas and floodbasin lake deposits, similar to those developed in the present-day Mississippi delta. This was then further developed by Scott (1978, 1979, 1984) who incorporated evidence of plant fossil distribution with the sedimentology, to try to establish an overall palaeoecological model for the swamps. The sedimentology of some of the sandstones has been investigated by Guion, including the large Langsettian sand body known as the Crawshaw Sandstone (Guion, 1971), and smaller sandstones that form wash-outs in some of the coal seams (Guion, 1984, 1987a, 1987b). A more complete historical review of sedimentological research on these beds is given by Guion and Fielding (1988).

Lithostratigraphy

The entire sequence covered in this chapter belongs to the Coal Measures Group. The junction between this group and the underlying Millstone Grit is not sharply marked lithologically, with a gradual change from the thick sandstones of the lower Yeadonian, through to the shale-dominated sequences of the middle Langsettian. For convenience, the boundary has been taken here to coincide with the base of the Subcrenatum Marine Band, thus coinciding with the base of the Westphalian Series.

The bulk of the Coal Measures in the Pennine coalfields, at least up to the middle Bolsovian, belongs to the Productive Coal Formation. Particularly in the Langsettian, however, there are a number of prominent fluvial sandstone bodies which merit formational status. Only those sandstone formations which are discussed in this chapter will be summarized below:

Productive Coal Formation (defined in South Wales - *q.v.*)

Crawshaw Sandstone Formation

Stratotype: Ridgeway Quarry

Base defined: the base of the major sandstone overlying the Subcrenatum Marine Band in the East Midlands Coalfield.

Characteristic facies: cross-bedded sandstones.

Chronostratigraphical range: basal Langsettian.

Wharncliffe Crags Formation

Stratotype: Wharncliffe Crags

Base defined: the base of the major sandstone overlying the Amaliae Marine Band in the Sheffield area.

Characteristic facies: relatively pure, quartzitic sandstone with cross-bedding. Chronostratigraphical range: lower Langsettian.

Greenmoor Rock Formation

Stratotype: Neepsend Brickworks

Base defined: the base of the first coarsening-upwards cycle overlying the 80 Yard seat earth in the area between Sheffield and Huddersfield.

Characteristic facies: coarsening-upwards cycles of mudstones, siltstones and thin sandstones, with ripple marks and small-scale cross-bedding.

Chronostratigraphical range: lower Langsettian.

Elland Flags Formation

Stratotype: Elland Lower Edge (Davies, 1967)

Base defined: the base of the major sandstone unit immediately underlying the Better Bed coal seam north of Huddersfield. Characteristic facies: massive sandstones, sheet sandstones with cross-bedding, and channel-sandstones with erosive bases.

Chronostratigraphical range: lower Langsettian.

Comment: this is a lateral equivalent of the Greenmoor Rock Formation (*q.v.*).

Above the Cambriense Marine Band, red beds dominate many parts of the sequence (Trotter, 1952; Goossens and Smith, 1973). Lithostratigraphical names exist for at least some of these strata, such as the Ardwick Formation in Lancashire. However, there are virtually no exposures now available and so these are not included in this discussion.

Geological setting

The sites dealt with in this chapter represent the classic coal-bearing strata of the Pennine Basin. It is essentially the same geographical area as the Central Province of the Namurian (see Chapter 9). In the Namurian, the area was dissected ipto a series of separate depositional 'basins', formed as the result of basement faulting during the Dinantian. However, by the Westphalian, the influence of this faulting had declined considerably and the area formed a more or less coherent depositional basin (Figure 10.2).

Strictly speaking, the sequences in the English Midlands (Wyre Forest, South Staffordshire, Warwickshire coalfields) are also in the Pennine Basin. However, being marginal deposits, onlapping against the Wales–Brabant Barrier, they are quite different from the more 'basinal' deposits seen in north Derbyshire, north Nottinghamshire, Yorkshire and Lancashire, and so have been dealt with separately (Chapter 7).

The northern margin of the Pennine Basin has been taken here to coincide with the North Craven Fault (i.e. the southern margins of the Askrigg Block). Some authors do not make this distinction, and refer to the entire area from the Wales–Brabant Barrier to the Southern Uplands as the Pennine Basin (e.g. Guion and Fielding, 1988). However, the deposits of these more northerly areas are rather different, and have been dealt with separately in Chapter 11.

The deposition in the area can be seen in terms of the interaction of two conflicting factors: (1) the flow of fluvial sediment from upland areas to the north (mainly from the Caledonian Highlands, and to a lesser extent the Southern Uplands and North Sea High); and (2) marine incursions periodically spreading in from the south-west and possible southeast. The result was a large, southwards-flowing fluvio-deltaic complex (Figure 10.3). For most of the time, the flow of fluvial sediment predominated, and the deposits seen in the Pennine coalfields represent a middle to upper delta-plain setting. Swamp deposits (including coals) and floodbasin lake fills (crevasse-splay and overbank floods) are the most common (e.g. Fielding, 1984a; Guion, 1987a). In the early Langsettian and late Duckmantian to early Bolsovian, however, marine influence became more important. The strata formed at these times represent lower delta-plain and delta-front deposits (Fielding, 1987), characterized by numerous marine bands (Calver, 1968), and channel-sandstones formed by elongate, river-dominated deltas (e.g. Crawshaw Sandstone — Guion, 1971).

What controlled the relative influence of the marine and non-marine environments is not clear. Eustasy probably had some effect, particularly in the detailed development of the marine bands (Calver, 1968; Ramsbottom, 1979a). However, it is unlikely that this alone could have generated the major progradation and retreat of the delta seen in the Pennine Basin. More likely, this large-scale movement of the delta was controlled by the balance of basin subsidence against the rate of sediment supply into the delta; increase the supply of sediment relative to the subsidence, then the delta expands, reduce it and it withdraws. Both basement subsidence and hinterland uplift were presumably controlled by tectonism, and may thus have been closely linked. Whether one or the other had the predominant effect on the sedimentation pattern is however, unclear.

GCR site coverage

As mentioned in the opening paragraph of this chapter, exposure of these strata is on the whole poor. It has thus not been possible to build up a comprehensive network of GCR sites for the Westphalian of the Pennine Basin, in the same way as proved possible in South Wales (Chapter 4) and the Millstone Grit of the Central Province (Chapter 9). The coverage can be divided into the following categories:

1. Sedimentological sites. These are mainly controlled by what parts of the succession have been subjected to detailed sedimentological investigation.

1. Crawshaw Sandstone Formation and its associated strata (Ridgeway Quarry,Stannington Ruffs, Ambergate Quarry see Guion, 1971).
2. Wharncliffe Crags Formation (Wharncliffe Crags).
3. Greenmoor Rock Formation (Neepsend Brickworks — see Davies, 1966, 1967).
4. The interval between the Lower Mountain Mine and Bullion Mines coals (Ravenhead Brickworks — see Broadhurst, 1988; Broadhurst *et al,* 1980).
5. Peel Hall Rock Formation (River Tonge, Mill Hill).

2. Marine band sites. The following have been selected wholly or in part because of the marine bands that they contain (the sites marked with a * are international boundary stratotypes, and are dealt with separately in Chapter 2).

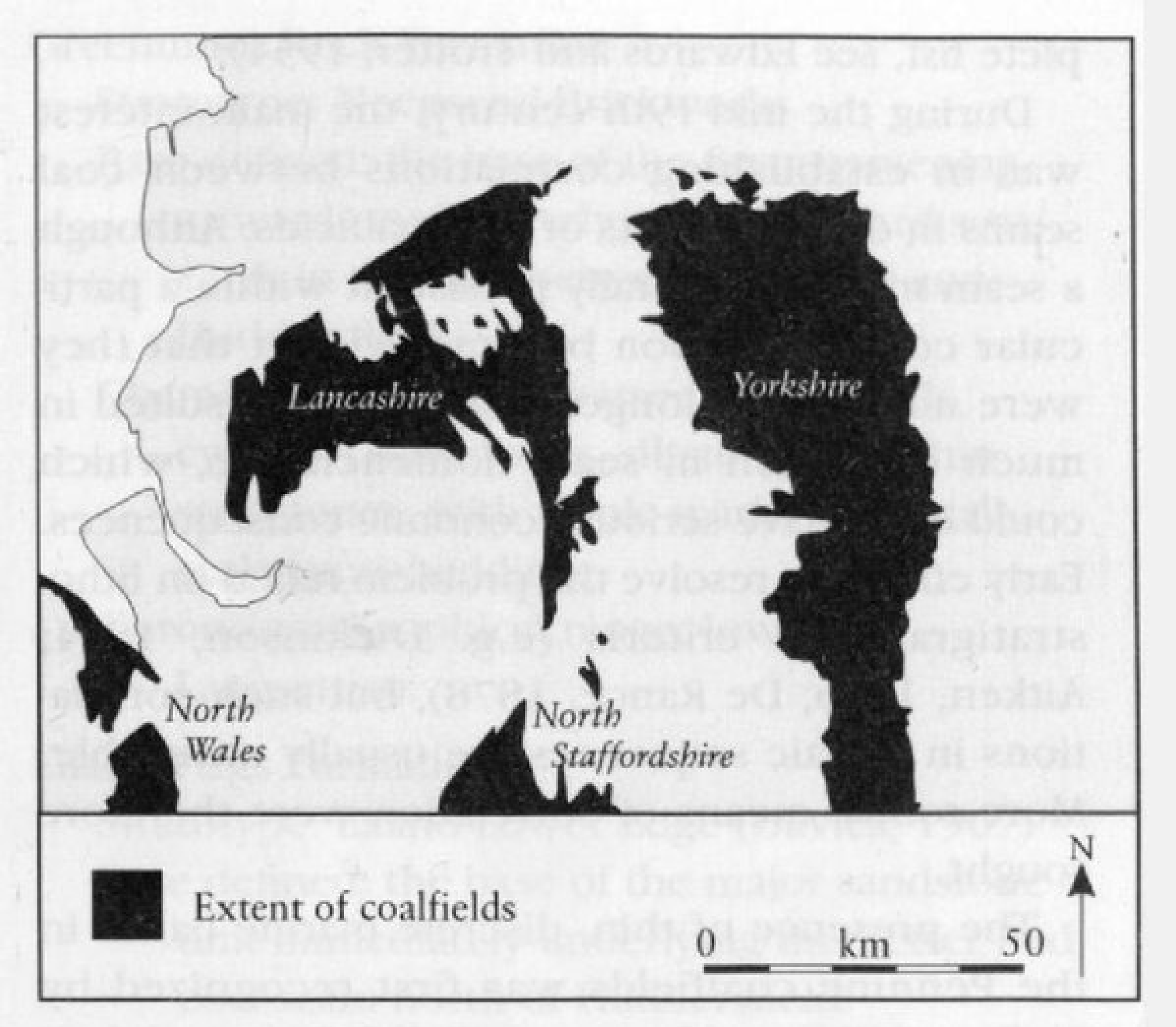
1. Subcrenatum Marine Band (Little Don*).
2. Holbrook Marine Band (Honley Station Cutting, Goyt's Moss, Neepsend Railway Cutting).
3. Springwood Marine Band (Honley Station Cutting).
4. Honley Marine Band (Goyt's Moss, Ravenhead Brickworks).
5. Listeri Marine Band (Ravenhead Brickworks, Neepsend Railway Cutting).
6. Parkhouse Marine Band (Ravenhead Brickworks).
7. Amaliae Marine Band (Elland Bypass Cutting).
8. Vanderbeckei Marine Band (Duckmanton Railway Cutting*, Bradgate Brickworks).
9. Maltby Marine Band (Ashclough).
10. Aegiranum Marine Band (River Doe Lea*, Stairfoot Brickworks).
11. Shafton Marine Band (Nostell Brickyard Quarry).
12. Cambriense Marine Band (Carlton Main Brickworks).

Clearly, there are gaps in this coverage, with seven of the nineteen marine bands listed by Ramsbottom *et al.* (1978) not being represented (Meadowfarm, Langley, Burton-Joyce, Clown, Haughton, Sutton, Edmondia). This was simply because no conservable outcrops showing them could be identified.

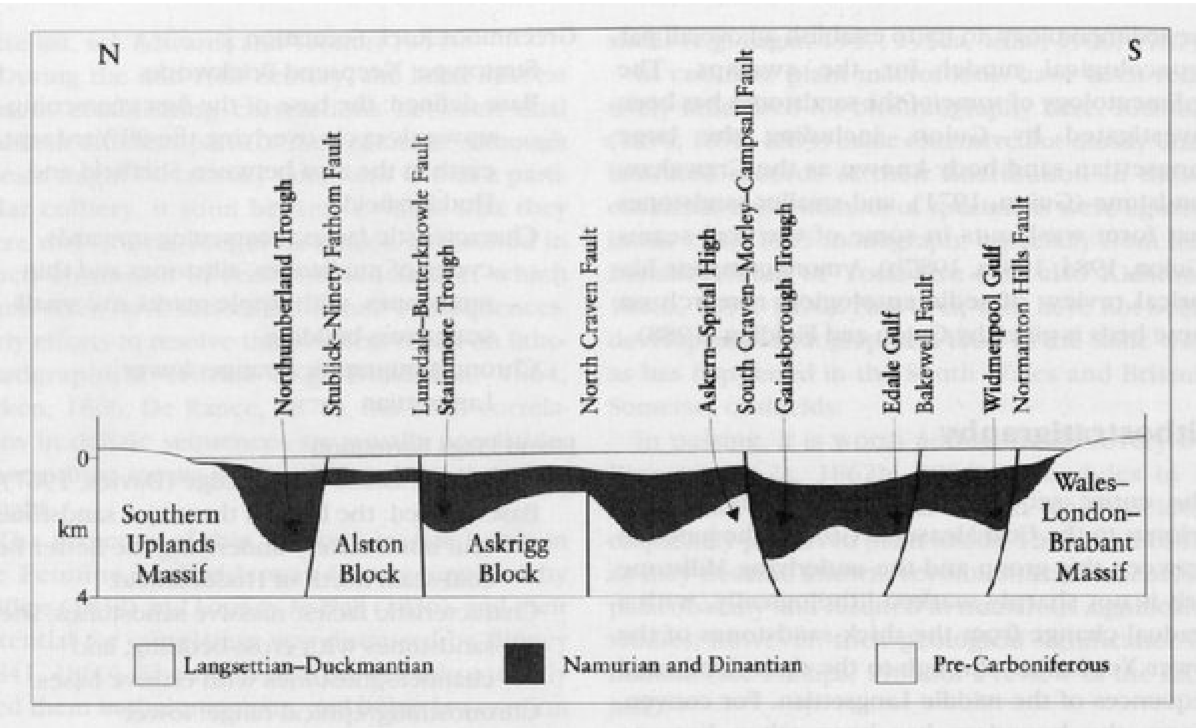
3. Non-marine bivalve sites. An attempt has been made to select sites to represent as many of the subzones as possible in this, the classic area for non-marine bivalve biostratigraphy. However, the restricted outcrop has meant that only seven subzones are represented;

1. *C. protea /C. fallax* Subzone (Little Don*, Honley Station Cutting, Goyt's Moss, Ravenhead Brickworks, Neepsend Railway Cutting).
2. *C. extenuata* Subzone (Ravenhead Brickworks).
3. *C. Proxima* Subzone (Elland Bypass Cutting).
4. *C. cristagalli* Subzone (Lowside Brickworks).
5. *A. regularis* Subzone (Bradgate Brickworks).
6. *A. ovum* Subzone (Duckmanton Railway Cutting*).
7. *A. phrygiana* Subzone (Duckmanton Railway Cutting*).

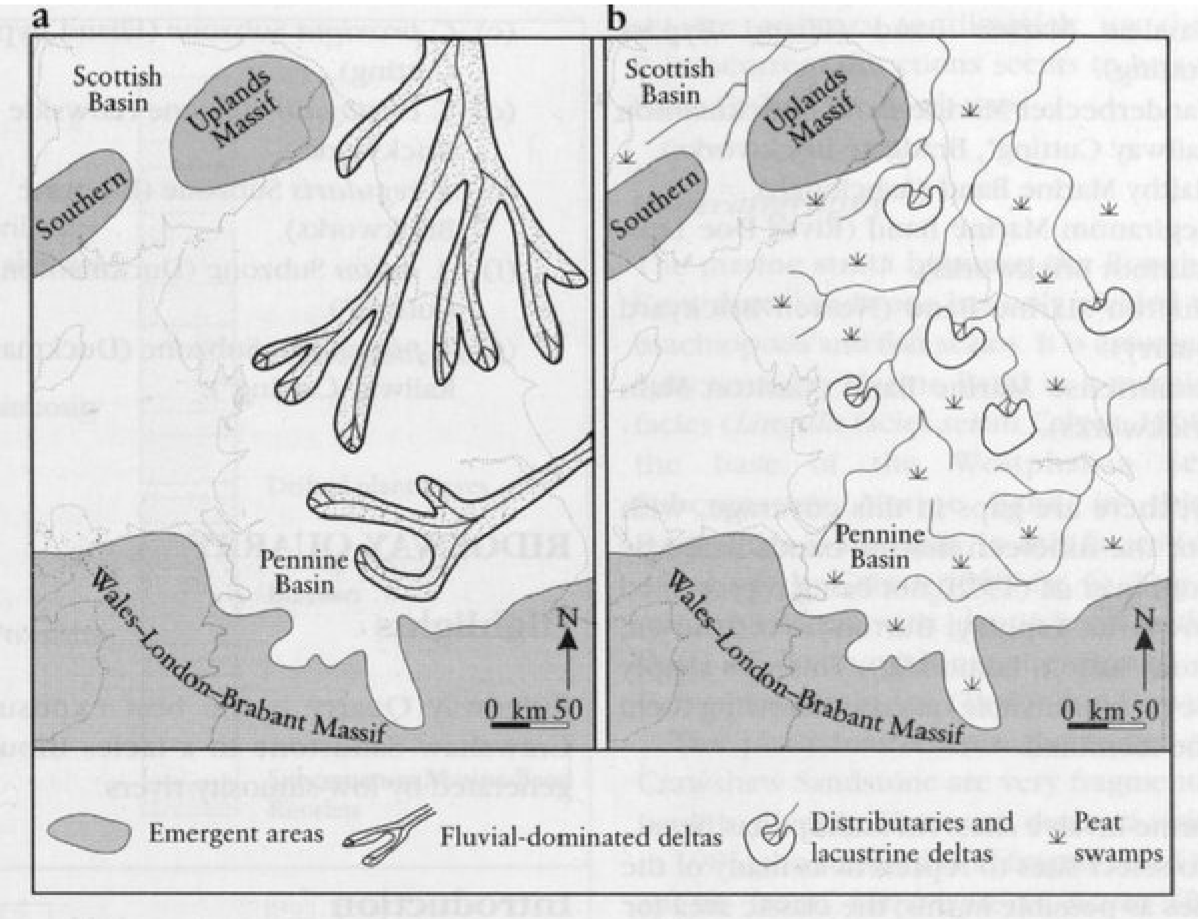
References



(Figure 10.1) Coal Measures outcrop in the Pennine Basin, between the Wales–Brabant Barrier to the south and the Askrigg Block to the north. Based on Guion and Fielding (1988, fig. 13.1).



(Figure 10.2) Relationship between the Coal Measures, Millstone Grit and Carboniferous Limestone in the Pennine Basin. Based on Guion and Fielding (1988, fig. 13.5).



(Figure 10.3) Generalized depositional models for the Pennine Basin Coal Measures. (a) Early Langsettian, lower delta-plain setting; (b) Late Langsettian to middle Duckmantian, middle to upper delta-plain setting. Based on Guion