Chapter 12 Scottish Basin

This chapter deals with the area of Late Carboniferous deposition that lay between the Southern Uplands Massif to the south and the Caledonian Highlands to the north (Figure 12.1). In terms of present-day geography, it mostly occupies the area known as the Midland Valley. This is the belt of relatively flat topography that extends between Glasgow and Edinburgh, and which has been the home of most of Scotland's traditional heavy industry (the recent growth of the oil industry in northern Scotland has now changed this balance, somewhat).

Geologically, the area was subject to complex basement control, with numerous fault-bounded basins and blocks, probably resulting from a combination of strike-slip movement and thermal subsidence (Read, 1988). The thickest development is in Fife, where some 280 m of mainly arenaceous strata known as the Passage Group, are overlain by 830 m of Coal Measures. The overall pattern of sedimentation differs somewhat from that of the Pennine Basin to the south, being more condensed and showing a different relationship between the predominantly arenaceous Namurian deposits and the predominantly argillaceous Westphalian strata. There is a further complication in that the majority of the marine bands, that have played such a significant role in establishing detailed correlations in the Pennines, are nowhere near as well developed in Scotland. As a consequence, other biostratigraphical means have had to be employed, particularly non-marine bivalves (e.g. Weir and Leitch, 1936; Brand, 1983) and palynology (e.g. Knox, 1942, 1946). It has also meant that Upper Carboniferous stratigraphical nomenclature has tended to follow a different path from that in the rest of Britain (Macgregor, 1960).

Today, coal is still a relatively important economic resource in the area, with an annual productivity of over 2 million tons (British Coal Corporation Annual Report 1990/91). Modern production is exclusively from the Coal Measures, but in the past coals from the Lower Carboniferous Lower Limestone Coal Group were more significant. In fact, prior to the mid-19th century the Limestone Coal Group was the source of practically all of the coal in this area, and the early records of mining, which extend back to the 12th century, refer to these Lower Carboniferous coals (Macgregor and Macgregor, 1948). In the 1850s, Hull (1861) gives the annual Scottish coal production as nearly 9 million tons, but it is impossible to extract from this which is Upper Carboniferous. The same problem exists in interpreting the figures given by Bone and Himus (1936) for the mid-20th century productivity.

Other important economic resources in the Upper Carboniferous of Scotland include iron ores and refractory clays. In the Namurian of Ayrshire, there are also the bauxitic clays resulting from contemporaneous decomposition of lavas, that have been used as a source of alum, as well as for special types of refractory ware. Further comments on the economic geology of this part of Scotland can be found in Macgregor and Macgregor (1948).

History of research

The Geological Survey started work in earnest in the Scottish coalfields in the mid-19th century. As well as publishing a number of maps, there were also a number of sheet memoirs (e.g. Etheridge, 1873, 1879; Geikie, 1900). During the First World War, the potential economic significance of the Scottish coalfields became evident and the Survey started a comprehensive re-surveying programme. In addition to the maps, a series of memoirs were produced under the titles 'Economic geology of the… Coalfield' (Central Coalfield, Ayrshire Coalfields, Stirling and Clackmannan Coalfield, Fife Coalfield). Between 1917 and 1961, 19 memoirs of this type were produced, a full list of which can be found in Macgregor and Macgregor (1961). The drawback of these memoirs is that, being concerned principally with economic geology, they deal mostly with underground workings and temporary exposures. However, there were also published a number of more normal sheet memoirs covering parts of the Scottish coalfields (e.g. Richey *et al.,* 1930; Francis *et al.,* 1970; Forsyth and Chisholm, 1977), as well as a number of extensive papers dealing with the field geology of selected areas (e.g. Lumsden and Calver, 1965; Mykura, 1967; Davies, 1970).

The group of fossils in the Upper Carboniferous of Scotland that has attracted most biostratigraphical attention are the non-marine bivalves. The earliest record appears to be in Ure (1793), which is also claimed by Weir and Leitch (1936) to be the earliest record of such fossils from anywhere in Britain. In the 19th century, there were records by Brown (1843,

1849), Skipsey (1866), Grossart (1868) and Young and Armstrong (1871). The studies by Skipsey and Grossart are particularly significant as they demonstrate that certain species have restricted stratigraphical distributions and are thus of biostratigraphical potential. Towards the end of the 19th century, Hind's (1894–1896) monograph on these fossils included many Scottish specimens, albeit often with only vague stratigraphical localization.

In the 20th century, major contributions in the study of Scottish Upper Carboniferous non-marine bivalves were by Pringle and Manson (1929), MacLennan (1943, 1946) and Manson (1957), not to mention the numerous records produced in the Geological Survey memoirs mentioned above. Perhaps most significant, however, was the work by Leitch (1936, 1940, 1942), Leitch *et al.* (1937) and Weir and Leitch (1936), which brought together much of the then available information on the distribution of these bivalves in Scotland and enabled a detailed correlation with the sequences in England. Most recently, Brand (1983) has provided a detailed analysis of the non-marine bivalve biostratigraphy of the Ayrshire Coalfield.

As stated at the beginning of this chapter, restricted development of marine bands have meant that they have played a less significant role in Upper Carboniferous stratigraphy in Scotland than in England. Their existence in the Scottish successions was noted by Skipsey (1865) and Kirkby (1888), and detailed studies on two of the most significant bands (Skipsey's and Queenslie) have been given by Currie *et al.* (1937) and Brand (1977).

However, they have not been given the same prominence as the marine bands in England, especially in the Pennines (see Chapter 10).

Despite one of Britain's greatest proponents of plant biostratigraphy being a Scotsman (Robert Kidston), there has been relatively little work of this type done here. Some specimens have been figured in the monographs by Kidston (1923–25) and Crookall (1955–76), and some distributional data provided Walton *et al.* (1938). However, there has been little documentation of the distribution of Upper Carboniferous plant fossils in Scotland, similar to that done in South Wales (see Chapter 4).

Plant microfossils were first studied here by Knox (1942, 1946), and more detailed distributional data for the Coal Measures are provided by Smith and Butterworth (1967). A major study on the palynological biostratigraphy of the Passage Group is given by Neves *et al.* (1965).

As pointed out by Read (1988), the thick Quaternary cover limits surface exposures and thus hinders detailed sedimentological analysis. The most significant advances have been made on the Passage Group, particularly by Read (1969, 1981, 1988) and Read and Dean (1982) using considerable additional data from boreholes. The only notable study on Coal Measures sedimentology in the Midland Valley of Scotland is by Kirk (1983).

Lithostratigraphy

The broad lithostratigraphical pattern of the Scottish Upper Carboniferous can be compared with that in England, especially Northern England. The Arnsbergian to the Langsettian, referred to in Scotland as the Passage Group, is in a predominantly arenaceous facies. This is overlain by more argillaceous beds of the Coal Measures Group. It is well known that the junction between these two groups is at a higher level in Scotland than the equivalent lithostratigraphical boundary in England, and this has caused some problems as to stratigraphical nomenclature (Macgregor, 1960; Lumsden and Wilson, 1979). As shown by Monro (1985), however, if the units are treated in a purely lithostratigraphical sense, the perceived difficulties mostly disappear.

Unfortunately, a full set of formations have yet to be proposed for the Passage Group. The following will only refer to those units relevant to the rest of this chapter:

Ayrshire Bauxitic Clay Formation

Stratotype: High Smithstone Quarry

Base defined: lowest occurrence of the bauxitic clay facies.

Characteristic facies: alumina-rich clays with subsidiary coals and seat earths. Chronostratigraphical range: Namurian (exact range uncertain).

Roslin Sandstone Formation

Stratotype: Joppa Shore

Base defined: base of the lowest thick sandstone above the Castlecary Limestone and its lateral equivalents.

Characteristic facies: thick, cross-bedded sandstones with subsidiary shales. Chronostratigraphical range: upper Arnsbergian to Yeadonian or possibly Langsettian.

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

Barren Red Formation

Stratotype: East Wemyss to Buckhaven Coast

Base: so far, undefined.

Characteristic facies: red sandstones, mudstones and seat earths.

Chronostratigraphical range: (?)Bolsovian to Westphalian D.

Geological setting

The Upper Carboniferous Scottish Basin lies between the Southern Uplands Massif and the Caledonian Highlands, the latter having provided the bulk of the sediment (Figure 12.2). The basin was bounded both to the north and the south by faults, although they were not always active during the Late Carboniferous, and sometimes sedimentation spread over them (e.g. the Sanquhar Coalfield). The basin itself was divided into numerous local fault-bounded blocks and grabens. The faults show widespread evidence of strike-slip movement. Read (1988) uses this to interpret the basin having resulted from thermal subsidence combined with lateral strike-slip, although he recognizes that most of the evidence could also fit with Leeder's (1982) extensional tectonics model (see also Leeder and McMahon, 1988).

A distinctive feature of the Upper Carboniferous of the Scottish Basin is the presence of contemporary volcanicity, particularly in the Ayrshire and Fife coalfields (Francis, 1978, 1983). The resulting lavas are of the alkaline basalt type, and thought to be the result of partial melting associated with 'within-plate' rifting. The lava-piles had a strong influence on basin morphology, affecting both sediment thickness and facies. Also, weathering of the lavas produced the bauxitic clays, which form such a characteristic feature of the Ayrshire Passage Group.

The base of the Passage Group in the Arnsbergian marked a major change in sedimentation pattern, with the progradation of major deltas over the area from the Caledonian Highlands. This is thought to be the result of tectonic activity, which caused uplift and erosion of the hinterland to the north, as well as causing uplift of local structural highs within the basin (Read, 1981, 1988; Read and Dean, 1982). Other than some localized deltaic deposits (e.g. Pendle Grit of the Craven Basin), this pre-dates the appearance of large-scale deltaic deposits in the Central Province of Northern England in the Kinderscoutian. Whether this reflects the more proximal position of the Scottish deposits remains to be seen.

Until the Kinderscoutian, marine incursions could still transgress over the delta. After this, however, marine conditions were kept at bay, and even the widely distributed Subcrenatum Marine Band has not been recognized.

During the early Westphalian, a major change in sedimentary regime occurred. Deltaic sand desposition declined, and delta-top flood-plain deposits become more important, resulting in the formation of the Coal Measures. Also, the effects of the basement fault-blocks reduced and volcanicity became restricted to present-day Fife. Finally, the Southern

Uplands Massif became for the first time a significant source of sediment.

In the late Westphalian, yet another change occurred, resulting in the disappearance of Coal Measure deposition, and its replacement by deposits of the Barren Red Formation. These are more characteristically fluvial sediments, exhibiting cal-cretes, desiccation cracks and angular mud-flake breccias (Mykura, 1967), suggesting an increasingly arid climate. However, it has been widely argued that the reddening of these strata occurred during the Permian (e.g. Mykura, 1960), but penecontem-poraneous coloration similar to that found in the Etruria Formation of the English Midlands (see Chapter 7) is considered more likely.

GCR site coverage

The selected sites are intended to demonstrate the main features of the Upper Carboniferous of the Scottish Basin.

1. Ayrshire Bauxitic Clay Formation–

(a) High Smithstone Quarry

2. Roslin Sandstone Formation–

(a) Joppa Shore

3. Productive Coal Formation–

(a) Dunaskin Glen (Langsettian)

(b) Polhote and Polneul Burns (Langsettian–lower Duckmantian)

(c) Lagrae Burn (upper Duckmantian–middle Bolsovian)

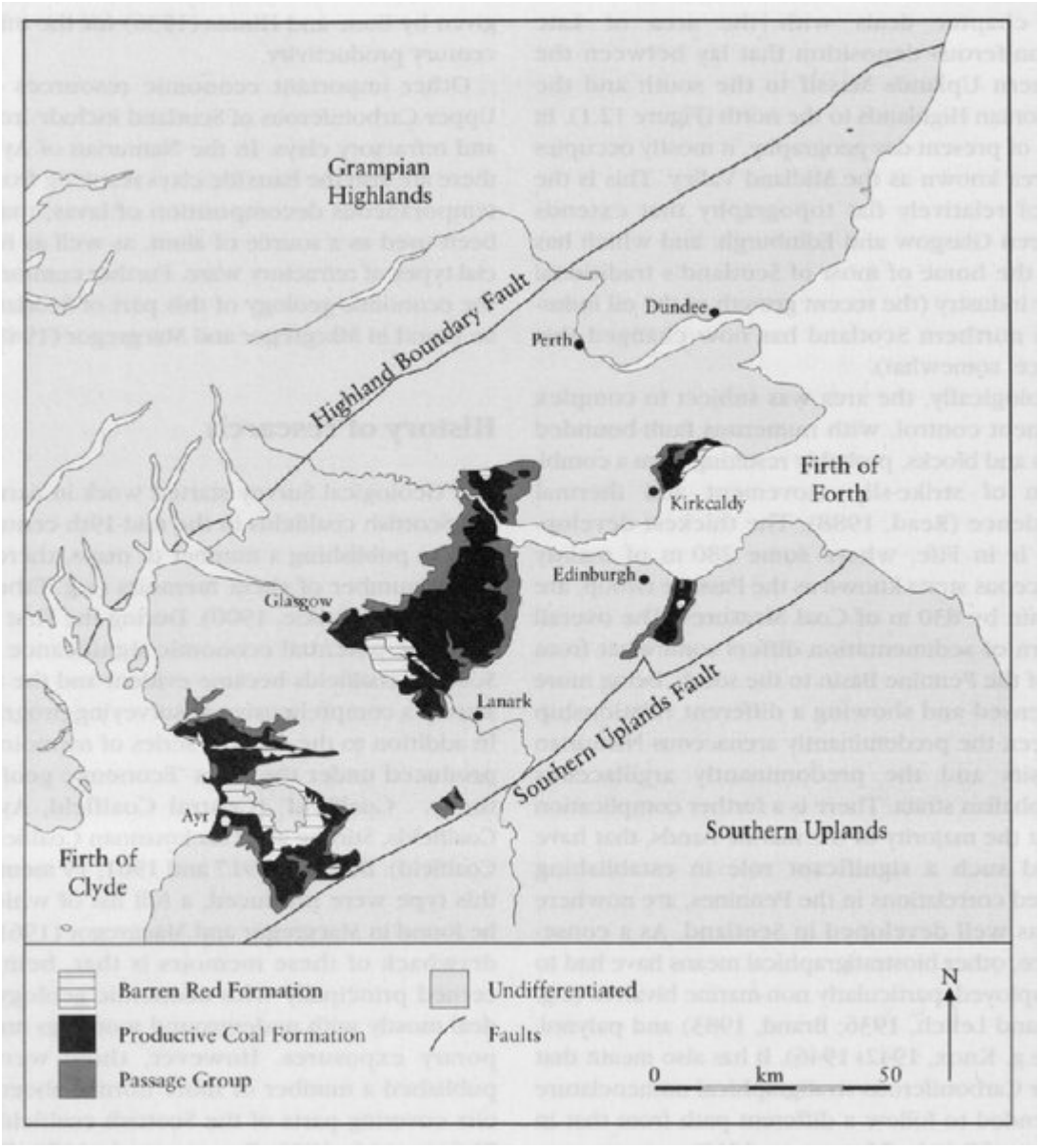
(d) Corrie Foreshore (marginal deposits)

4. Barren Red Formation–

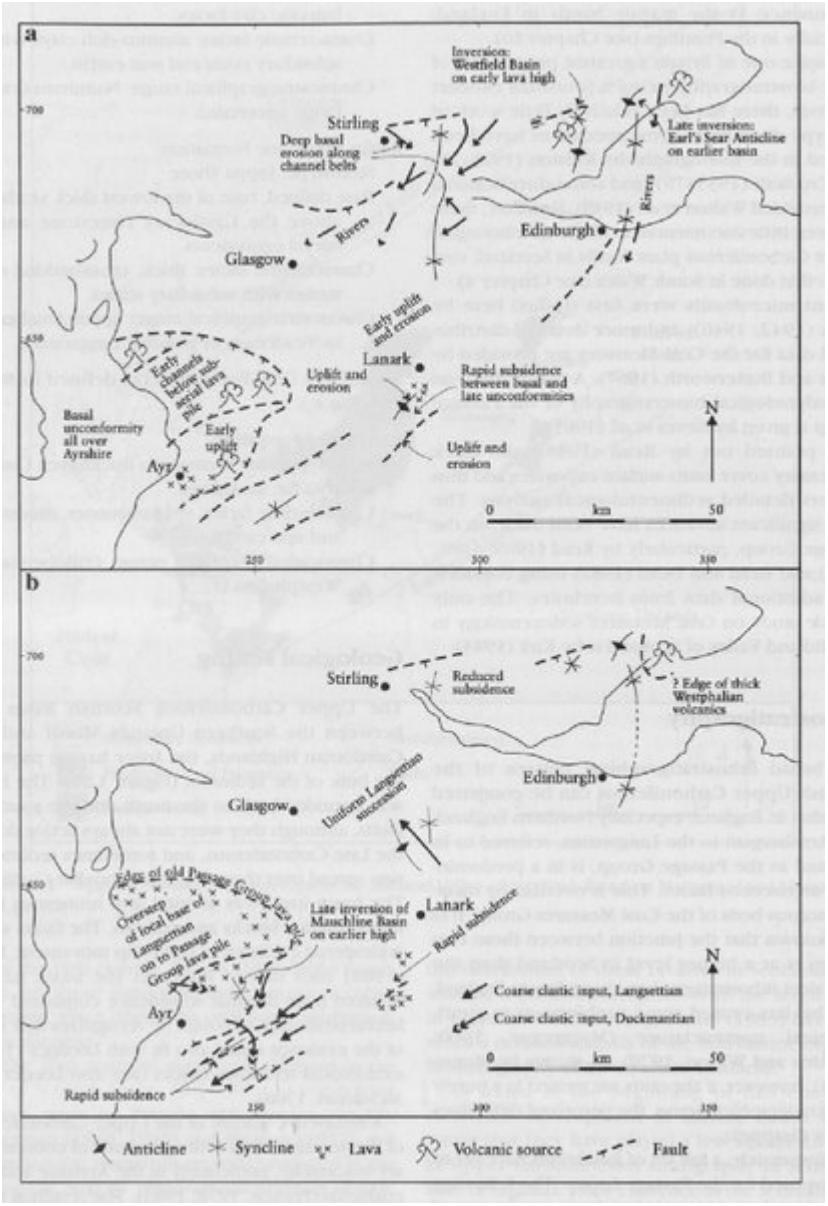
(a) East Wemyss to Buckhaven Coast

In addition, Inninmore Bay is selected for the enigmatic Coal Measures deposits north of the Highland Boundary Fault.

References



(Figure 12.1) Upper Carboniferous outcrops in the Midland Valley of Scotland. Based on Macgregor and Macgregor (1961, pl. 8).



(Figure 12.2) Main controls on sedimentation in the Scottish Basin in the Late Carboniferous. (a) Namurian; (b) lower Westphalian. Based on Read (1988, figs 16.12 and 16.14).