Chapter 4 South Wales

The Upper Carboniferous outcrops in South Wales in an elongate area about 75 km long and up to 16 km wide (Figure 4.1). The main part of the outcrop extends from Pontypool in the east to near Kidwelly in the west. Carmarthen Bay separates this from a smaller area of outcrop in Pembrokeshire. With the exception of the Iberian Peninsula (Lemos de Sousa and Oliviera; 1983, Martinez Diaz, 1983), South Wales provides by far the best exposed sequences of non-marine Upper Carboniferous in Europe. Good coastal exposures occur in Pembrokeshire, complemented by numerous inland exposures in the main area of outcrop. At one stage, South Wales was being considered as a potential stratotype for at least part of the Westphalian Series (George and Wagner, 1970, 1972). Rather strangely, the working group of the SCCS investigating this matter could not find any suitable exposures there and so opted for the much smaller outcrops in the Pennines (Calver *in* George and Wagner, 1972, p. 147). Nevertheless, in view of the extent of the outcrop, and the quality of the non-marine faunas and macrofloras, South Wales remains a key area for Upper Carboniferous stratigraphy.

As well as its scientific interest, the Upper Carboniferous of South Wales has been of considerable economic significance. Most important is the coal from the Westphalian part of the sequence. In 1857, South Wales had an annual production of 8.9 million tons, representing 13.5% of the UK's production, and over 9% of the entire world's (Hull, 1861). In 1933, this had gone up to more than 33 million tons, 16% of the UK's production (Bone and Himus, 1936), by the end of the 1980s this had declined to a mere 3.1 million tons per annum (British Coal Corporation Annual Report 1990/91)

During the 19th century, South Wales was also a major producer of iron ore (Joseph, 1880). However, it is a carbonate ore (siderite) unsuitable for modern smelting methods, and so its exploitation had ceased by the early 20th century (North, 1931).

History of research

Geological observations on the Upper Carboniferous of South Wales go back to the 16th century. However, serious geological work on the area started in the early 19th century, with the publication of William Smith's classic map in 1815, followed shortly by investigations undertaken by the newly-formed Geological Survey (De la Beche, 1846). This early phase in geological work in South Wales is discussed by North (1928, 1933, 1934, 1936) and a full inventory of the early literature is provided by Bassett (1963).

The economic importance of the Upper Carboniferous of South Wales resulted in a number of studies during the 19th century. These concentrated on subjects of immediate practical significance, such as seam correlations, the nature of seatearths, and changes in rank of coal (e.g. Logan, 1840; Bevan, 1858; Brown, 1865, 1874; Joseph, 1870; Lewis and Reynolds, 1870; Barrow, 1873; Jordan, 1876; Hannah, 1892; Arnold, 1895 again, see Bassett, 1961, 1963 for a full list of the relevant publications). This information was eventually brought together in a series of maps and monographs published by the Geological Survey (Strahan, 1899, 1907a, 1907b; Strahan and Gibson, 1900; Strahan and Cantrill, 1902, 1904; Strahan *et al.,* 1903, 1904, 1907, 1909, 1914; Cantrill *et al.,* 1916; Dixon, 1921).

During the early 20th century, most published data on the Upper Carboniferous of South Wales continued to be based on observations made in underground mines (e.g. Jordan, 1903, 1908, 1910, 1915). However, there gradually developed an awareness of the importance of natural surface outcrop for refining geological ideas. This is most obviously seen in some of the later editions of the Geological Survey memoirs, initially those by Robertson (1927, 1932), and subsequently by Woodland and Evans (1964), Archer (1968) and Squirrell and Downing (1969), Barclay *et al.* (1988), Barclay (1989) and Wilson *et al.* (1990). Also arising from this work by the Survey, documenting the exposed geology of South Wales, were a number of individual papers, such as by Woodland *et al.* (1957), Squirrell and Downing (1964) and Downing and Squirrell (1965).

Other than the Survey officers, the single most important contributor to the study of the Upper Carboniferous geology of South Wales during the first half of the century was Trueman. His significance is two-fold. Firstly, he and his colleagues introduced rigorous biostratigraphical methods. Although non-marine bivalve fossils had been previously recorded from the area (Hind, 1894–1905), most attempts at stratigraphical correlation were based on lithological comparisons. Trueman was the first to use bivalves for detailed biostratigraphical work (e.g. Davies and Trueman, 1923; Dix and Trueman, 1924; Trueman and Ware, 1932; Trueman, 1933). His contribution to this field has been usefully summarized by George (1974).

Trueman's other main contribution was to encourage students to investigate the area. Outstanding amongst these was Dix who, as well as studying the non-marine bivalves, made major advances in our understanding of the plant fossils of the area (Dix, 1933, 1934, 1937). Also, Moore made significant contributions to the detailed correlations of the strata, especially in the eastern part of the area (Moore, 1945, 1948; Moore and Cox, 1943; Moore and Blundell, 1952; Sullivan and Moore, 1956).

Most of the work mentioned so far deals with the Coal Measures. The Millstone Grit of South Wales was for many years not treated with the same interest, presumably because of its lesser economic importance. The group was mentioned in the various Survey memoirs, and there were also a few isolated publications describing the geology (e.g. Evans and Jones, 1929; Ware, 1939). However, significant progress was not made until the work of D.G. Jones, who established detailed correlations over large parts of the outcrop (e.g. Jones, 1958, 1969, 1974; Jones and Owen, 1957, 1967).

More recent work on the area is reviewed by Owen (1984). Some of the most important has been by Kelling and his students. Kelling himself has concentrated mainly on the sedimentology of the Rhondda Beds in the lower South Wales Pennant Formation (e.g. Kelling, 1964, 1968, 1969), although he has also published some more wide-ranging accounts on the Upper Carboniferous sedimentology and basin-evolution of the area (Kelling, 1974, 1988). Kelling's students have also published important contributions on the subject (Bluck and Kelling, 1963; Williams, 1968; Kelling and George, 1971; Thomas, 1974). Perhaps of greatest significance, however, are the unpublished theses produced by his students, which provide the most comprehensive accounts of the field geology of the respective areas surveyed by them (Bluck, 1961; Williams, 1966; Thomas, 1967; Oguike, 1969; G.T. George, 1970).

Lithostratigraphy

It has been accepted for many years that the Upper Carboniferous of South Wales is divisible into two major units, referred to here as the Millstone Grit and Coal Measures groups. The most widely used formational classification was introduced in the first editions of the Geological Survey memoirs for the area (Strahan, 1899, 1907a, 1907b; Strahan and Gibson, 1900; Strahan and Cantrill, 1902, 1904; Strahan *et al.,* 1903, 1904, 1907, 1909, 1914; Cantrill *et al.,* 1916; Dixon, 1921). A revised classification for the Coal Measures was proposed by Stubblefield and Trotter (1957) and Woodland *et al.* (1957), but this was somewhat of a hybrid scheme, with greater emphasis being given to ensuring that the formational boundaries were isochronous, than to reflecting the lithological variations of the sequence. There is clearly no point in duplicating the internationally recognized Heerlen chronostratigraphy, and the revised scheme certainly fails to express the lithological variations. For this reason, this review has reverted largely to the earlier classifications, as follows.

Basal Grit Formation

Stratotype: Vale of Neath

Base defined: lowest coarse sandstone in the Millstone Grit.

Characteristic facies: medium to coarse sandstones often with low-angle trough cross-bedding, with subsidiary beds of dark, ammonoid-bearing mudstones.

Chronostratigraphical range: Arnsbergian to Marsdenian.

Middle Shales Formation

Stratotype: Marros Sands

Base defined: base of mudstone representing the start of the lowest coarsening-upwards cycle above the Basal Grit Formation.

Characteristic facies: dark mudstones and siltstones, including some marine bands, and with subsidiary sandstones.

Chronostratigraphical range: Marsdenian to Yeadonian in the west of the basin, extending up to the Langsettian in the middle and east.

Farewell Rock Formation

Stratotype: Nant Llech

Base defined: erosive base of massive sand stone overlying the Subcrenatum Marine Band.

Characteristic facies: massive, trough cross-bedded sandstone.

Chronostratigraphical range: lower Langsettian.

Bishopston Formation

Stratotype: Barland Common

Base defined: base of lowest Namurian mudstone lying unconformably on Carboniferous Limestone.

Characteristic facies: mudstones of mainly marine or littoral origin, and with only occasional thin ribs of sandstone. Chronostratigraphical range: Chokierian to Marsdenian in the middle part of the south crop, extending up to the Yeadonian in the west.

Upper Sandstone Formation

Stratotype: Tenby–Saundersfoot Coast

Base defined: base of thick fluvial sandstone above the *Anthracoceratites* Marine Band. Characteristic facies: massive, trough cross-bedded sandstones, with occasional, thin marine shales.

Chronostratigraphical range: Yeadonian.

Productive Coal Formation

Stratotype: Cwm Gwrelych–Nant Llyn Fach Base defined: base of lowest mudstone above Farewell Rock Formation

Characteristic facies: coals, mudstones and siltstones, with subsidiary sandstones.

Chronostratigraphical range: Yeadonian (south crop) to Langsettian (north crop) at the base, ranging up to upper Bolsovian.

South Wales Pennant Formation

Stratotype: no specific site is designated, but the sequences exposed along the Rhondda Valley may be regarded as typical

Base defined: base of first thick sandstone bed above the Cambriense Marine Band.

Characteristic facies: mainly thick bedded, coarse-grained sandstones of the so-called 'Pennant-type', with some intervals of coals and mudstones.

Chronostratigraphical range: upper Bolsovian to upper Westphalian D.

Grovesend Formation

Stratotype: Penllergaer Railway Cutting; although this does not show the base of the formation, it is the best available sur face outcrop of part of the formation

Base defined: base of mudstone, siltstone and coal interval overlying the thick sandstones of South Wales Pennant Formation.

Characteristic facies: mainly mudstones, siltstones and coals; strata usually grey, but sometimes showing evidence of readening.

Chronostratigraphical range: upper Westphalian D to lower Cantabrian.

Comment: this is not the same as the Suprapennant Formation of the Forest of Dean, which occupies a different strati graphical position (Cleal, 1992).

Forest of Dean Pennant Formation

Defined in the Forest of Dean (see Chapter 5). The existence of this formation in the eastern part of the coalfield, and which is distinct from the South Wales Pennant Formation found further west, is based on Cleal (1992).

The relative positions of these formations in South Wales is summarized in (Figure 4.2). There are other formations recognizable, such as the Llanelen Sandstone in the Marsdenian of the Gower (Ramsbottom *et al,* 1978), but they are not present in any of the sites covered in this review and so are not dealt with further here.

For convenience, the Productive Coal Formation is divided into lower, middle and upper members, with their junctions placed at the Vanderbeckei and Cambriense marine bands. This is based essentially on the proposals of Stubblefield and Trotter (1957). However, it should be noted that the Upper Productive Coal Member is only present in the eastern part of the coalfield. In the central part of the basin, strata above the Cambriense Marine Band belong to the South Wales Pennant Formation.

The subdivisions of the South Wales Pennant Formation proposed by Woodland *et al.* (1957) have also been retained in a modified form, as members. The Llynfi Member only occurs in the central part of the coalfield. In the eastern part, the base of the South Wales Pennant Formation is taken to be in the Rhondda Member, and the strata there that are coeval with the Llynfi Member assigned to the upper member of the Productive Coal Formation. The 'Grovesend Beds' of Woodland *et al.* have been raised in rank to formation, for the argillaceous beds above the South Wales Pennant Formation on the north crop.

Geological setting

The Upper Carboniferous of South Wales is the remains of an extensive fluvio-delatic system, occupying an area of downwarp on the southern margins of the Wales–Brabant Barrier. According to Kelling (1988), both this crustal downwarping and the associated uplift of neighbouring areas that provided the sediment-sources, were the result of nappe-loading as the Variscan Front migrated north.

The South Wales sequences represent progressively more proximal deposits, indicating the progradation of the delta (Figure 4.3). The dominant sediments are mudstones and siltstones, representing mainly pro-delta and littoral deposits in the Namurian (Middle Shales Formation), lower and then middle delta-plain deposits in most of the Westphalian (Productive Coal Formation), and upper delta-plain deposits in the uppermost Westphalian and Stephanian (Grovesend Formation). The delta was frequently flooded during the Namurian by eustatic rises in sea-level (Ramsbottom, 1978). Marine influence declined during the Westphalian and seems to have entirely disappeared by the upper Bolsovian. Kelling (1974) argued on sedimentological grounds that some of the lower South Wales Pennant Formation might be littoral or lagoonal deposits, but the highest strata to yield marine fossils, the Cambriense Marine Band, are mid-Bolsovian (Ramsbottom's (1984) suggestion that the estheriids found in the South Wales Pennant Formation were evidence of brackish conditions is not supported by the study by Vasey, 1985).

Imposed on this pattern of mainly mud/silt deposition were periodic inundations of alluvial sands. Sands form a natural part of any deltaic sedimentary system, in particular as distributary channel deposits. However, the main sandstone intervals of the South Wales basin seem to have been generated by exceptional, probably tectonic processes. The most significant produced the following formations.

1. Basal Sandstone Formation. This represents the first influx of sediment into the basin. Mainly derived from the north, it is thought to have been a result of uplift of the Wales–Brabant Barrier, which in turn was a response to the crustal downwarping that produced the basin (Kelling, 1988). It was coeval with the first influx of sands from the Wales–Brabant Barrier into the southern part of the Central Province, such as north Staffordshire. However, it was significantly earlier than the appearance of the northerly-derived deltas (e.g. Kinderscout delta), that did not reach most of the Central Province until the Kinderscoutian.
2. Farewell Rock Formation. This again represents sediments mainly derived from the Wales–Brabant Barrier to the north (Bluck, 1961). They were probably generated by an early Langsettian pulse of uplift of this landmass, which also caused slumping of coeval mudstones in Pembrokeshire (Kuenen, 1949). However, it seems to have been an essentially local event, with little evidence of major tectonic activity elsewhere, even in the closely related Bristol–Somerset basin.
3. South Wales Pennant Formation. This marks a significant change in the depositional pattern in the basin, with the major sediment source changing from north to south. Also, particularly in the southern part of the basin, the sediment becomes significantly more proximal in nature (Kelling, 1974). The late Bolsovian uplift of land to the south that caused this change correlates with the basin inversion and tectonic deformation of the Culm Trough (present-day Devon and Cornwall), which in turn is thought to reflect a northwards migration of the Variscan Front (Kelling, 1988).
4. Forest of Dean Pennant Formation on the east crop. Mid-Westphalian D tectonic uplift of the Usk Axis has resulted in a non-sequence on the eastern margins of the basin. However, the newly uplifted area provided a fresh source of Pennant-like sediment, that extended over this eastern area in the late Westphalian D and probably early Cantabrian (Cleat, 1992). In contrast, the southern source seems to have ceased producing the coarse alluvial sands in the late Westphalian D, and so the South Wales Pennant Formation gives way to the Grovesend Formation in the main part of the basin. The middle to late Westphalian D timing of these changes is of interest, as it is coeval with the so-called Leonian phase of tectonic activity recognized elsewhere in Europe, such as Spain (Wagner, 1966), Poland (Kotas, 1985), the former Czechoslovakia (Wagner, 1977), the French Alps (Haudour and Sarrot-Reynauld, 1960), and the English Midlands (Cleal, 1987).

There must have been a close relationship between the South Wales basin, and the Upper Carboniferous deposits of the Bristol–Somerset area, since both have broadly similar histories of sedimentation. Little detailed evidence of the sedimentology of the latter area is available, however, and so a full comparison is impossible.

GCR site coverage

This has been based around a series of key sites that show, as far as possible, complete Upper Carboniferous sequences in the main parts of the basin. They are as follows.

1. North crop (Pembrokeshire)

(a) Marros Sands (Kinderscoutian–Langsettian)

(b) Amroth Coast (Langsettian–Duckmantian)

(c) Nolton Haven (Bolsovian–Westphalian D)

2. North crop (central part of basin)

(a) Vale of Neath (?Chokierian–Langsettian)

(b) Nant Llech (Langsettian)

(c) Cwm Gwrelych–Nant Llyn Fach (Langsettian–Bolsovian)

3. East crop

(a) Llamarch Dingle (Marsdenian–Langsettian)

(b) Brynmawr Road Cutting (Langsettian)

(d) Wern Ddu (Langsettian–Bolsovian)

(e) Coed-y-Darren (Bolsovian)

4. South crop (central part of basin)

(a) Barland Common (Chokierian–Marsdenian)

5. South crop (Pembrokeshire)

(a) Tenby–Saundersfoot Coast (Chokierian–Langsettian)

Arranged around this network of key sites, are a group of other localities demonstrating specific palaeontological (Lower House Stream Section, Cwm Twrch) or sedimentological (Earlswood Road Cutting, Blaenrhondda Road Cutting, Trehir Quarry, Penllergaer Railway Cutting) features.

There remain a number of major gaps in the coverage. In the case of the Productive Coal Formation on the south crop, and the Grovesend Formation on the north crop, this is due to poor exposure. Exposure of the South Wales Pennant Formation on the north crop, however, is generally excellent. The lack of sites demonstrating this part of the Upper Carboniferous is due to the absence of detailed biostratigraphical or sedimentological work on the surface exposures, the only notable exception being Kelling's (1964, 1968, 1969) sedimentological analysis of the Rhondda Member. There is clearly much scope for future work here.

References

The Upper Carboniferous outcrops in South Wales in an elongate area about 75 km long and up to 16 km wide (Figure 4.1). The main part of the outcrop extends from Pontypool in the east to near Kidwelly in the west. Carmarthen Bay separates this from a smaller area of outcrop in Pembrokeshire. With the exception of the Iberian Peninsula (Lemos de Sousa and Oliviera; 1983, Martinez Diaz, 1983), South Wales provides by far the best exposed sequences of non-marine Upper Carboniferous in Europe. Good coastal exposures occur in Pembrokeshire, complemented by numerous inland exposures in the main area of outcrop. At one stage, South Wales was being considered as a potential stratotype for at least part of the Westphalian Series (George and Wagner, 1970, 1972). Rather strangely, the working group of the SCCS investigating this matter could not find any suitable exposures there and so opted for the much smaller outcrops in the Pennines (Calver *in* George and Wagner, 1972, p. 147). Nevertheless, in view of the extent of the outcrop, and the quality of the non-marine faunas and macrofloras, South Wales remains a key area for Upper Carboniferous stratigraphy.

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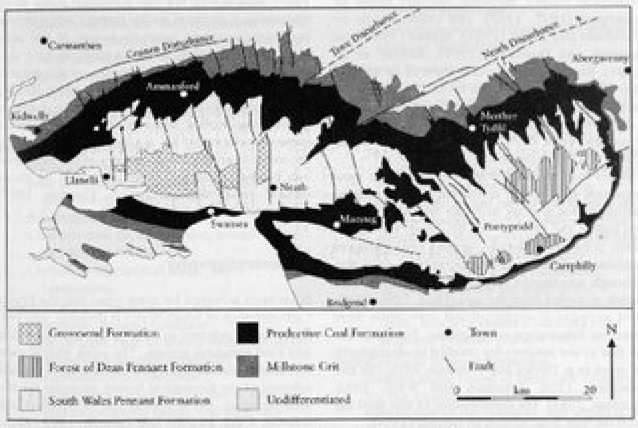

Figure 4.1 Map of the Upper Carboniferous of South Wales. Based on George (1970).

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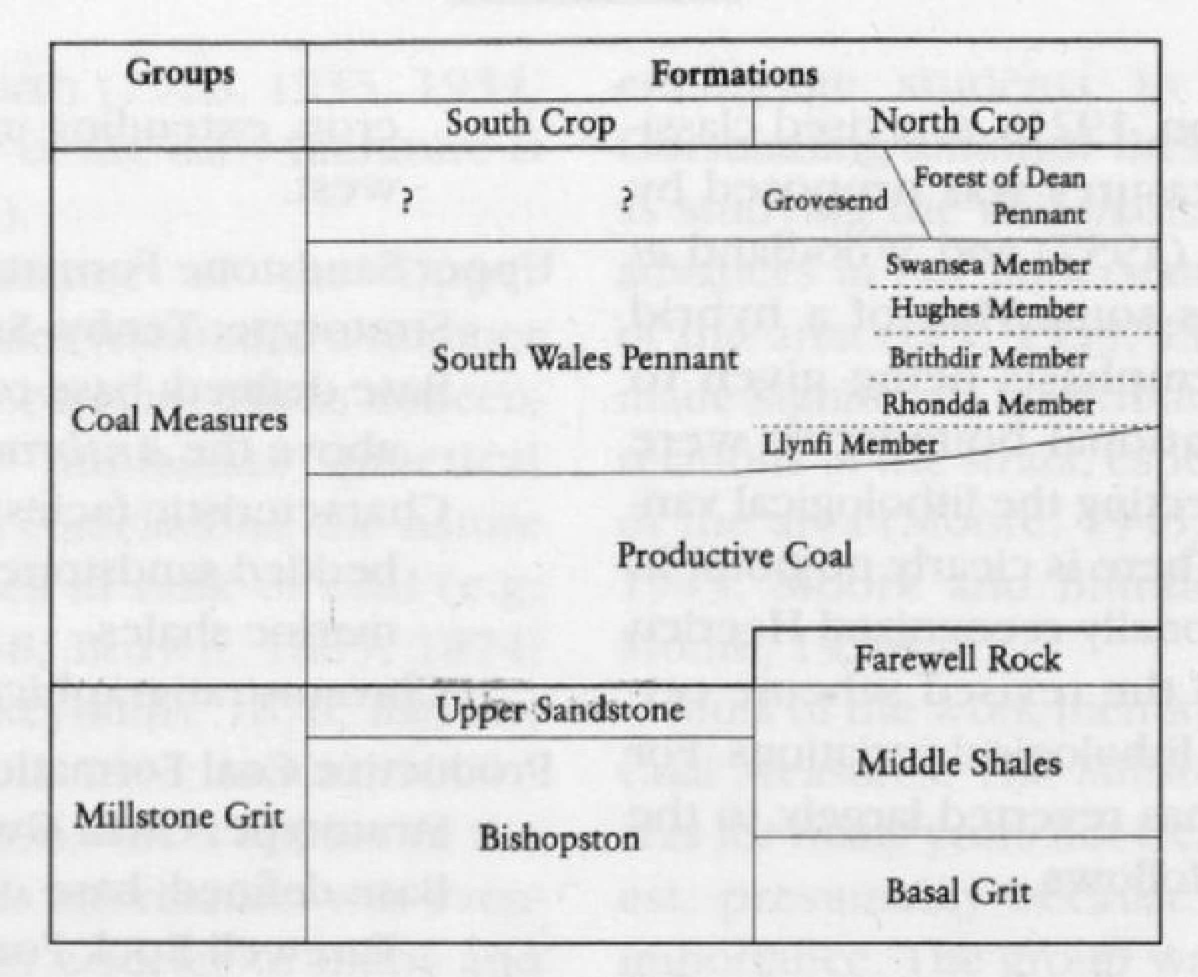
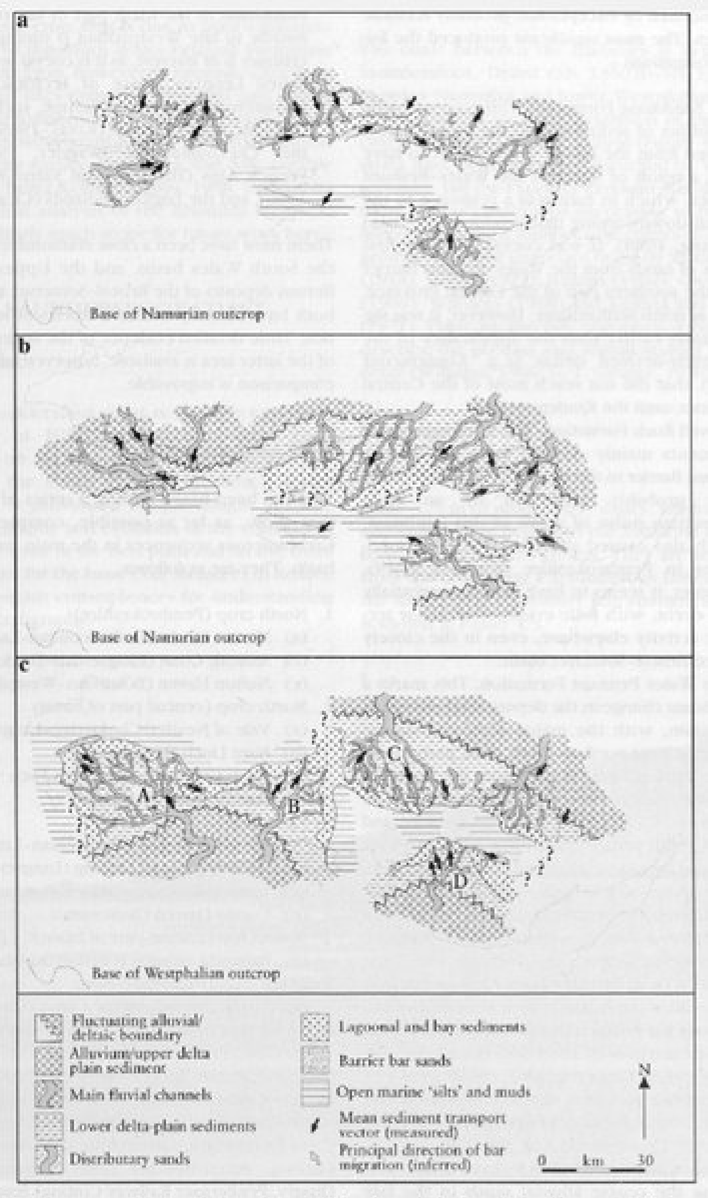


(Figure 4.2) Formational classification of the Upper Carboniferous of South Wales.



(Figure 4.3) Palaeogeographical evolution of South Wales through the Late Carboniferous. (a) Kinderscoutian; (b) Yeadonian; (c) Duckmantian — note that whereas deltaic complexes A and B were most fully-developed in the early part of this time interval, delta-lobes C and D were more prcminent in the period immediately preceeding the Cefn Coed marine transgression. Based on Kelling (1974, figs 45–7).