Chapter 9 South Wales–Mendip Shelf

A.E. Adams, V.P. Wright and P.J. Cossey

Introduction

The South Wales–Mendip Shelf area embraces Dinantian outcrops in an area some 200 km in greatest extent, from the shores of Milford Haven in the west, through South Wales to the Forest of Dean, and across the River Severn to Bristol and the Mendips, with the most southeasterly exposures found near Frome in Somerset (Figure 9.1). In South Wales, strata are folded into a giant syncline, which becomes more complex westwards into Gower and Pembrokeshire. This allows the distinction between the broadly southerly dipping north crop, running from Haverfordwest to Abergavenny, and a broadly northerly dipping south crop, running from the Pembroke Peninsula to north of Cardiff. The syncline closes at its eastern end, allowing delineation of an *east* crop which is much attenuated in thickness as a result of erosion prior to deposition of the Namurian Series (Figure 9.1).

In the Forest of Dean, Lower Carboniferous strata surround the synclinal coalfield, except in the south-east where they are overstepped by the Upper Carboniferous sequence, and there is an extension of the outcrop south-westwards to Chepstow and Magor. An isolated outcrop occurs 60 km to the north of the Forest of Dean at Titterstone Clee. East of the Severn, Lower Carboniferous rocks rim the north side of the Bristol Coalfield, cropping out in an arc from Alveston to Chipping Sodbury. Around the Bristol area, Lower Carboniferous rocks occur in a number of inliers, and to the south, form the spine of the Mendips running for more than 50 km from the Bristol Channel coast to Frome. Isolated outcrops occur on Flat Holm and Steep Holm, islands In the Bristol Channel, and to the south at Cannington, west of Bridgwater (Figure 9.1).

Exposures vary from the superb shoreline sections of Gower and Pembrokeshire (although access to these can be limited by the steepness of the cliffs), to weathered inland exposures such as those of Burrington Combe and Cheddar Gorge in which details of fauna and lithology can be difficult to distinguish. The Carboniferous Limestone has been extensively quarried and most of the best inland exposures are in disused or working quarries. These range from small quarries which produced stone for local use, to the vast quarry complexes of ARC and Foster Yeoman in the Mendips, which supply aggregate to much of southern England, and to the largely disused quarries of the north crop between Abergavenny and Merthyr Tydfil used formerly to supply flux to the now-defunct local iron and steel industry and more recently in the supply of aggregate to the South Wales area.

History of research

The original geological survey of this area leading to the production of maps at a one-inch-to-a-mile scale was undertaken in the mid-19th century. The main results of the survey were summarized by De la Beche (1846). During the late 19th century and early 20th century, mapping at a six-inches-to-a-mile scale was undertaken, and the first editions of sheet memoirs were published, much of it under the guidance of Mr (later Sir) Aubrey Strahan. These included the 13 parts of *The Geology of the South Wales Coalfield,* which began with the Newport area (Strahan, 1899). Other early memoirs in this series that have descriptions of Lower Carboniferous rocks include Abergavenny (Strahan and Gibson, 1900), Cardiff (Strahan and Cantrill, 1902), Merthyr (Strahan *et al.,* 1904), Bridgend (Strahan and Cantrill, 1904), Ammanford (Strahan *et al.,* 1907) and Swansea (Strahan, 1907a).

East of the Severn, after the initial survey the most important contribution in the 19th century was the publication of the explanatory memoir on the Bristol and East Somerset coalfields (Woodward, 1876). Other 19th century work included Morgan (1889) and Winwood (1889) on sections in the Tytherington area. The publication of Arthur Vaughan's seminal account on the faunal zonation of the Carboniferous Limestone, based on his work in the Avon Gorge (Vaughan, 1905, 1906), marked a turning point in stratigraphical studies and a stimulus to many other researchers who applied his scheme to rock successions throughout the area. This included the remaining memoirs in the series *The Geology of the South Wales Coalfield,* namely those for West Gower (Strahan, 1907b), Carmarthen (Strahan 1909), Haverfordwest

(Strahan *et al.,* 1914), Milford (Cantrill *et al.,* 1916) and Pembroke and Tenby (Dixon, 1921). At the same time, second editions of the Newport and Cardiff memoirs, incorporating an application of Vaughan's zones, were published (Strahan, 1909; Strahan and Cantrill, 1912). Other important works on the Carboniferous Limestone of South Wales, which built upon Vaughan's contribution at this time, were by Dixon and Vaughan (1911) on Gower, Dixey and Sibly (1918) on the south-eastern part of the area, and Sibly (1920) on the Cardiff area.

In the Bristol, Weston-super-Mare and Mendips area, many publications built on the work of Vaughan, notably those of Sibly (1905a,b, 1906), Reynolds and Vaughan (1911), Bamber (1924), Bush (1925, 1929) and Welch (1929, 1933) on the Mendips; Reynolds and Innes (1914) and Wallis (1924a) on the area to the north of Bristol; and Reynolds (1918, 1920, 1921, 1926, 1936) mainly on the area around Bristol and south-west to Clevedon. The limestones of the inlier at Cannington Park were described by Wallis (1924b). In the Forest of Dean, the early work of Wethered (1883, 1886, 1888) was followed by the contributions of Sibly (1912, 1918, 1919) and Sibly and Reynolds (1937). The succession at Titterstone Clee was described by Dixon (1917).

One of the most significant contributors to our understanding of the structure, stratigraphy and depositional history of the Carboniferous Limestone in South Wales was T. Neville George, whose publications on the area span more than 50 years. Important works include George (1927, 1954) and Robertson and George (1929) on the north crop, George (1933) on the western part of the Vale of Glamorgan, George (1956a) on the east crop, George (1956b) on the Usk Anticline and Titterstone Clee, and George (1940, 1978b) on Gower. George (1958), on the Lower Carboniferous palaeogeography of the British Isles, contains substantial information on the whole of the area covered by this chapter. A review of the Dinantian geology of South Wales was also published (George, 1974).

Second editions of the memoirs for Abergavenny and Merthyr were produced (Robertson, 1927, 1933) and subsequent memoirs include those for the Forest of Dean and surrounding areas (Trotter, 1942; Welch and Trotter, 1961), Wells and Cheddar (Green and Welch, 1965); and the third edition for Newport (Squirrel and Downing, 1969). In recent years, new memoirs or editions of memoirs for a number of areas have been published, such as Taunton, which includes the outcrop at Cannington (Edmonds and Williams, 1985), Weston-super-Mare (Whittaker and Green, 1983), Cardiff (Waters and Lawrence, 1987), Merthyr (Barclay *et al.,* 1988), Abergavenny (Barclay, 1989), Bridgend (Wilson *et al.,* 1990) and Bristol (Kellaway and Welch, 1993).

Other contributions to our knowledge of the structure and stratigraphy of the Dinantian strata of the area include Kellaway and Welch (1955) who reviewed stratigraphical nomenclature in the eastern part of the area; Evans and Cox (1956) and Gayer *et al.* (1973) on the basal Carboniferous Limestone to the north of Cardiff; Owen and Jones (1961) on the Neath disturbance; R. Sullivan (1964, 1965, 1966) on aspects of the Dinantian succession in Pembrokeshire; Rhodes *et al.* (1969) and Butler (1972, 1973) on conodont faunas around Bristol and the Mendips; Dolby (1970), Dolby and Neves (1970), Utting and Neves (1970) and Higgs and Clayton (1984) on Tournaisian miospore assemblages from the Bristol and Mendips area; and H.J. Sullivan (1964a,b) and Spinner (1984) on miospore and megaspore assemblages from the Forest of Dean. Other faunal studies include those of Batten (1966) on gastropod faunas from the Hotwells Limestone, Mitchell (1971, 1972, 1981, 1993) mostly on the Bristol and Mendips area, Mitchell *et* al. (1986) on Tournaisian–Viséan boundary rocks in Gower, Strank (1981) on the foraminiferal faunas of various sections across the region, and Austin (1987) and Simpson and Kalvoda (1987) on the Arundian type section in southern Pembrokeshire. Contributions on the palaeobotany of the Lower Carboniferous succession in the Forest of Dean area are by Cleal (1986), Rowe (1988) and Cleal and Thomas (1995). The Carboniferous Limestone north of Bristol was described by Murray and Wright (1971), and aspects of the Courceyan and Chadian stages of the eastern part of the Vale of Glamorgan by Waters (1984). The Knap Farm Borehole at Cannington, which proved Lower Carboniferous strata to a depth of more than 1100 m, was described by Whittaker and Scrivener (1978, 1982), Lees and Hennebert (1982) and Mitchell *et al.* (1982).

Namurian strata of the area are described in the memoirs mentioned above. The lower part of this succession is, at least in some places, demonstrably of Pendleian and Arnsbergian age, and hence falls within the remit of this volume.

Papers that include a discussion of the stratigraphy of the lower part of the Millstone Grit and the contact with the Carboniferous Limestone include Owen (1954), Jones and Owen (1957), Archer (1965) and Ramsbottom (1971). The Namurian succession of South Wales was reviewed by Jones (1974) and Kelling (1974) and the large-scale cyclicity

interpreted by Ramsbottom (1978b). Upper Carboniferous GCR sites in the area are described by Cleal and Thomas (1996).

Our understanding of depositional environments and diagenesis of Lower Carboniferous strata in the area has been dramatically improved by the expansion in geological research during the last 30 years. This has been particularly true in South Wales, but the Forest of Dean and the Bristol and Mendips areas have not received the same degree of attention. Many research theses (MPhil, MSc and PhD) have involved studies of the sedimentology of Lower Carboniferous rocks in the area. These include George (1970) on the Namurian rocks of Pembrokeshire, Kirkham (1976) on the Clifton Down Limestone, Burchette (1977) and Lovell (1978) on the Lower Limestone Shale, Thorne (1978) on the Oxwich Head Limestone, Jeffreys (1979) on the volcaniclastic and carbonate rocks at Weston-super-Mare, Wright (1981a) on the Llanelly Formation, Spalton (1982) on terrestrial deposits, Atta-ntim (1984) on the Drybrook Sandstone, Raven (1983) on the diagenesis of the Oolite Group, Simpson (1985a) on the Arundian Stage, Searl (1986) on the diagenesis of oolites, Hird (1986) on dolomitization, Weedon (1987) on the Clifton Down Mudstone, Scott (1988) on the Holkerian Stage, Faulkner (1989a) on the Black Rock Limestone Group, and Vanstone (1993) on palaeosols. Publications resulting from this postgraduate research include Kelling and George (1971), Burchette and Riding (1977), George and Kelling (1982), Simpson (1985b, 1987), Burchette (1987), Hird *et al.* (1987), Faulkner (1988, 1989b), Hird and Tucker (1988), Searl (1988a,b,c, 1989a,b), Faulkner *et al.* (1990) and Vanstone (1991, 1996).

'itvo authors stand out as having made a particularly significant contribution to our understanding of Dinantian environments in South Wales. Ramsay (1987, 1989, 1991) reports the results of a long-term field study of the Carboniferous Limestone with a detailed analysis of environments and controls on deposition. Wright, in a long series of papers, has made a special contribution to the understanding of subaerial exposure within marine limestone successions with many examples drawn from the Welsh Dinantian succession, as well as authoring more general papers on Lower Carboniferous environments in the area (Wright, 1980, 1981b,c, 1982a,b,c,d, 1983, 1984, 1986a,b, 1987a,b, 1988, 1990b; Riding and Wright, 1981; Wright and Wright, 1981, 1985; Wright *et* al., 1991; Wright and Vanstone, 2001).

Other contributions to the sedimentology and palaeoecology of the Lower Carboniferous succession of the South Wales–Mendip Shelf include Kelling and Williams (1966) on sedimentary structures in the Lower Limestone Shale of Pembrokeshire, Whitcombe (1970) on the diagenesis of the Lower Limestone Shale, Bhatt (1975, 1976) on evidence for evaporites in the Dinantian sequence and regional petrology and geochemistry, Wu (1982) on storm deposits and trace fossils, and Beus (1984) on faunas in the High Tor Limestone.

Stratigraphy

In early surveys of the area, the major units recognized included the Lower Limestone Shale, the Main Limestone or, particularly in the Mendips, the Mountain Limestone, and the Millstone Grit. Towards the end of the 19th century and into the 20th century these units began to be subdivided, often using a mixture of lithostratigraphical terms, such as 'Gully Oolite', introduced by Morgan (1889), units named after characteristic fossils such as '*Lithostrotion* Beds', and numbered beds or groups of beds as used in Pembrokeshire by Dixon (1921). Vaughan's (1905) zonal scheme for the Carboniferous Limestone and its later revisions gave a biostratigraphical framework with which local successions could be correlated, and much effort was expended in fitting sequences from all areas into the Avonian scheme. Many anomalies remained, and facies terms such as '*Modiola* Phase', used for lagoonal limestones with an impoverished fauna, tended to be used as stratigraphical units.

Gradually, names for lithostratigraphical units across the area of the South Wales–Mendip Shelf were adopted, many as a result of the work of the [British] Geological Survey in revising maps and memoirs and also as a result of the report on Dinantian stratigraphy by George *et al.* (1976). In this report, a series of regional stages for the Dinantian rocks of Britain was proposed, with the type section of one of them, the Arundian Stage (at Hobbyhorse Bay, Pembrokeshire; see Blucks Pool–Bullsaughter Bay GCR site report, this chapter), within the area covered by this chapter.

Since this chapter covers an area of 200 km from west to east, and great changes in facies and thickness occur from north to south, a large number of names of varying geographical application have been proposed. Those in most common use are tabulated in (Figure 9.2). Some features of this table call for comment. The Caswell Bay Mudstone was

originally regarded as being of Chadian age (e.g. George *et al.,* 1976; Whittaker and Green, 1983), but was placed in the Arundian Stage on sedimentological grounds (Riding and Wright, 1981; Wright, 1986b). Since then, there has been some variation in usage, with Ramsay (1987), for example, still regarding it as Chadian in age. Some units are demonstrably diachronous, such as the Drybrook Sandstone of the Forest of Dean (Welch and Trotter, 1961) and the Gully Oolite (Searl, 1988b). No doubt many other lithostratigraphical units are also diachronous, but it may not be possible to demonstrate it unequivocally. There are areas where there is still no uniform usage of lithostratigraphical names. On Gower, for example, the older name from the Bristol area, 'Gully Oolite' has been used by some workers (e.g. Searl, 1988a,b) to replace the local name 'Caswell Bay Oolite', which is used on the published geological map (Institute of Geological Sciences, 1973). Similarly the term 'Black Rock Limestone', taken from the Bristol area, has been applied by Mitchell *et al.* (1986) to the Gower succession, where others have used the name 'Penmaen Burrows Limestone'. Note that in this account the term 'Castel Coch Limestone' is used both as a formation name in the description of sites in the Clydach and Cardiff areas, and as the name given to a subdivision of the 'Castell Coch Formation' in the description of sites in the Forest of Dean area, in keeping with current usage (see (Figure 9.2)).

Geological setting

The whole area under consideration In this chapter formed an area of carbonate-dominated sediment deposition in relatively shallow water lying between the Wales-Brabant Massif (St George's Land of earlier workers) to the north and the deep waters of the CuIm Trough to the south. No single name to embrace the whole area is in general use, but for convenience we have adopted the term 'South Wales–Mendip Shelf' in this work. The succession thickens markedly from the north crop of the South Wales Coalfield to the south crop, Gower and southern Pembrokeshire ((Figure 9.3)a) and from the Forest of Dean to Bristol and the eastern Mendips ((Figure 9.3)b). The thickest known Dinantian succession in this area is on the south side of the Pembroke Peninsula where upwards of 1500 m of Dinantian strata are exposed (George, 1974).

At the base of the Carboniferous succession there is a gradual transition from Old Red Sandstone facies to marine limestones and shales but it is often difficult to establish the exact position of the Devonian–Carboniferous boundary. North of Cardig the facies change appears to be more-or-less coincident with the system boundary, but in Pembrokeshire (Skrinkle Sandstone) and around Bristol (Shirehampton Beds) Old Red Sandstone facies have been dated as extending into the Courceyan Stage (Bassett and Jenkins, 1977).

For the Courceyan to Arundian interval, Wright (1986a) interpreted the area as a southerly dipping carbonate ramp. The inner ramp is represented on the north crop of the South Wales Coalfield, and consists of a thin succession of oolitic carbonate sand-bodies and peritidal limestones, with evidence of repeated episodes of subaerial exposure and non-sequence. Occasional uplift resulted in fluvial incision. The mid-ramp facies found over much of the south crop of the coalfield and around Bristol and the Mendips comprises bioclastic limestones, probably deposited below normal wave-base, but with abundant evidence of storm activity. Occasional regressive episodes led to the southwards progradation of oolitic sand-bodies such as the Gully Oolite or Caswell Bay Oolite. Deposits of the outer-ramp zone are seen in the southern part of the Pembroke Peninsula and are also known from the Knap Farm Borehole at Cannington Park (Lees and Hennebert, 1982). They comprise thick successions of muddy bioclastic limestones, often with a rich fauna (the 'zaphrentid-phase' limestones) and local developments of Waulsortian mud-mounds. Wright (1986a) regarded subsidence plus eustatic sea-level rise as the major controls on sedimentation. The Culm Trough to the south consists of basinal facies, but the transition zone between the carbonate ramp and the basinal deposits is not exposed.

Holkerian strata overstep older beds suggesting renewed subsidence or sea-level rise. A major carbonate sand-body then prograded southwards, just reaching into southern Pembrokeshire at the close of the stage. A relative sea-level fall then led to widespread subaerial exposure and non-sequence. Early Asbian strata are unknown except in southern Pembrokeshire where the base of the Crickmail Limestone contains *Daviesiella llangollensis* and early Asbian foraminifera (Swank, 1981). The Asbian and much of the Brigantian stages comprise a relatively thin succession compared with many other areas (George *et al.*, 1976). However, facies are similar to other shelf areas, with massive bioclastic and some oolitic limestones separated by palaeokarstic surfaces and palaeosol clays. Elsewhere in the British Isles it has been inferred that the early Carboniferous ramp had developed into a flat-topped shelf by Asbian times and this may have occurred also in South Wales (Wright, 1986a, 1987a). It is certainly true that relative sea-level falls have as

profound an effect on the south crop and Pembrokeshire successions as on the north crop successions at this time — a situation very different from that in the Courceyan to Arundian interval. However, the whereabouts of any contemporary margin to the South Wales–Mendip Shelf are unknown; apparently it lay to the south of all present outcrops. At the end of Brigantian times, a deepening of the environment affected all areas, with the deposition of the Upper Limestone Shales.

Within successions there are many local variations. For example, in the Forest of Dean and Bristol areas there is more coarse terrigenous clastic material than in other areas, as local rejuvenation of the Wales–Brabant Massif led to the southwards progradation of quartz sands, particularly during the Holkerian to Brigantian interval (Wilson *et al.,* 1988). In the western Mendips, around Weston-super-Mare, there are basaltic lavas and pyroclastic deposits of Courceyan and Arundian ages (Whittaker and Green, 1983: Stephenson *et al,* 2003). Examples of palaeogeographies at various times for part of the area are shown in (Figure 9.4).

Across the area, Namurian successions rest with non-sequence on Dinantian strata, although the break may be slight in the more southerly exposures such as Gower and south Pembrokeshire. In most places in South Wales, the early Namurian succession is represented by the Basal Grit, but only in south-west Pembrokeshire and possibly In west Carmarthenshire is this confirmed as beginning in early Carboniferous times (Kelling, 1974). The Basal Grit has been interpreted as a deltaic sand-body (Kelling and George, 1971). In Gower, the basal Namurian Bishopston Formation is partly of early Carboniferous age and is of open marine shale facies. Marine fossils of Pendleian age are also reported from the base of the Quartzitic Sandstone Group north of Bristol (Kellaway and Welch, 1993). A reconstruction of the early Namurian palaeogeography of South Wales is shown in (Figure 9.5).

GCR site coverage

The Lower Carboniferous limestones of this region provide one of the finest examples of an ancient carbonate ramp succession in the world. The limestones form a thick, southerly thickening wedge (Figure 9.3) with marked variations in the types of limestones deposited in different areas, reflecting original water depth differences. This is particularly the case for the Courceyan–Holkerian interval, but less so for the latest Viséan sequence. Sites were chosen both to provide coverage of key stratigraphical units and facies variations, and to illustrate specific aspects of the depositional regime and of approaches in detecting climate fluctuations, in order to provide models for research at national and international level. The later Viséan succession is somewhat different and provides examples of the effects of global climate changes and the onset of the late Palaeozoic ice age.

Sites were rarely chosen for a single reason and most have both stratigraphical and sedimentological significance. Some sites were chosen at least partly because they provided the type sections for stratigraphical units, such as Caswell Bay, Brofiscin Quarry and Llanelly Quarry. Some, such as the Avon Gorge, Tenby Cliffs, Three Cliffs Bay and Blucks Pool–Bullslaughter Bay were chosen because they provided very extensive stratigraphical sections, and also in some cases provided type sections. For example, Three Cliffs Bay is of international significance for the definition of stratigraphical models in limestone successions, and Blucks Pool–Bullslaughter Bay includes the nationally important stratotype section for the Arundian Stage. Another group of sites were selected as they offered the best examples of certain stratigraphical units, such as llston Quarry (Oxwich Head Limestone — and also illustrating the depositional style of gjacio-eustatically controlled cyclicity), Tongwynlais Road Section (Lower Limestone Shale Group), Barnhill Quarry (Clifton Down Limestone), Oystermouth Old Quarry (Oystermouth Beds) and Burrington Coombe (Black Rock Limestone Group). Others were selected because they illustrate significant facies variations that allow depositional models to be developed (e.g. Danygraig and Flat Holm) or because they contain features of specific palaeontological and/or sedimentological interest (Bracelet Bay and Pwlldu Head).

A group of sites in South Wales was chosen to illustrate the range of features that develop when limestone-producing environments are subaerially exposed following sea-level falls. These are Llanelly Quarry, Clydach Halt Lime Works, Cwar yr Ystrad and Hendre, Baltic Quarry, Odynau Tyle'r Bont and Blaen Onneu Quarry. These sites exhibit palaeokarsts, palaeosols and related terrestrial deposits, with marked variations in the successions at each site resulting from the complex phases of landscape development and climate change that took place in those areas during the Chadian–Holkerian time interval.

Central to those sites selected in southern England is the classic Avon Gorge section at Bristol where Vaughan (1905) established the first widely used biostratigraphical (coral–brachiopod) zonal scheme for the Lower Carboniferous sequence. Elsewhere, the choice of sites reflects regional variations in sedimentary facies developed across the shelf area during Early Carboniferous times.

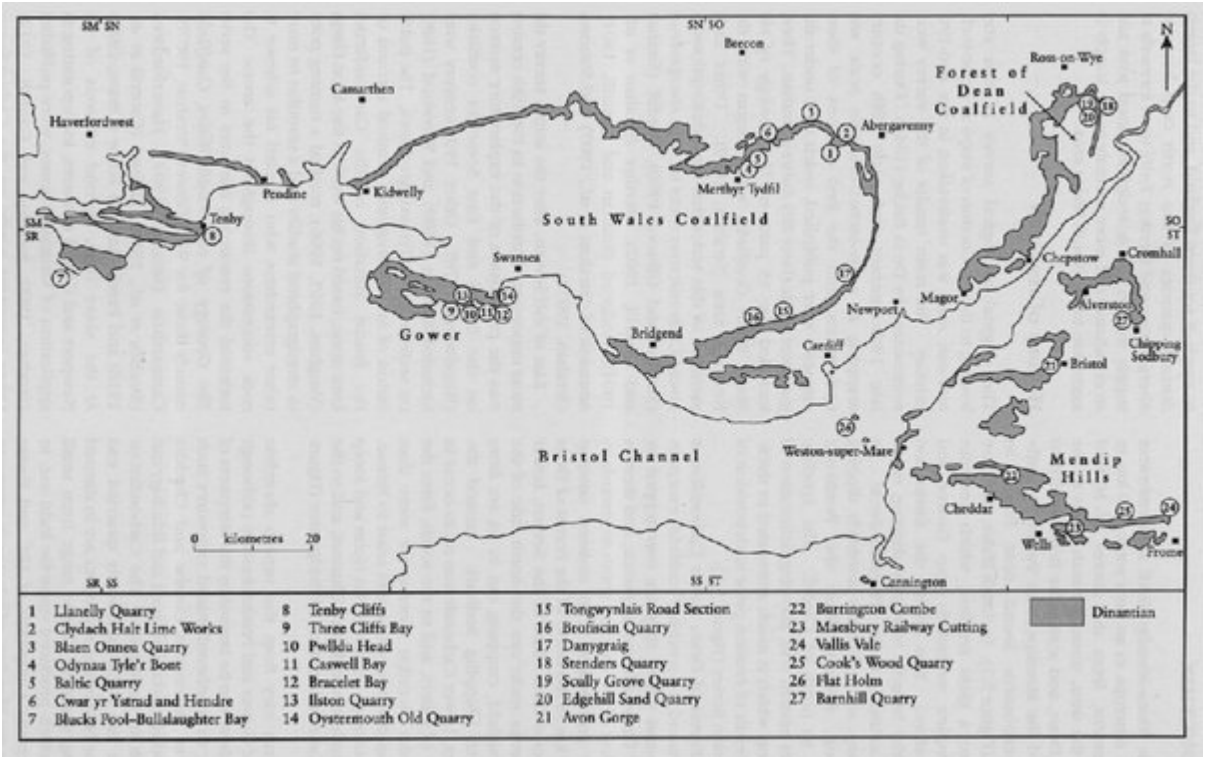
To the south, in the Mendips area, they include sites of historical, stratigraphical and sedimentological significance from the more distal parts of the carbonate ramp where successions are known to be thicker and more complete than in the Bristol district. These sites include Burrington Combe (Courceyan–Asbian, Lower Limestone Shale Group to Hotwells Limestone), Maesbury Railway Cutting (Courceyan, Lower Limestone Shale Group and lower Black Rock Limestone), Cook's Wood Quarry (Holkerian–Asbian, Clifton Down Limestone to Hotwells Limestone) and Vallis Vale (Courceyan-Arundian, upper part of the Black Rock Limestone to Vallis Limestone). The feature of particular interest at Vallis Vale is the spectacular and historically important angular unconformity between the Carboniferous Limestone and a much younger Jurassic section of the Middle Jurassic Inferior Oolite of Bajocian age. The unconformity and the Bajocian strata with which it is associated are described in detail in the *British Middle Jurassic Stratigraphy* GCR volume by Cox and Sumbler (2002). Although clearly of secondary importance to the unconfonnity, the Lower Carboniferous succession at this locality is significant because It includes a particularly thick sequence and a unique lateral facies equivalent of the Buffington Oolite (the Vallis Limestone). An account of the Lower Carboniferous rocks at Vallis Vale is given in this chapter for the sake of completeness.

North of Bristol, a more proximal ramp facies is evident In the attenuated successions of the Forest of Dean and Chipping Sodbury areas. Sites in the Forest of Dean include Stenders Quarry (Courceyan, Lower Limestone Shale Group), Scully Grove Quarry (Chadian–Arundian, Crease Limestone and Whitehead Limestone) and Edgehill Sand Quarry (Holkerian, Drybrook Sandstone), while Barnhill Quarry at Chipping Sodbury provides an outstanding section of the Holkerian Clifton Down Limestone unconformably overlain by Rhaetian deposits. The latter are described as a part of an Upper Triassic GCR site at Barnhill Quarry in a companion GCR volume *Permian and Triassic Red Beds* and *the Penarth Group of Great Britain,* by Benton *et al.* (2002).

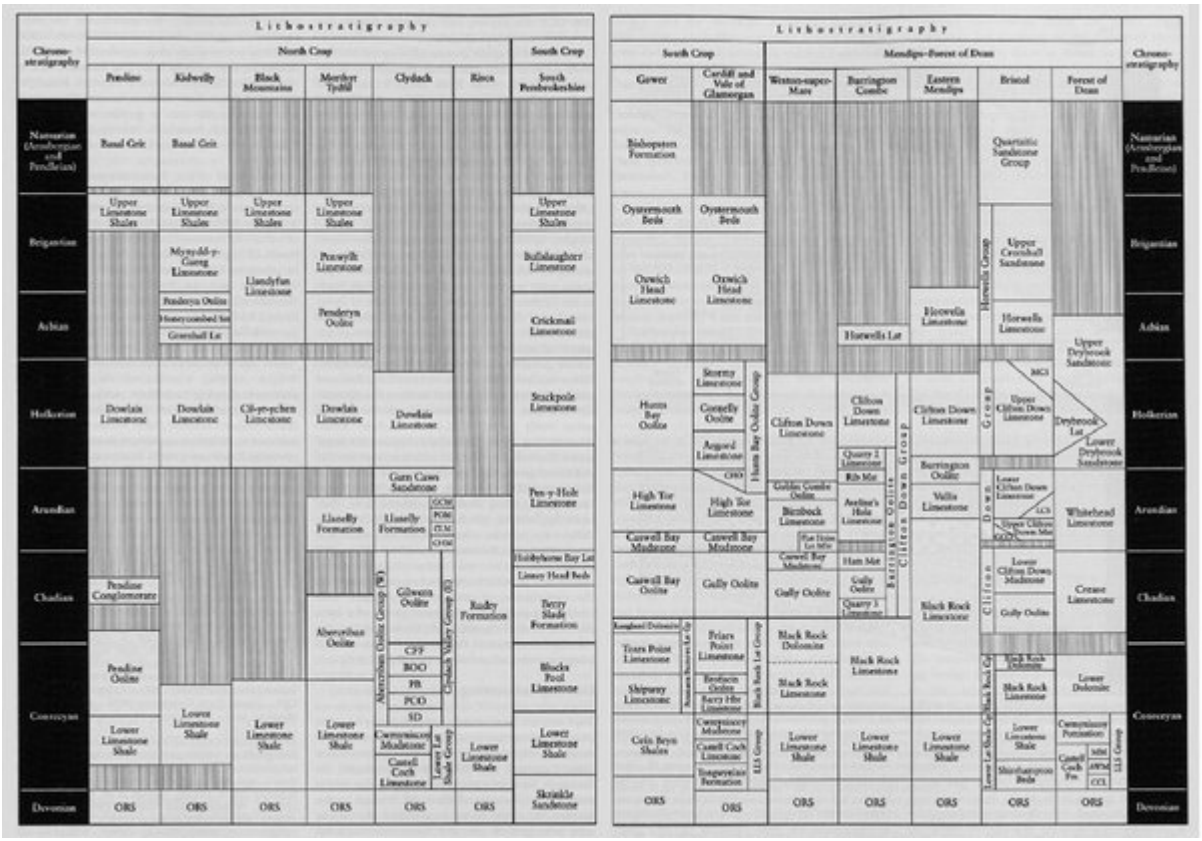
Other GCR sites of Lower Carboniferous age near Weston-super-Mare at Middle Hope (Courceyan–Chadian Black Rock Limestone-Gully Oolite) and at Spring Cove (Arundian, Birnbeck Limestone) are of interest primarily because of the spectacular volcanic rocks they contain. These are described in the GCR volume, *Carboniferous and Permian Igneous Rocks of Great Britain North of the Variscan Front* (Stephenson *et al.,* 2003).

The lack of GCR sites containing lower Namurian rocks in this chapter is partly a function of limited outcrop and exposure, and partly because substantial Pendleian–Arnsbergian sections have yet to be recognized in many areas. However, other GCR sites that may include strata of a Pendlelan and/or Arnsbergian age (e.g. Marros Sands and Barland Common) are described by Cleal and Thomas (1996) in the *British Upper Carboniferous Stratigraphy* GCR volume. Further gaps in the site coverage to be considered in the future include the representation of the Holkerian–Brigantian interval in parts of South Wales (North Crop especially), and of isolated Lower Carboniferous inners and outliers in other parts of central and southern England.

References

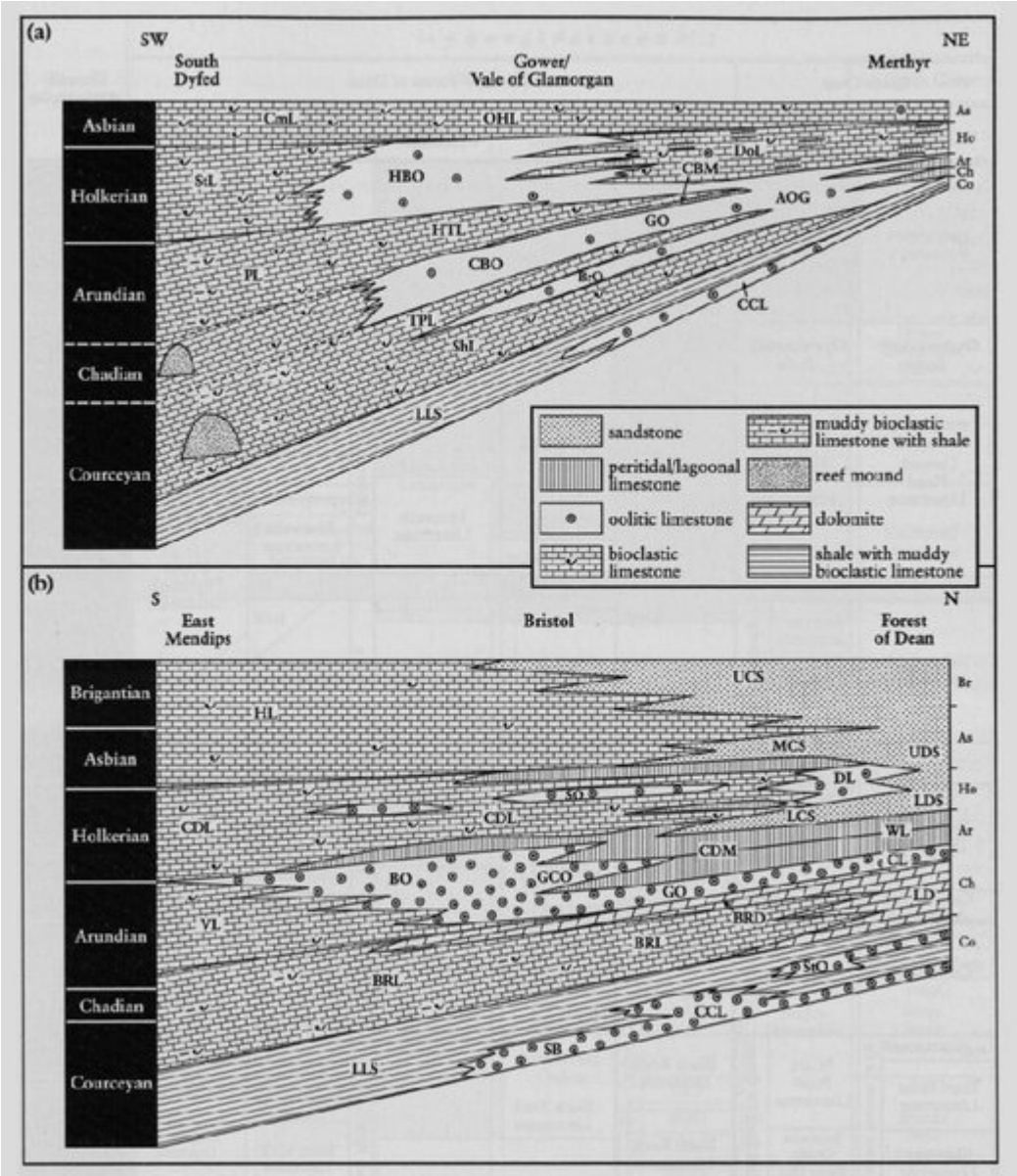


(Figure 9.1) Outcrop map showing the distribution of Dinantian strata in South Wales, Gloucestershire, Avon and north Somerset, and the locations of GCR sites described in the text. Compiled from various sources and including information from [British] Geological Survey maps of the area (principally Institute of Geological Sciences, 1979b).

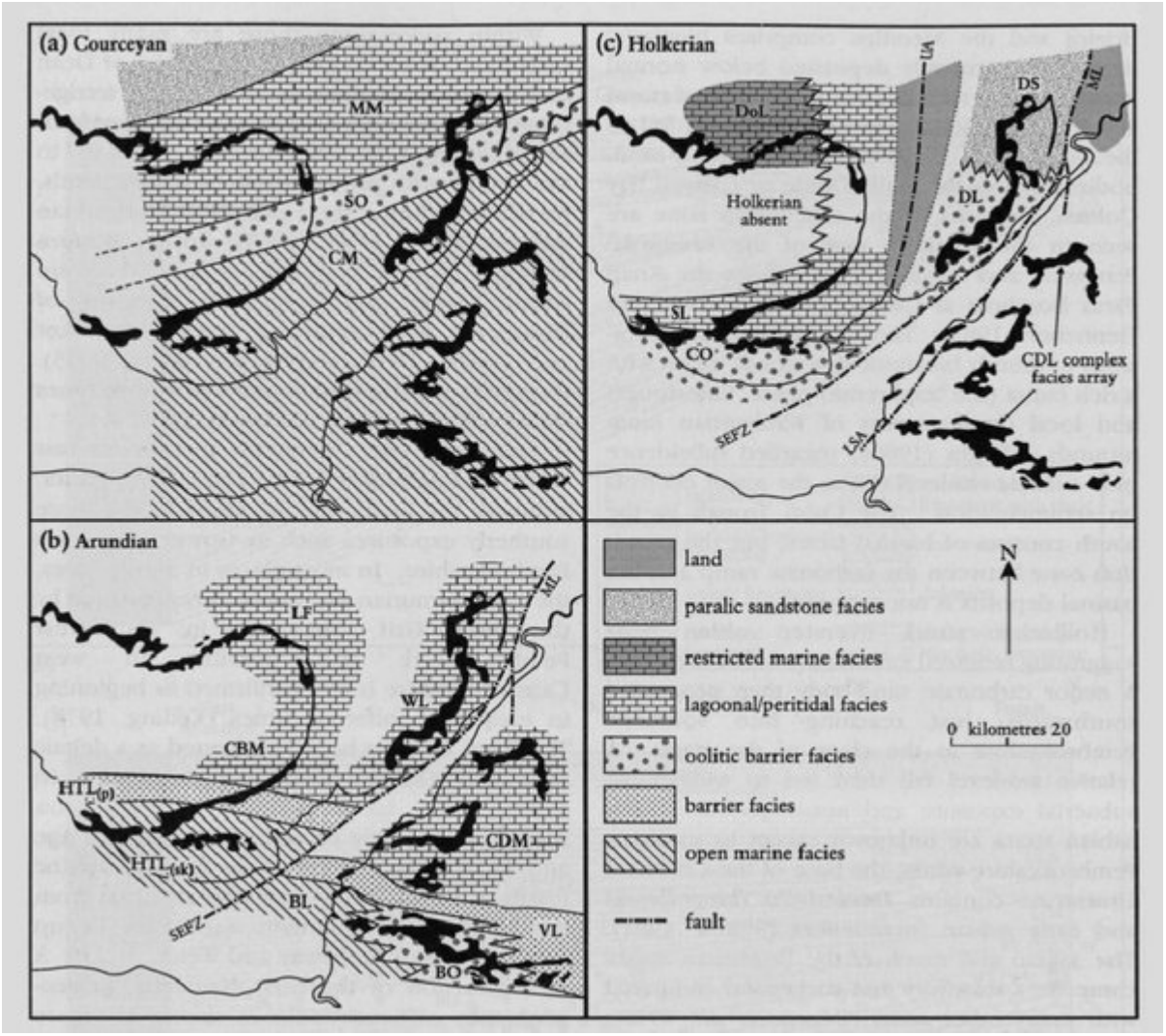


(Figure 9.2) Simplified stratigraphical chart illustrating the most widely used lithostratigraphical terms for the Lower Carboniferous sequences in South Wales, the Forest of Dean, Bristol and the Mendips. (SD — Sychnant Dolomite; PCO — Pwil y Cwm Oolite; PB — Pantydarren Beds; BOO — Blaen Onnen Oolite; CFF — Coed Ffyddlwn Formation; CHM — Clydach Halt Member; CLM —Cheltenham Limestone Member; POM — Penllwyn Oolite Member; GCM — Gilwern Clay Member; LIS —Lower Limestone Shale; CHO — Cefnyrhendy Oolite; CCL — Castell Coch Limestone; AWM — Astridge Wood Member; MM — Mitcheldean Member; GCO — Goblin Combe Oolite; LCS — Lower Cromhall Sandstone; MCS — Middle Cromhall Sandstone.) Areas of vertical ruling indicate non-sequences. Not to scale. Based on information from

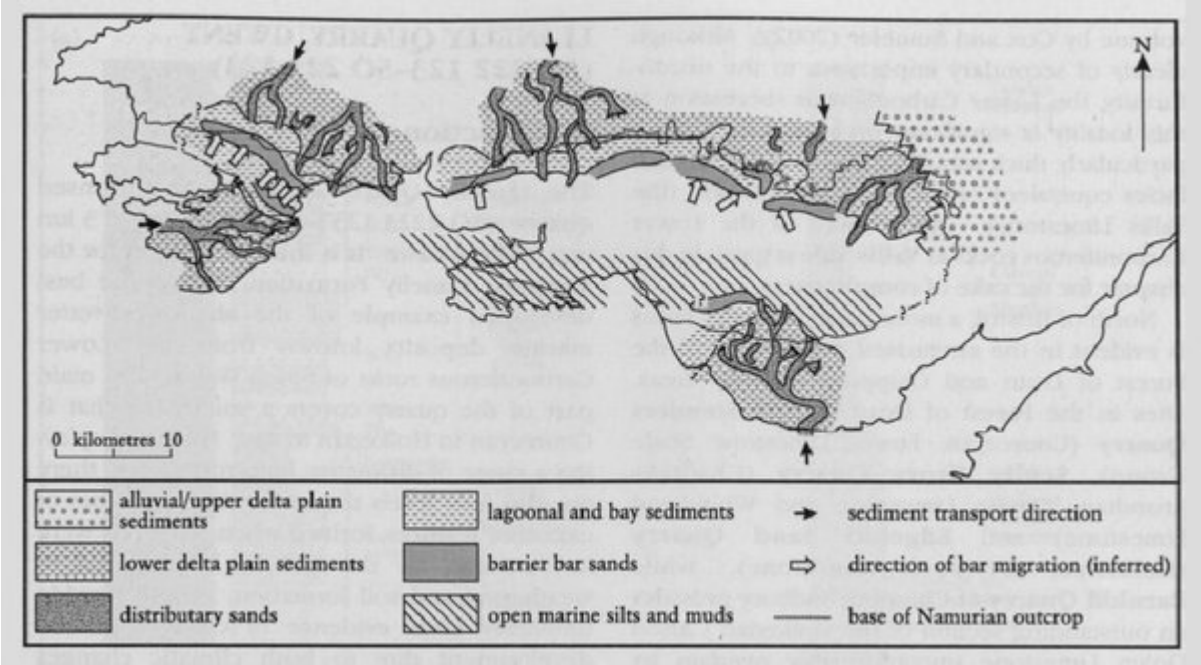
and after Welch and Trotter (1961), Green and Welch (1965), Institute of Geological Sciences (1973, 1977c), George et al. (1976), Wright (1982b), Whittaker and Green (1983), Burchette (1987), Waters and Lawrence (1987), Barclay et al. (1988), Scott (1988), Barclay (1989), Wilson et al. (1990) and Kellaway and Welch (1993).



(Figure 9.3) Simplified stratigraphical sections of Dinantian strata in south-west Britain illustrating the distribution of Dinantian lithofacies. Section (a) based on Wright (1986a) and Burchette et al. (1990); approximate length of section, 100 km. Section (b) based on information from Kellaway and Welch (1955, 1993), Burchette et al. (1990) and Green (1992); approximate length of section, 80 km. (LLS — Lower Limestone Shale; CCL — Castell Coch Limestone; ShL — Shipway Limestone; BrO — Brofiscin Oolite; TPL — Tears Point Limestone; CBO Caswell Bay Oolite; GO — Gully Oolite; AOG — Abercriban Oolite Group; CBM — Caswell Bay Mudstone; PL — Pen-y-Holt Limestone; HTL — High Tor Limestone; StL — Stackpole Limestone; HBO — Hunts Bay Oolite; DoL — Dowlais Limestone; CmL — Crickmail Limestone; OHL — Oxwich Head Limestone; SB — Shirehampton Beds; StO — Stowe Oolite; BRL — Black Rock Limestone; BRD — Black Rock Dolomite; LD — Lower Dolomite; CL — Crease Limestone; VL — Vallis Limestone; BO — Burrington Oolite; GCO — Goblin Combe Oolite; CDM — Clifton Down Mudstone; WL — Whitehead Limestone; CDL — Clifton Down Limestone; SO — Seminula Oolite; DL — Drybrook Limestone; LDS — Lower Drybook Sandstone; UDS — Upper Drybook Sandstone; LCS — Lower Cromhall Sandstone; MCS Middle Cromhall Sandstone; UCS — Upper Cromhall Sandstone; HL — Hotwells Limestone.)



(Figure 9.4) The Lower Carboniferous palaeogeography of south-east Wales and part of southern England illustrating the distribution of facies for the (a) Courceyan, (b) Arundian, and (c) and Holkerian stages. (MM — Mitcheldean Member; SO — Stowe Oolite; CM — Cwmyniscoy Mudstone; LF — Llanelly Formation; CBM — Caswell Bay Mudstone; HTL — High Tor Limestone (p — peloidal; sk — skeletal); BL — Birnbeck Limestone; BO — Burrington Oolite; VL — Vallis Limestone; CDM — Clifton Down Mudstone; WL — Whitehead Limestone; DL — Drybrook Limestone; DoL — Dowlais Limestone; SL — Stormy Limestone; DS — Drybrook Sandstone; CO — Cornelly Oolite; CDL — Clifton Down Limestone; UA — Usk Axis; ML — Malvern Line; SEFZ — Severn Estuary Fault Zone; LSA — Lower Severn Axis.) Based on Burchette (1987) and Wilson et al. (1988).



(Figure 9.5) Early Namurian palaeogeography of South Wales. After Kelling (1974).