Chapter 5
South Wales

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Carboniferous rocks in this region occur in a broadly east-west trending syncline, the core of which includes the South Wales and Pembrokeshire coalfields (Fig. 5.1). Tournaisian and Visean strata (Avon and Pembroke Limestone groups) represent deposition on a southward prograding carbonate ramp evolving into a carbonate shelf (Wright 1987), in a succession which shows similarities to that of the Bristol and Mendips areas (Chapter 6). The main outcrops, in south Pembrokeshire, Gower and the Vale of Glamorgan, occur along the southern periphery of the coalfields and are commonly affected by Variscan thrusting and folding. Thinner successions occur along what is termed the East Crop and North Crop of the South Wales Coalfield, where much of the Visean succession is absent due to sub-Namurian and intra-Visean unconformities. Namurian fluvio-deltaic deposits (Marros Group) flank the South Wales and Pembrokeshire coalfields. Much of the lower and middle Namurian succession is absent across the region, except in the west of the South Wales Coalfield where only small parts are absent beneath an intra-Namurian unconformity. Westphalian fluvio-lacustrine deposits (South Wales Coal Measures Group) form the South Wales and Pembrokeshire coalfields, located to the east and west of Carmarthen Bay, respectively. Westphalian to Stephanian Pennant alluvial facies (Warwickshire Group) occur in the core of the South Wales Coalfield syncline. Deposition of the South Wales Coal Measures and Warwickshire groups was probably laterally contiguous with those in the Bristol and Somerset coalfields (Chapter 6), but the Usk-Cowbridge High controlled and restricted sedimentation for much of the Carboniferous, with pre-Namurian uplift and erosion removing the Tournaisian and Visean succession. Later uplift is also believed to have caused attenuation of the Warwickshire Group in the east of the South Wales Coalfield. The lithostratigraphical nomenclature for the region is that of Waters *et al.* (2007; 2009).

Tournaisian

Tournaisian strata extend across the region, conformably overlying the upper Devonian Upper Old Red Sandstone Group, apart from in the north, where a basal disconformity is developed. They comprise a predominantly mudstone-dominated ramp succession, the Avon Group (formerly Lower Limestone Shales), overlain by a limestone-dominated ramp succession, the Black Rock Limestone Subgroup of the Pembroke Limestone Group, which extends into the early Visean (Chadian).

In the south-east of the region, a carbonate ooidal shoal facies (the Castell Coch Limestone Formation) allows subdivision of the Avon Group into three formations, with an underlying Tongwynlais Formation (absent on the North Crop and northern part of the East Crop (Fig. 5.2, Cols. 5, 6 & 7) and overlying Cwmyniscoy Mudstone Formation (Burchette 1987; Waters & Lawrence 1987). In the south of the region, the base of the Avon Group is broadly coincident with the base of the Tournaisian and reflects the first Carboniferous transgression. The VI spore Biozone is present in the basal part of the Tongwynlais Formation in the Vale of Glamorgan (McNestry 1988; Davies *et al.* 1991) (Fig. 5.2, Col. 4 ^[1]). In south Pembrokeshire, VI spores occur in

the uppermost, marine part of the predominantly Devonian Skrinkle Sandstones Subgroup (Dolby 1970; Bassett & Jenkins 1977; Fig. 5.2, Col. 1 ^[1]), in strata now assigned to the Avon Group (Waters *et al*. 2007). In the Vale of Glamorgan (Fig. 5.2, Col. 4) the Avon Group is well constrained by spore data (McNestry 1988). The remainder of the Tongwynlais Formation spans the HD Biozone ^[2]. The succeeding BP Biozone first appears in the middle part of the Castell Coch Limestone ^[3] whereas the base of the overlying PC Biozone is in the uppermost part of the formation ^[4]. The Cwmyniscoy Mudstone is entirely of PC Biozone age. On the North Crop of the South Wales Coalfield, Lovell (1978) has shown that the base of the Avon Group, is younger than in the south, Tn2a (post-VI/pre-PC) miospores being recorded from the base of the disconformable Castell Coch Limestone (Fig. 5.2, Col. 6 ^[1]). In the east of the Vale of Glamorgan, the Tongwynlais, Castell Coch and lowermost part of the Cwmyniscoy Mudstone formations yield conodonts, including *Polygnathus spicatus* and *P. inornatus* and rare siphonodellids, typical of *Siphonodella* Biozone shallow water facies (Waters & Lawrence 1987) (Fig. 5.2, Col. 4 [O5]). *P. inornatus* occurs in the upper part of the Tongwynlais Formation and the basal Cwmyniscoy Mudstone, but is absent from the high energy barrier facies of the Castell Coch Limestone, suggesting a strong facies control linked to transgressive events. *Siphonodella* cf. *isosticha*, indicative of the *Siphonodella crenulata* Biozone of Sandberg *et al.* (1978) (high *Siphonodella* Biozone), is reported from the base of the Cwmyniscoy Mudstone, and a shallow water fauna similar to those in the *Siphondella/Pseudopolygnathus multistriatus* interregnum occurs in the uppermost part of the formation [O5]. In the north, in the Abergavenny area (Fig. 5.2, Col. 6, [O2]), similar shallow water *Siphonodella* Biozone conodont assemblages are reported (Rhodes *et al*. 1969; Barclay 1989). *P. inornatus* is reported from the basal and topmost beds of the Castell Coch Limestone, both representing transgressive facies.

The crinoidal packstones of the Black Rock Limestone Subgroup (Pembroke Limestone Group) can be divided across the region into a lower, Barry Harbour Limestone (approximates to the Shipway Limestone of Gower; George *et al*. 1976) and an upper, Friars Point Limestone (approximates to the Tears Point Limestone of Gower; George *et al*. 1976), but these units have only been mapped to date in the Vale of Glamorgan. Both formations were storm-generated, the former representing mid ramp deposition between fair weather and storm wave base (Waters & Lawrence 1987; Faulkner 1988) and the latter more distal deposition, predominantly below mean wave base (Waters & Lawrence 1987; Ramsay 1987). They are separated in the Vale of Glamorgan and locally in Gower (Fig. 5.2, Cols. 3 & 4) by a shallowing event represented by the Brofiscin Oolite Formation, deposited in a shoal environment subjected to subaerial exposure (Waters & Lawrence 1987; Faulkner 1988). Modern work on the conodont, foraminifer and coral faunas of the Black Rock Limestone Subgroup is limited to the Vale of Glamorgan (Waters & Lawrence 1987; Fig. 5.2, Col. 4) and south west Gower (Mitchell *et al*. 1986; Fig. 5.2, Col. 3). In the Vale of Glamorgan the Barry Harbour Limestone contains shallow water conodonts typical of the *Siphondella/Pseudopolygnathus multistriatus* interregnum (Fig. 5.2, Col. 4 [0*6]), but in more distal settings, such as Barry, where the Brofiscin Oolite is absent, it ranges into the *Ps. multistriatus* Biozone. In the Vale of Glamorgan the formation yields coral faunas of the *Zaphrentis delanouei* Assemblage Biozone [0*6]. The Brofiscin Oolite contains *Ps. multistriatus* Biozone conodonts [07]. At Barry in the Vale of Glamorgan, the Tournaisian part of the Friars Point Limestone spans the *Ps multistriatus and Poygnathus mehli* shallow water conodont Biozones (Fig. 5.2, Col.

4 [0*8]). Deeper water distal ramp indices such as *Eotaphrus bultynki, Dollymae bouckaerti* and *Scaliognathus anchoralis* have been noted. Coral faunas span the *Zaphrentis delanouei and Caniniophyllum patulum* assemblage biozones [0*8], but their distribution on the ramp is diachronous (see Riley 1993a), the caniniod corals first appearing with the onset of muddy, lower energy conditions. In Gower (Fig. 5.2, Col. 3), the base of the *Caninophyllum patulum* Assemblage Biozone [*1] occurs within the lowermost part of the Friars Point Limestone (formerly Tears Point Limestone) (Mitchell *et al*. 1986), a position similar to that at Barry in the Vale of Glamorgan (Waters & Lawrence 1987).

The most distal Black Rock Limestone Subgroup occurs in South Pembrokeshire (Fig. 5.2, Col. 1 [*2]), where both the Barry Harbour Limestone and Friars Point Limestone formations are present and span the *Zaphrentites delanouei and Caniniophyllum patulum* assemblage biozones (Mitchell *et al*. 1982). Waulsortian reefs (Berry Slade Formation), a feature of distal ramp settings, are present above the Black Rock Limestone Subgroup and are probably mainly Tournaisian in age (Mitchell *et al.* 1982). Tournaisian conodonts including *S. anchoralis* occur just below the base of the Berry Slade Formation (Fig. 5.2, Col. 1 [03]) and Visean conodonts have been found immediately above the top [04]. In the North Crop of the South Wales Coalfield the equivalent succession is represented by the shallow water Clydach Valley (Fig. 5.2, Col. 6) and Abercriban Oolite (Fig. 5.2, Col. 7) subgroups. In the Abergavenny area (Fig. 5.2, Col. 6), Tournaisian shallow water conodonts suggestive of the *Siphondella/Pseudopolygnathus multistriatus* interregnum occur in the lower part of the Blaen Onnen Oolite Formation, whereas those of the *Pseudopolygnathus multistriatus* Biozone occur near the top and within the overlying Coed Ffyddlwn Formation [O3] (Barclay 1989).

Visean

Visean strata, assigned to the Pembroke Limestone Group, extend across the region. The base of the Visean Stage, taken at the entrance of the conodont *Mestognathus beckmanni* lies about 36 m below the top of the Friars Point Limestone at Tears Point in west Gower (Mitchell *et al.* 1986; Fig. 5.2, Col. 3 [O*2]) and about 100 m below it at Barry in the Vale of Glamorgan (Waters & Lawrence 1987; Fig. 5.2, Col. 4 [0*9]). This is supported by the presence of Chadian foraminifers in Gower. The base of the *S. cylindrica* Assemblage Biozone is coincident with the entrance of *M. beckmanni* in Gower (Mitchell *et al*. 1986) and approximately so in the Vale of Glamorgan (Waters & Lawrence 1987). In the North Crop, the base of the Visean is problematical as the Gilwern Oolite Formation (Fig. 5.2, Col. 6) yields conodonts of the Tournaisian *Polygnathus mehli* Biozone [O*4] (Barclay 1989) together with the Visean (V_1) foraminifer *Tetrataxis* cf. *paraminimus* and ammodiscids (George *et al*. 1976). The coral *Palaeosmilia murchisoni* which occurs in the basal coral bed, is not known from the Tournaisian. On balance, the Gilwern Oolite is of Visean age (Barclay 1989).

The Gully Oolite (formerly Caswell Bay Oolite) Formation extends over most of the South and East Crop of the South Wales Coalfield. Shown by ammonoids and foraminifers (fusilinaceans and *Dainella*) to be of Chadian age in Gower (Fig. 5.2, Col. 3 [+03]) by Conil & George (1973), it represents a series of progradational events (Waters 1984; Burchette *et al*. 1990). From Cardiff northwards, there is evidence for

an intra-Chadian non-sequence at the base of the Gully Oolite, in common with the Bristol district (Waters & Lawrence 1987; Faulkner *et al*. 1990).

In south Pembrokeshire (Fig. 5.2, Col. 1) the Gully Oolite is absent and the Visean succession commences with the Linney Head Formation. This comprises crinoidal wackestone and packstone with abundant cherts interbedded with mudstone and nodular limestone. It contains Visean conodonts, including *M. beckmanni*, and Chadian foraminifers including *Biseriella bristolensis* and *Eoparastafella sp.*[04] (Mitchell *et al*. 1982; Simpson & Kalvoda 1987). The overlying Hobbyhorse Bay Limestone Formation comprises thick-bedded, coarsely crinoidal packstone.

The base of the Pen-y-holt Limestone Formation at Hobbyhorse Bay (Fig. 5.2, Col. 1) is the basal Arundian stratotype (George *et al*. 1976; Simpson & Kalvoda 1987; Cossey *et al*. 2004, p425-428), defined as the first lithological change 16 m below the entry of the foramiferan family Archaediscidae [O5] (see Chapter 2). The appearance of the Arundian conodont *Gnathodus symmutatus* occurs just above the base of the formation (Austin 1987). Elsewhere, the top of the Gully Oolite Formation is a disconformity marked by a palaeokarstic surface and palaeosol formation (Wright 1986). The overlying calcitic and dolomitic mudstone and micritic limestone of the Caswell Bay Mudstone Formation are interpreted as a shallow-water to supratidal sabkha-type deposit formed in a tidal flat lagoon complex behind a beach barrier (Wright 1986). Formerly considered to occur within the Chadian (George *et al*. 1976), the formation is now regarded as Arundian on regional sedimentological grounds (Riding & Wright 1981; Wilson *et al*. 1990). The overlying High Tor Limestone Formation contains a rich Arundian fauna in the Vale of Glamorgan, including the brachiopod *Delepinea carinata*, the coral *Siphonophyllia garwoodi* and foraminifers (Waters & Lawrence 1987; Wilson *et al*. 1990; Fig. 5.2, Col. 4 [0*10]), and V_{2a} foraminifers *Permodiscus* and *Nodosoarchaediscus* (Conil & George 1973) in Gower (Fig. 5.2, Col. 3 [O4]). On the North Crop of the South Wales Coalfield, the Arundian is represented by the peritidal carbonate rocks of the Llanelly Formation which rest disconformably on a palaeokarstic surface at the top of the Gilwern Oolite Formation and Abercriban Oolite Subgroup. It contains foraminifers, including archaediscids (George 1954), indicating an Arundian age (Fig. 5.2, Col. 6 [05]).

During the late Arundian and the Holkerian, ooidal shoals of the Cornelly Oolite Formation (Hunts Bay Oolite Subgroup) were deposited on the seaward side of the ramp, behind which shallow-water peritidal deposition of the Stormy Limestone Formation occurred (Waters & Lawrence 1987; Wilson *et al.* 1990). In the Vale of Glamorgan, the lowest part of the Cornelly Oolite Formation contains late Arundian foraminifers and corals [0*11], whereas the rest of the formation contains a rich Holkerian coral and brachiopod fauna in the Vale of Glamorgan (Waters & Lawrence 1987) and Gower (Barclay in press). By comparison with the succession in North Wales (Chapter 8) the Holkerian/Asbian boundary probably lies in the uppermost part of the Stormy Limestone. On the North Crop (Fig. 5.2, Cols. 6 [*^6] & 7 [*1]) the presence of the brachiopod *Davidsonina carbonaria* (George *et al*. 1976), the coral *Lithostrotion* cf. *araneum* and miospore assemblages (Barclay 1989) in the Dowlais Limestone Formation indicates a Holkerian age.

A carbonate shelf became established during the Asbian to early Brigantian, with deposition of the skeletal packstones of the Oxwich Head Limestone Formation.

Repeated sea-level change produced cyclicity within the formation in which shoaling limestone cycles culminate in palaeokarstic surfaces, and locally, thin coals. Wilson *et al.* (1990) reported Asbian foraminifers from the base of the Oxwich Head Limestone in the Vale of Glamorgan (Fig. 5.2, Col. 4 [012]). The presence of *Davidsonina septosa* in the Oxwich Head Limestone Formation of south Pembrokeshire and Gower (Fig. 5.2, Cols. 1 [*6] & 3 [*5]) and in the Penderyn Oolite Member of the North Crop (Fig. 5.2, Col. 7 [*2]) indicates a late Asbian age (George *et al.* 1976).

The late Brigantian Oystermouth Formation was deposited as a result of an increase of terrigenous clastic input into the basin, which culminated in the end of carbonate production. The ammonoids *Sudeticeras* sp. and *Neoglyphioceras* sp. of the P_2 Zone were recovered from the Kenfig Borehole, Port Talbot (Fig. 5.2, Col. 4 [+13]; Ramsbottom 1954). The presence of the brachiopods *Spirifer oystermouthensis* and *Martinia multicostata* near Kidwelly (Fig. 5.2, Col. 7 [*3]) suggests a P_{1d} age (George *et al*. 1976).

Namurian

There is no complete section of strata of Namurian age (Marros Group) in South Wales, although the Bishopston–Llanelli section (Fig. 5.2, Col. 3; Ramsbottom 1978c) is the thickest and most complete. Strata of Pendleian to early Marsdenian age are absent over parts of Pembrokeshire and much of the eastern part of the South Wales Coalfield. Ramsbottom (1978c) recognised that index marine faunas are absent at the base of many of the ammonoid biozones (his mesothems), suggesting that most of the South Wales region occupied a basin margin setting during the Namurian.

The oldest strata comprise mudstone with radiolarian chert (the Aberkenfig Formation) in the Bishopston [+6] (Fig. 5.2, Col. 3; Dix 1931, Barclay in press), Margam (Fig. 5.2, Col. 4) and Ammanford (Fig. 5.2, Col. 8) areas. They contain ammonoids of Pendleian age in the Bishopston area.

The Twrch Sandstone Formation (formerly Basal Grit) is dominated by quartzitic sandstone, which in Pembrokeshire is interpreted as a fan-delta sequence (George & Kelling 1982), but in the East Crop formed in more littoral and fluvial environments (Kelling 1974). The base of this formation becomes increasingly younger towards the east of the North Crop. It ranges from Arnsbergian in the west of the Merthyr Tydfil district (Fig. 5.2, Col. 7; Barclay *et al*. 1988), the *Nuculoceras stellarum* ($E_{2b}3$) and overlying *Isohomoceras subglobosum* (H_{1a}) marine bands being near the base [+4], to Yeadonian (G_{1a}) in the east of the Abergavenny district (Barclay 1989). Strata of Alportian age appear to be absent, the basal part of the upper part of the formation containing the *Reticuloceras circumplicatile* ($R_{1a}2$) and overlying *R. reticulatum* marine bands [+5] (Fig. 5.2, Col. 7; Barclay *et al*. 1988). In the Tenby area (Fig. 5.2, Col. 2) the age of the formation is in part constrained by marine fauna thought to indicate a *Homoceras beyrichianum* Zone (late Chokierian) age [+1] (Cleal & Thomas 1996). In the Kidwelly area (Fig. 5.2, Col. 9; Archer 1968) *Isohomoceras subglobosum* (base Chokierian) [+1] and *Reticuloceras circumplicatile* ($R_{1a}2$) [+2] marine bands occur near the base and top of the formation, respectively. The formation is absent in the Bishopston and Aberkenfig areas (Fig. 5.2, Cols. 3 & 4), which may have been a topographical high at the time. Diagnostic plant fossils are generally rare in the formation, although *Lyginopteris stangeri* Zone floras have been reported in the lower part from near Abercrave and the upper Neath Valley (Dix, 1933; Jones, 1958).

The overlying Bishopston Mudstone Formation (formerly Middle Shale Group) consists predominantly of fluvial and deltaic sediments that prograded from the northeast of the basin, interspersed with marine deposits (Oguike in Kelling 1974). These prograde from the south and west and probably reflect eustatic sea-level rises. In Bishopston–Llanelli area (e.g. Barland Common), by contrast, 'basinal' muds accumulated in prodelta and interdistributary bay settings. The base of the formation lies at the base of the *Bilinguites superbilinguis* Marine Band over most of Pembrokeshire [+2] (Fig. 5.2, Col. 2), and the Kidwelly (Fig. 5.2, Col. 9 [+3]; Archer 1968) and Merthyr Tydfil districts (Fig. 5.2, Col. 7[+6]; George 1970; Barclay *et al.* 1988). In the Margam area (Fig. 5.2, Col. 4) conodonts and the ammonoid *Cravenoceratoides*? suggest a possible late Arnsbergian age for the lower part of the formation, although the lowest identified marine bands are *Vallites eostriolatus* ($H_{2c}1$) and *Hodsonites magistrorum* ($R_{1a}1$) [+14] (Woodland & Evans 1964). Here, the *B. superbilinguis* Marine Band [+15] lies within the upper part of the formation. The section at Barland Common, (Fig. 5.2, Col. 3) includes ammonoid-bearing marine bands ranging from E_2 to R_2 age [+7] (Ramsbottom 1971b; Cleal & Thomas 1996; Barclay in press), indicating that the base of the formation is no younger than late Arnsbergian age. In the St Brides area (Fig. 5.2, Col. 1) the earliest deposition took place in the *Verneulites sigma* Subzone [+7] (Archer 1965). The *Cancelloceras cancellatum* Marine Band occurs within the formation in the Margam (Fig. 5.2, Col. 4 [+16]; Woodland & Evans 1964) and Kidwelly (Fig. 5.2, Col. 9 [+4]; Archer 1968) areas. On the East Crop of the South Wales Coalfield, the base of the formation is placed at the base of the *Cancelloceras cumbriense* Marine Band. This marine band is found extensively throughout the district (Fig. 5.2, Cols. 4 [+17], Col. 5[+1], 7 [+7] & 9 [+5]; Barclay 1989; Squirrell & Downing 1969).

The Telpyn Point Sandstone Formation (formerly Farewell Rock) is restricted to the margins of the Pembrokeshire Coalfield, Gower and on the East Crop of the South Wales Coalfield, representing the fluvial fill of incised valleys (Hampson 1998; George 2001). In the Tenby-Marros area (Fig. 5.2, Col. 2 [+3]) the formation lies between the *Cancelloceras cumbriense* and Subcrenatum marine bands, indicating a late Yeadonian (G_{1b}) age.

Westphalian

Grey, mudstone-dominated fluvio-lacustrine deposits of the South Wales Coal Measures Group accumulated in the South Wales Coalfield basin in the Langsettian to early Bolsovian. From the late Bolsovian, there was a transition to dominantly fluvial deposition represented by the Pennant Sandstone and Grovesend formations, formerly referred to as Upper Coal Measures but now assigned to the Warwickshire Group (Waters *et al*. 2007).

The South Wales Coal Measures Group is thickest (about 900 m), in the Swansea area in the southwest of the main coalfield, thinning to about 240 m on the East Crop, where coals thicken and amalgamate, or thin and fail (Fig. 5.3) approaching the Usk Anticline (Waters & Davies 2006). Deposition was in a foreland basin setting (Gayer *et al.* 1993; Hartley 1993a; Burgess & Gayer 2000), with coals and mainly fine-grained clastic rocks deposited in an upper coastal plain environment (Hartley 1993a; 1993b). Many of the coals are of basin-wide extent and formed as peat mires

controlled by eustatic sea-level rise (Ramsbottom 1984; Hartley 1993a). The group is divided into South Wales Lower, Middle and Upper Coal Measures formations using widespread marine bands, in a scheme established by Stubblefield & Trotter (1957). Stream exposures in the Glyn-neath area, on the North Crop of the main coalfield, provide sections through Langsettian to Bolsovian strata (Evans *et al*. 2003).

The Subcrenatum Marine Band, which marks the base of the South Wales Lower Coal Measures Formation, is proved across the region (Fig. 5.2, Cols. 2 $^{+4}$, 4 $^{+18}$, 5 $^{+2}$, 7 $^{+8}$, 8 $^{+1}$ & 9 $^{+6}$) and attains thicknesses of up to 25 m both in the west and east. A closely spaced succession of five marine bands, traditionally named M1-5, is present in the lower part of the formation (Fig. 5.3), broadly corresponding with the Lenisulcata Chronozone. These horizons are mainly *Lingula* bands and can be correlated across the main and Pembrokeshire coalfields (Fig. 5.3). They have been correlated with marine bands in the Pennine Basin and given the names of their correlatives (see Chapter 11). Non-marine bivalve assemblages in the Tenby area are attributed to the *C. fallax-C. protea* Subzone (lower Lenisulcata Chronozone), the only part of the region where this subzone has been reported (Cleal & Thomas 1996; Fig. 5.2, Col. 2 $^{\sim 5}$). The lower part of the formation contains sandstones collectively known as the Farewell Rock and thin, impersistent coals. Overlying the Farewell Rock are the Nant Llech Plant Beds, which have yielded the only well-documented macrofloras of this age in Britain (Dix 1933). The upper part of the formation includes numerous thick coals (Fig. 5.3), seatearth palaeosols and ironstones, but no marine bands. A major change in the macrofloras recognised as the base of the *Laveineopteris loshii* Subzone (Cleal 2007) occurs at the Gellideg Seam. This represents the appearance of the floras typical of the Coal Measures in South Wales, which progressively increase in diversity through the formation.

The Vanderbeckei (Amman) Marine Band, which marks the base of the South Wales Middle Coal Measures Formation, occurs throughout the main and Pembrokeshire coalfields (Fig. 5.3), and is mainly a *Lingula* band. The lower part of the formation is characterised by thick coal seams and an absence of marine bands (Fig. 5.3). Its macrofloras are also essentially similar to those of the South Wales Lower Coal Measures Formation, although a zonal boundary is conventionally placed at the Vanderbeckei Marine Band (Cleal 2007). The late Duckmantian part of the formation contains generally thinner coals and up to three marine bands (Fig. 5.3). A change in the macrofloras is represented by the base of the *Paripteris linguaefolia* Zone, at which a number of species typical of the upper Westphalian appear (Cleal 2007).

The Aegiranum (Cefn Coed) Marine Band occurs across the region. At Aberbaiden, near Margam (Fig. 5.2, Col. 4 $^{+19}$), it contains the richest fauna of any Coal Measures marine band in Britain (Ramsbottom 1952). The Bolsovian part of the South Wales Middle Coal Measures Formation contains thin coals and four marine bands, in addition to the Aegiranum Marine Band. The top of the uppermost of these, the Cambriense (Upper Cwmgorse) Marine Band, defines the top of the formation. It marks a major change in the terrestrial biotas - the base of the Flora Zone G of Dix (1934), the base of the *Laveineopteris rarinervis* Subzone of Cleal & Thomas (1994) and the base of the non-marine bivalve Phillipsi Chronozone. Coal Measures facies above this marine band are identified as the South Wales Upper Coal Measures Formation (Fig. 5.3).

In the east of the main coalfield (Fig. 5.2, Col. 5) primary red-beds (Downing & Squirrell 1965) named the Deri Formation were deposited in well drained alluvial plains in the vicinity of the active Usk Axis. They pass westwards into the Llynfi and Rhondda members of the Pennant Sandstone Formation (Fig. 5.3, Pontypridd area). The sandstones in the Deri Formation are quartzitic and show a prominent component of palaeocurrents towards the WSW, distinct from the typical litharenite petrography and NNW-directed palaeocurrents of the overlying Pennant Sandstone Formation (e.g. Kelling 1968).

A succession dominated by multistorey fluvial channel sandstones, the Pennant Sandstone Formation (formerly Pennant Measures) was deposited during the Bolsovian to Asturian. This formation shows similar composition dominated by lithic arenites and a similar southerly provenance to the Halesowen Formation of the Pennine Basin (see Chapters 8-10). The formation is subdivided by coal seams, using the definitions established by Woodland *et al*. (1957). The units referred to as beds by these authors were later reclassified as members (Cleal & Thomas 1996). The lower part of the formation (Llynfi Member) represents a sinuous fluvial system (Kelling 1974; Jones 1989; Hartley 1983b). The overlying Rhondda Member formed in an extensive alluvial delta encroaching from the south, with immature detritus derived from a strongly elevated region, probably the result of thrust-nappes generated by the northwards-advancing Variscan Front (Kelling 1964; 1974; 1988). In the southern part of the basin, the formation represents mostly upper or alluvial plain conditions, but along the north crop it is more lower delta plain in character.

The base of the Pennant Sandstone Formation is diachronous, being typically oldest in the south-west of the region (Pembrokeshire Coalfield; Fig. 5.3) and youngest in the north-east crop of the main coalfield. In the upper part of the Pennant Sandstone Formation in St Brides Bay (Fig. 5.2, Col. 1) the position of the base of the Asturian is taken at the base of the non-marine bivalve Tenuis Chronozone (Jenkins, 1962) and the base of the macrofloral *Linopteris bunburii* Zone [^~8] (Cleal 1997). In the Swansea region, an Asturian flora in the Brithdir Member (Fig. 5.3; Thomas & Cleal 2001) confirms that the base of the Asturian lies in the Rhondda Member (Cleal 1978, 1997, 2007; Cleal & Thomas 1996). The area around the Swansea and Neath valleys is unique in Europe in having a continuous section of Asturian coal-bearing strata, represented mainly by the Pennant Sandstone Formation. The formation contains an exceptionally diverse macrofloras of the *Lobatopteris vestita* Zone (Cleal 1978, 2007; Fig. 5.2, Col. 4 [^~20]).

The overlying mudstone-dominated fluvial floodplain or lacustrine deposits of the Grovesend Formation (Kelling 1974) were formerly included as beds within the Pennant Measures of Woodland *et al.* (1957). In the Swansea area (Fig. 5.2, Col. 4) the formation includes plant macrofossils of the *Lobatopteris vestita* Zone (Cleal 1978, 2007) and non-marine bivalves of the Tenuis Chronozone [^~21], the former indicative of the late Asturian (Cleal & Thomas 1996).

In the eastern part of the coalfield (Fig. 5.3), attenuation of the Pennant Sandstone Formation and absence of the Swansea Member is caused by a non-sequence at the base of the Mynyddislwyn (No. 3 Llantwit) Seam. The overlying beds were correlated with the Grovesend Formation by Woodland *et al*. (1957), Woodland & Evans (1964), Squirrell & Downing (1969) and Barclay (1989), a correlation supported by

palynological evidence (Dimitrova *et al*. 2005). However, Cleal (1986a, 1991b, 1997) has proposed that the beds (his 'Llantwit Beds') are not the equivalent of the Grovesend Formation and correlate with his Forest of Dean Pennant Formation (see Chapter 6).

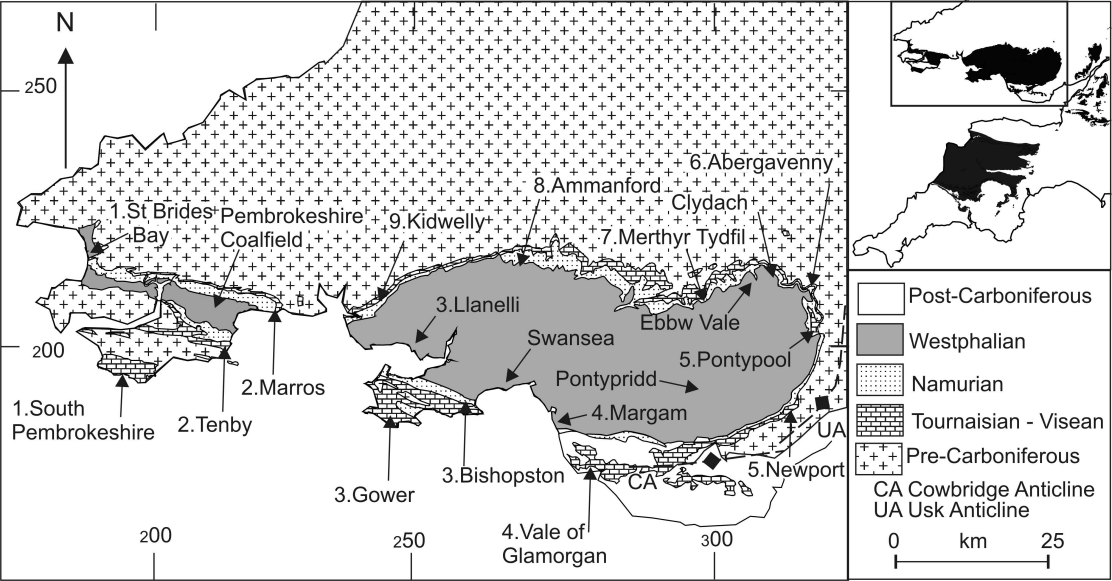
Stephanian

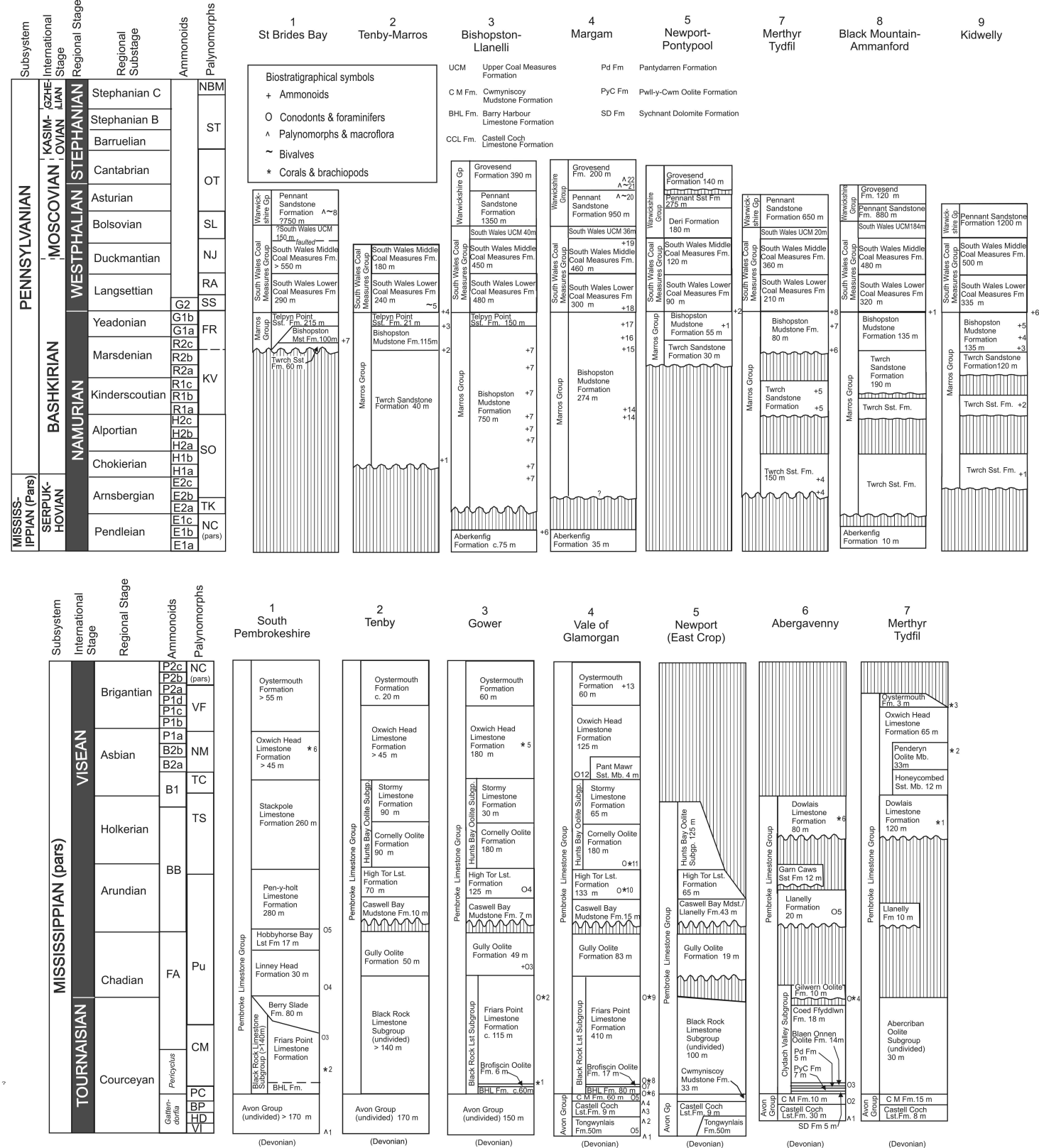
Macroflora of the *Odontopteris cantabrica* Zone are recorded in the Grovesend Formation of the Swansea area (Figure 5.2, Col. 4), indicative of a Cantabrian age [^22] (Cleal 1997). Palynological evidence from the upper part of the 'Llantwit Beds' also suggest a Cantabrian age (Dimitrova *et al*. 2005).

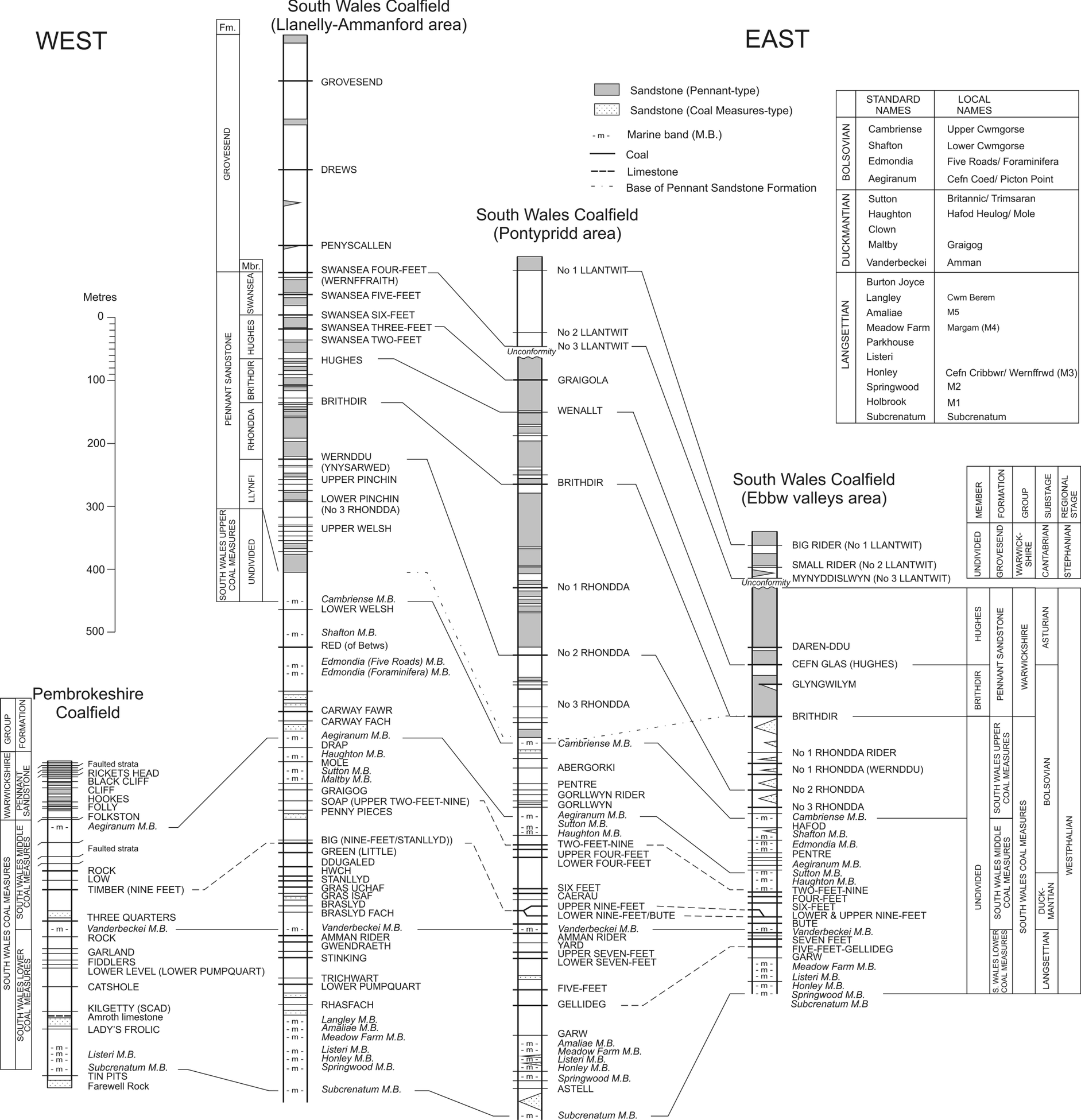
Fig. 5.1. Geological map showing the distribution of Carboniferous strata of South Wales, adapted from IGS (1979).

Fig. 5.2. Correlation of Carboniferous successions in South Wales. The nomenclature is that of Waters *et al*. (2007; 2009), with details from the following publications: Col. 1 from Waters *et al*. (2009); Col. 2 from Waters *et al*. (2009); Col. 3 from Barclay (in press); Col. 4 from Wilson *et al*. (1990) and Woodland & Evans (1964); Col. 5 from Squirrell & Downing (1969) and Waters *et al*. (2009); Col. 6 from Barclay (1989); Col. 7 from Barclay *et al*. (1988); Col. 8 from Archer (1968); Col. 9 from Archer (1968).

Fig. 5.3. Correlation of Westphalian to Stephanian successions in South Wales. The nomenclature is that of Waters *et al*. (2007; 2009), with details modified from Ramsbottom *et al.* (1978) and from the following publications: Pembrokeshire Coalfield (Jenkins 1962); Swansea area (Barclay in press); Pontypridd (Woodland & Evans 1964); Ebbw Vale (Barclay 1989).


N
250
200
200
250
300
1.St Brides Bay
Pembrokeshire Coalfield
9.Kidwelly
8.Ammanford
6.Abergavenny
Clydach
7.Merthyr Tydfil
3.Llanelli
Ebbw Vale
Swansea
5.Pontypool
Pontypridd
4.Margam
2.Marros
1.South Pembrokeshire
2.Tenby
3.Gower
3.Bishopston
CA
UA
5.Newport
4.Vale of Glamorgan
Post-Carboniferous
Westphalian
Namurian
Tournaisian - Visean
Pre-Carboniferous
CA Cowbridge Anticline
UA Usk Anticline
0
km
25


Subsystem
International Stage
Regional Stage
Regional Substage
Ammonoids
Palynomorphs
PENNSYLVANIAN
MISSISSIPPIAN (Pars)
GZHELIAN
KASIMOVIAN
MOSCOVIAN
BASHKIRIAN
SERPUKHOVIAN
NAMURIAN
WESTPHALIAN
STEPHANIAN
Stephanian C
Stephanian B
Barruelian
Cantabrian
Asturian
Bolsovian
Duckmantian
Langsettian
Yeadonian
Marsdenian
Kinderscoutian
Alportian
Chokierian
Arnsbergian
Pendleian
G2
G1b
G1a
R2c
R2b
R2a
R1c
R1b
R1a
H2c
H2b
H2a
H1b
H1a
E2c
E2b
E2a
E1c
E1b
E1a
NBM
ST
OT
SL
NJ
RA
SS
FR
KV
SO
TK
NC (pars)
1 St Brides Bay
2 Tenby-Marros
3 Bishopston-Llanelli
4 Margam
5 Newport-Pontypool
7 Merthyr Tydfil
8 Black Mountain-Ammanford
9 Kidwelly
Biostratigraphical symbols
+ Ammonoids
O Conodonts & foraminifers
^ Palynomorphs & macroflora
~ Bivalves
* Corals & brachiopods
UCM Upper Coal Measures Formation
C M Fm. Cwmyniscoy Mudstone Formation
BHL Fm. Barry Harbour Limestone Formation
CCL Fm. Castell Coch Limestone Formation
Pd Fm Pantydarren Formation
PyC Fm Pwll-y-Cwm Oolite Formation
SD Fm Sychnant Dolomite Formation
Warwickshire Group
Pennant Sandstone Formation ?750 m
?South Wales UCM 150 m faulted
South Wales Coal Measures Group
South Wales Middle Coal Measures Fm. > 550 m
South Wales Lower Coal Measures Fm 290 m
Marros Group
Telpyn Point Sst. Fm. 215 m
Bishopston Mst Fm.100m
Twrch Sst Fm. 60 m
South Wales Middle Coal Measures Fm. 180 m
South Wales Lower Coal Measures Fm 240 m
Telpyn Point Sst. Fm. 21 m
Bishopston Mudstone Fm.115m
Twrch Sandstone Formation 40 m
Grovesend Formation 390 m
Pennant Sandstone Formation 1350 m
South Wales UCM 40m
South Wales Middle Coal Measures Fm. 450 m
South Wales Lower Coal Measures Fm 480 m
Telpyn Point Sst. Fm. 150 m
Bishopston Mudstone Formation 750 m
Aberkenfig Formation c.75 m
Grovesend Fm. 200 m
Pennant Sandstone Formation 950 m
South Wales UCM 36m
South Wales Middle Coal Measures Fm. 460 m
South Wales Lower Coal Measures Fm 300 m
Bishopston Mudstone Formation 274 m
Aberkenfig Formation 35 m
Grovesend Formation 140 m
Pennant Sst Fm 275 m
Deri Formation 180 m
South Wales UCM 20m
South Wales Middle Coal Measures Fm. 120 m
South Wales Lower Coal Measures Fm 90 m
Bishopston Mudstone +1 Formation 55 m
Twrch Sandstone Formation 30 m
Pennant Sandstone Formation 650 m
South Wales UCM 20m
South Wales Middle Coal Measures Fm. 360 m
South Wales Lower Coal Measures Fm 210 m
Bishopston Mudstone Fm. 80 m
Twrch Sandstone Formation
Twrch Sst. Fm. 150 m
Grovesend Fm. 120 m
Pennant Sandstone Fm. 880 m
South Wales UCM184m
South Wales Middle Coal Measures Fm. 480 m
South Wales Lower Coal Measures Fm 320 m
Bishopston Mudstone Formation 135 m
Twrch Sandstone Formation 190 m
Twrch Sst. Fm.
Twrch Sst. Fm.
Aberkenfig Formation 10 m
Pennant Sandstone Formation 1200 m
South Wales Middle Coal Measures Fm. 500 m
South Wales Lower Coal Measures Fm 335 m
Bishopston Mudstone Formation 135 m
Twrch Sandstone Formation120 m
Twrch Sst. Fm.
Twrch Sst. Fm.
Subsystem
International Stage
Regional Stage
Ammonoids
Palynomorphs
MISSISSIPPIAN (pars)
TOURNAISIAN
VISEAN
Brigantian
Asbian
Holkerian
Arundian
Chadian
Courceyan
P2c
P2b
P2a
P1d
P1c
P1b
P1a
B2b
B2a
B1
FA
Gattendorfia
Pericyclus
NC (pars)
VF
NM
TC
TS
BB
Pu
CM
PC
BP
HD
VI
1 South Pembrokeshire
2 Tenby
3 Gower
4 Vale of Glamorgan
5 Newport (East Crop)
6 Abergavenny
7 Merthyr Tydfil
Pembroke Limestone Group
Oystermouth Formation > 55 m
Oxwich Head Limestone Formation > 45 m
Stackpole Limestone Formation 260 m
Pen-y-holt Limestone Formation 280 m
Hobbyhorse Bay Lst Fm 17 m
Linney Head Formation 30 m
Berry Slade Fm. 80 m
Friars Point Limestone Formation
Black Rock Limestone Subgroup (>140m)
BHL Fm.
Avon Group (undivided) > 170 m
Oystermouth Formation c. 20 m
Oxwich Head Limestone Formation > 45 m
Stormy Limestone Formation 90 m
Hunts Bay Oolite Subgp.
Cornelly Oolite Formation 90 m
High Tor Lst. Formation 70 m
Caswell Bay Mudstone Fm.10 m
Gully Oolite Formation 50 m
Black Rock Limestone Subgroup (undivided) > 140 m
Avon Group (undivided) 170 m
Oystermouth Formation 60 m
Oxwich Head Limestone Formation 180 m
Stormy Limestone Formation 30 m
Cornelly Oolite Formation 180 m
High Tor Lst. Formation 125 m
Caswell Bay Mudstone Fm. 7 m
Gully Oolite Formation 49 m
Friars Point Limestone Formation c. 115 m
Brofiscin Oolite Fm. 6 m
BHL Fm. c.60m
Black Rock Lst Subgroup
Avon Group (undivided) 150 m
Oystermouth Formation 60 m
Oxwich Head Limestone Formation 125 m
Pant Mawr Sst. Mb. 4 m
Stormy Limestone Formation 65 m
Cornelly Oolite Formation 180 m
High Tor Lst. Formation 133 m
Caswell Bay Mudstone Fm.15 m
Gully Oolite Formation 83 m
Friars Point Limestone Formation 410 m
Brofiscin Oolite Fm. 17 m
BHL Fm. 80 m
C M Fm. 60 m
Castell Coch Lst.Fm. 9 m
Tongwynlais Fm.50m
Avon Group
Hunts Bay Oolite Subgp. 125 m
High Tor Lst. Formation 65 m
Caswell Bay Mdst./ Llanelly Fm.43 m
Gully Oolite Formation 19 m
Black Rock Limestone Subgroup (undivided) 100 m
Cwmyniscoy Mudstone Fm. 33 m
Castell Coch Lst.Fm. 9 m
Tongwynlais Fm.50m
Avon Gp
Dowlais Limestone Formation 80 m
Garn Caws Sst Fm 12 m
Llanelly Formation 20 m
Gilwern Oolite Fm. 10 m
Coed Ffyddlwn Fm. 18 m
Blaen Onnen Oolite Fm. 14m
Pd Fm 5 m
PyC Fm 7 m
C M Fm.10 m
Castell Coch Lst.Fm. 30 m
SD Fm 5 m
Clydach Valley Subgroup
Avon Group
Oystermouth Fm. 3 m
Oxwich Head Limestone Formation 65 m
Penderyn Oolite Mb. 33m
Honeycombed Sst. Mb. 12 m
Dowlais Limestone Formation 120 m
Llanelly Fm 10 m
Abercriban Oolite Subgroup (undivided) 30 m
C M Fm.15 m
Castell Coch Lst.Fm. 8 m
(Devonian)


WEST
EAST
South Wales Coalfield
(Llanelly-Ammanford area)
South Wales Coalfield
(Pontypridd area)
South Wales Coalfield
(Ebbw valleys area)
Pembrokeshire
Coalfield
Metres
0
100
200
300
400
500
Fm.
Mbr.
GROVESEND
PENNANT SANDSTONE
SWANSEA
HUGHES
BRITHDIR
RHONDDA
LLYNFI
UNDIVIDED
SOUTH WALES UPPER COAL MEASURES
Sandstone (Pennant-type)
Sandstone (Coal Measures-type)
Marine band (M.B.)
Coal
Limestone
Base of Pennant Sandstone Formation
STANDARD NAMES
LOCAL NAMES
BOLSOVIAN
Cambriense
Upper Cwmgorse
Shafton
Lower Cwmgorse
Edmondia
Five Roads/ Foraminifera
Aegiranum
Cefn Coed/ Picton Point
DUCKMANTIAN
Sutton
Britannic/ Trimsaran
Haughton
Hafod Heulog/ Mole
Clown
Maltby
Graigog
Vanderbeckei
Amman
LANGSETTIAN
Burton Joyce
Langley
Cwm Berem
Amaliae
M5
Meadow Farm
Margam (M4)
Parkhouse
Listeri
Honley
Cefn Cribbwr/ Wernffrwd (M3)
Springwood
M2
Holbrook
M1
Subcrenatum
Subcrenatum
MEMBER
FORMATION
GROUP
SUBSTAGE
REGIONAL STAGE
UNDIVIDED
GROVESEND
WARWICK-SHIRE
CANTABRIAN
STEPHANIAN
GROVESEND
DREWS
PENYSCALLEN
SWANSEA FOUR-FEET (WERNFFRAITH)
SWANSEA FIVE-FEET
SWANSEA SIX-FEET
SWANSEA THREE-FEET
SWANSEA TWO-FEET
HUGHES
BRITHDIR
WERNDDU (YNYSARWED)
UPPER PINCHIN
LOWER PINCHIN (No 3 RHONDDA)
UPPER WELSH
Cambriense M.B.
LOWER WELSH
Shafton M.B.
RED (of Betws)
Edmondia (Five Roads) M.B.
Edmondia (Foraminifera) M.B.
CARWAY FAWR
CARWAY FACH
Aegiranum M.B.
DRAP
Haughton M.B.
MOLE
Sutton M.B.
Maltby M.B.
GRAIGOG
SOAP (UPPER TWO-FEET-NINE)
PENNY PIECES
BIG (NINE-FEET/STANLLYD))
GREEN (LITTLE)
DDUGALED
HWCH
STANLLYD
GRAS UCHAF
GRAS ISAF
BRASLYD
BRASLYD FACH
Vanderbeckei M.B.
AMMAN RIDER
GWENDRAETH
STINKING
TRICHWART
LOWER PUMPQUART
RHASFACH
Langley M.B.
Amaliae M.B.
Meadow Farm M.B.
Listeri M.B.
Honley M.B.
Springwood M.B.
Subcrenatum M.B.
No 1 LLANTWIT
No 2 LLANTWIT
No 3 LLANTWIT
Unconformity
GRAIGOLA
WENALLT
BRITHDIR
No 1 RHONDDA
No 2 RHONDDA
No 3 RHONDDA
Cambriense M.B.
ABERGORKI
PENTRE
GORLLWYN RIDER
GORLLWYN
Aegiranum M.B.
Sutton M.B.
Haughton M.B.
TWO-FEET-NINE
UPPER FOUR-FEET
LOWER FOUR-FEET
SIX FEET
CAERAU
UPPER NINE-FEET
LOWER NINE-FEET/BUTE
Vanderbeckei M.B.
AMMAN RIDER
YARD
UPPER SEVEN-FEET
LOWER SEVEN-FEET
FIVE-FEET
GELLIDEG
GARW
Amaliae M.B.
Meadow Farm M.B.
Listeri M.B.
Honley M.B.
Springwood M.B.
ASTELL
Subcrenatum M.B.
BIG RIDER (No 1 LLANTWIT)
SMALL RIDER (No 2 LLANTWIT)
MYNYDDISLWYN (No 3 LLANTWIT)
Unconformity
DAREN-DDU
CEFN GLAS (HUGHES)
GLYNGWILYM
BRITHDIR
No 1 RHONDDA RIDER
No 1 RHONDDA (WERNDDU)
No 2 RHONDDA
No 3 RHONDDA
Cambriense M.B.
HAFOD
Shafton M.B.
Edmondia M.B.
PENTRE
Aegiranum M.B.
Sutton M.B.
Haughton M.B.
TWO-FEET-NINE
FOUR-FEET
SIX-FEET
LOWER & UPPER NINE-FEET
BUTE
Vanderbeckei M.B.
SEVEN FEET
FIVE-FEET-GELLIDEG
GARW
Meadow Farm M.B.
Listeri M.B.
Honley M.B.
Springwood M.B.
Subcrenatum M.B
HUGHES
BRITHDIR
PENNANT SANDSTONE
WARWICKSHIRE
ASTURIAN
UNDIVIDED
SOUTH WALES UPPER COAL MEASURES
SOUTH WALES MIDDLE COAL MEASURES
SOUTH WALES LOWER COAL MEASURES
SOUTH WALES COAL MEASURES
BOLSOVIAN
DUCK-MANTIAN
LANGSETTIAN
WESTPHALIAN
GROUP
FORMATION
WARWICKSHIRE
PENNANT SANDSTONE
SOUTH WALES COAL MEASURES
SOUTH WALES MIDDLE COAL MEASURES
SOUTH WALES LOWER COAL MEASURES
Faulted strata
RICKETS HEAD
BLACK CLIFF
CLIFF
HOOKES
FOLLY
FOLKSTON
Aegiranum M.B.
Faulted strata
ROCK
LOW
TIMBER (NINE FEET)
THREE QUARTERS
Vanderbeckei M.B.
ROCK
GARLAND
FIDDLERS
LOWER LEVEL (LOWER PUMPQUART)
CATSHOLE
KILGETTY (SCAD)
Amroth limestone
LADY'S FROLIC
Listeri M.B.
Subcrenatum M.B.
TIN PITS
Farewell Rock