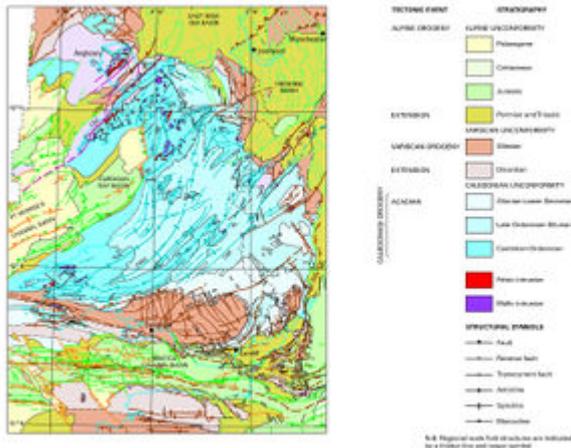


Westphalian, Silesian, Carboniferous, Wales

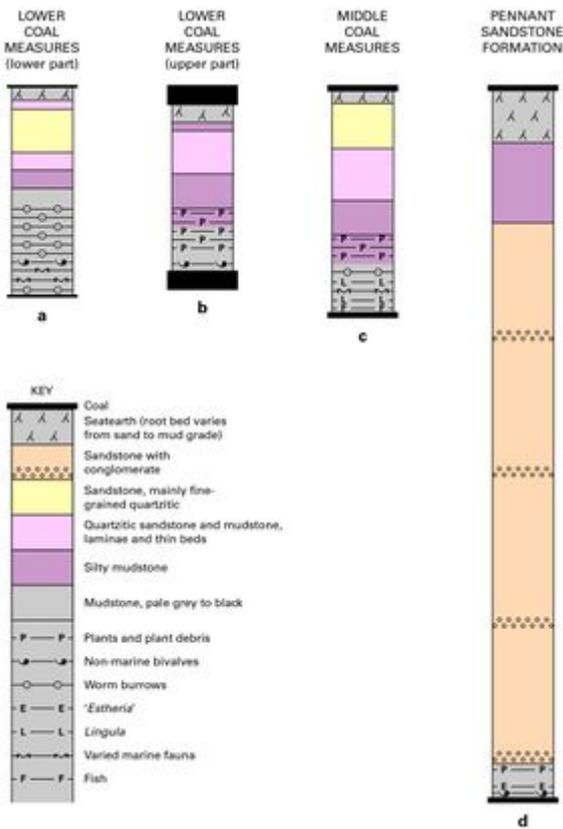
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From: Howells, M F. 2007. [British regional geology: Wales](#). Keyworth, Nottingham: British Geological Survey.



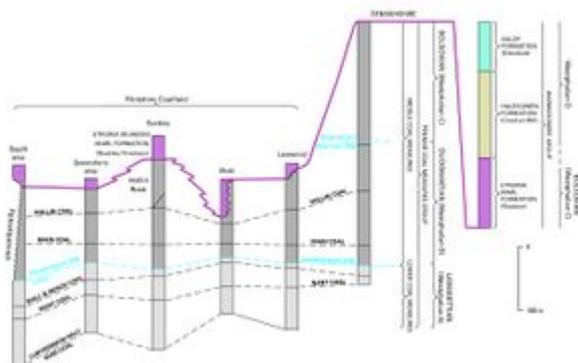
Tectonic map of Wales — key opposite (adapted from BGS, 1996). BD Berwyn Dome; BF Bala Fault; CSF Church Stretton Fault; CVF Conwy Valley Fault; CWS Central Wales Syncline; DS Dolwyddelan Syncline; HD Harlech Dome; LS Llŷn Syncline; LsS Llanystumdwy Syncline; LSZ Llŷn Shear Zone; ML Malvern Lineament; MSF Menai Straits Fault; ND Neath Disturbance; PL Pontesford Lineament; SS Snowdon Syncline; TA Tywi Anticline; TeA Teifi Anticline; UA Usk Anticline. Inferred age of structures: magenta Precambrian to Early Palaeozoic; blue Acadian; brown Variscan; green Mesozoic; orange Cainozoic (mainly Alpine). P916176.



Idealised contrasting cyclothem (after Woodland and Evans, 1964). a-c South Wales Coal Measures Group d Warwickshire Group. P916193.

[File:P916194.jpg](#)

Generalised vertical sections of the Westphalian strata of south Wales showing selected coals and marine bands (adapted from Thomas, 1974). P916194.



Generalised vertical sections of the Westphalian strata of north-east Wales showing selected coals and marine bands (Davies et al, 2004). P916195.

In south Wales, Westphalian strata occupy the core of the east-west-oriented syncline between St Bride's Bay in the west and its closure in Monmouthshire in the east ([P916176](#)). In north Wales, the

strata crop out in the Flintshire and Denbighshire coalfields, in the Vale of Clwyd, in restricted outcrops within the Menai Straits Fault System, and about Malltraeth in south-west Anglesey. Each of these outcrops is the downfolded (post-Westphalian) remnant of a more extensive area of sedimentation, with numerous minor folds and a well-developed fault pattern. The tectonic influence is most intense close to the deformation front in Pembrokeshire. The strata in south Wales were deposited during the final infilling of the Variscan foreland basin on the southern edge of the Wales-Brabant Massif, and those in north Wales are part of the infill of the extensional Pennine Basin to the north of the massif.

In south Wales, the lower part of the succession, up to early Bolsovian (Westphalian C), is argillaceous (South Wales Coal Measures Group), and about 1000 m thick ([P916194](#)). The upper part of the sequence is dominated by lithic sandstone (Warwickshire Group) of Bolsovian and Westphalian D age, and is about 1500 m thick. The lower sequence was deposited in a lower to upper delta plain environment, where intermittent rises in sea level induced marine incursions. Sediment was derived mainly from the north and the east, but initiation of the Variscan orogeny in early Bolsovian times caused uplift to the south. Emergence of the Variscan mountain chain led to an influx of coarse immature debris, which was deposited in alluvial braidplains that prograded northwards into the basin. In late Westphalian times, the delta plain environment was re-established.

Most of the Lower and Middle Coal Measures formations are dominated by mudstone and siltstone in coarsening upward units, cyclothems ([P916193](#)), in which facies are repeated cyclically. They were deposited in freshwater lakes on delta plains. Within the sequence, marine bands record periodic marine transgression and deposition in prodeltas and wetlands. Fluvial sandstones form extensive tabular sheets from both confined flow and flood events. In the Pennant Sandstone Formation, major distributary, channelised, fining-upwards sandstones are common around the margins of the basin and break the pattern of cyclicity. The cycles are capped by rootlet-bearing palaeosols (seatearths), which become more prominent towards the basin margin, and coal seams which, in the same direction, show evidence of erosion (washout) and splitting. The coals developed from peat accumulation when a rise in water table level with decreasing clastic input caused plant colonisation and the establishment of mires. The thick seams, with low ash and sulphur contents, probably accumulated in raised mires. Mire growth ceased when a rise in the water table formed brackish and fresh water lakes with communities of bivalves. Clastic input was low. The regional extent of the main cycles suggests that fluctuating water table depth was the main influence on sedimentation. However, recent facies interpretations have related the cycles to parasequences and to water table fluctuations caused by eustatic changes. Their thickness ranges from a few metres on the basin margin to up to 30 m in the centre. The correlation of the principal marine bands throughout the Westphalian basins of Europe and America show Maximum flooding that they were formed during eustatic sea level rise linked to the melting of the ice sheets on Gondwana. The grey mudstones in the nonmarine, lacustrine cycles are generally more organic-rich and darker at the base, and paler and siltier upwards. The freshwater bivalve (mussel) communities that thrived in these lakes form the basis of the broad traditional biostratigraphical classification of the Westphalian succession ([P916194](#)) that was first established in south Wales. However, as with the marine bands, the mussel fauna becomes impoverished towards the basin margin. Plant debris is abundant in the mudstone sequences and petrifications are common in the sandstones. Spores, together with the remains of mosses and relatives of the ferns and conifers, have also contributed to the biostratigraphical classifications. Thickness variation, coal seam splitting and small-scale synsedimentary growth faulting reflect local tectonic activity. Later, end-Variscan tectonism severely affected the incompetent Middle Coal Measures, causing shortening along bedding planes and reactivation of earlier extensional faults.

The base of the Coal Measures Group is marked by the Subcrenatum Marine Band, which has not

been proved in the Swansea district, but is a persistent element of the stratigraphy elsewhere. The ammonoid-brachiopod fauna is well developed and is particularly rich in the condensed sequences at the edge of the basin. In the strata up to the Garw Coal, there are seven marine bands, mostly *Lingula* bands with *Planolites ophthalmoides*, and few coals. Some bands are only locally preserved and only a few bands persist to the east crop. The M1 Marine Band, represented by two bands in the Gwendraeth valley and on the north crop, is particularly rich in fauna at Margam, where it contains burrowing and crawling molluscs, brachiopods, ammonoids and sponge spicules. The M2 Marine Band lies in the roof of the Crows Foot Coal at Margam, and at an equivalent level in relation to the Sun Vein on the south-east crop. The M3 Marine Band (Cefn Cribwr/Wernffrwd) contains a varied fauna, including *Gastrioceras listeri*, on the south crop. The M4 Marine Band (Margam) contains abundant foraminifera and the ammonoids *Anthracoceras* sp. and cf. *Domatoceras* on the south crop. The M5 Marine Band occurs only in the western part of the north crop and, in addition to the ubiquitous *Lingula mytilloides*, foraminifera are abundant in Cwm Clydach, in the Gwendraeth valley. The Cwm Berem Marine Band has been recognised only in the Gwendraeth valley. Towards the eastern crop, and the Usk Axis, channel fill sandstones within these strata indicate local emergence and reworking. Similar sandstones are common in the north and south crops, the most extensive being the Farewell Rock along the north crop, and the Cefn Cribwr Rock of the south crop. The sandstones developed as southward-prograding delta lobes. The coals that cap the cycles are mostly thin, the thickest being the Sun Vein about Pontypool and the Crows Foot of Cefn Cribwr. The commercially important coals of the Coal Measures Group were referred to many local names, but were subsequently rationalised, mainly by applying names from the Aberdare area ([P916194](#)). However, local names were retained in the west of the coalfield.

The Garw Coal is the lowest coal that was worked commercially, although it rarely exceeds 0.75 m in thickness and is generally less. It carries a distinctive fauna of fish fragments in its roof and marks a change from cycles capped by thin coals below, to cycles capped by thick coals above. Above the Garw Coal, cyclothems contain few marine beds whereas seatearths and coals are common; sideritic ironstones are well developed, both as beds and as nodules within the mudstones. The ironstones were the principal source of industrial iron in south Wales and, as in the Merthyr district, were extensively mined. Towards the west, the ironstones are more numerous but their quality decreases. Cycles between the Garw and Gellideg coals commence with mussel-bearing mudstone rich in thick calcite-shelled *Carbonicola*, the 'pseudorobusta' faunas. The succeeding cycles are predominantly argillaceous and capped by the Gellideg, Five Feet, Seven Feet and Yard seams, all worked coals, but subject to splitting and, in the east, merging into composite seams. The thin Amman Rider Coal contains the Vanderbeckei (Amman) Marine Band in its roof, and it marks the Lower to Middle Coal Measures boundary. The band comprises mudstone containing *Lingula mytilloides*, *Planolites ophthalmoides* and fish fragments, but in the south-east it is richly fossiliferous. The band persists throughout the coalfield and its thickest development, some 6 m, is at Brynmawr. It forms the base of a thick parasequence, which contains ironstones that have been worked, and is capped by the Bute Coal, which is the lowest in a group of commercially important coals — the others being the Nine Feet, Red Vein, Six Feet, Four Feet, and Two Foot Nine coals. The coals between the latter and the Cefn Coed Marine Band are thin and generally of poor quality, but the interval is characterised by fining upwards, channel fill, quartzitic sandstones (Upper and Lower Cockshot Rock and Elled Rock), which indicate derivation from the south and west. The sandstones are the earliest expression of the Pennant Sandstone Formation lithology. In the west, three thin marine bands, Graigog, Mole and Trimsaran, occur in this interval, but only the latter two are present in the central part of the coalfield where they have been named the Hafod Heulog and Britannic, respectively. The Cefn Coed Marine Band, at the base of the Bolsovian, is present throughout the coalfield, and at Aberbaiden, on the south crop, it contains the richest fauna of any marine band in Britain. From a 14 cm layer in the 0.46 m marine band, at least 80 species have been recorded; these include *Anthracoceras aegiranum*, corals, crinoids, horny and calcareous brachiopods with chonetids being particularly

abundant, bivalves, nautiloids, trilobites, ostracods and conodonts. In the southern area, between Pontardawe and Margam, the biofacies reflects clear water and open marine conditions. Farther north, between Cynheidre and Glynneath, the impoverished fauna is more indicative of muddy waters and, in the Cynon and Taff valleys, the band is dominated by brackish water assemblages.

The succeeding beds contain numerous ironstones that have been extensively worked in the Black Pins Mine Ground.

In the sequence between the Cefn Coed and Upper Cwmgorse marine bands, the coals that cap the cycles are generally thinner than those below, but they have been worked. They include the Gorllwyn, Gorllwyn Rider, Eighteen Inch, Lower Pentre, Pentre, Pentre Rider, Abergorky and Hafod seams. In the Abergavenny and Newport districts, tonsteins, indicating distant volcanic activity, have been determined in the roofs of the Gorllwyn Rider and Pentre Rider seams, and within the Lower Pentre seam. Marine bands occur in the roof of the Pentre Rider (Edmondia Marine Band), Abergorky (Shafton) and the Hafod (Cambriense) seams, and the only occurrence of the Carway Marine Band, with foraminifera as its only marine fossil, is in the Gwendraeth valley. The Five Roads Marine Band is best developed in the west of the Gwendraeth valley, where its fauna is dominated by bivalves, including cf. *Edmondia goldfussi*, *E. aff. transversa* and *Myalina compressa*, but it has been recognised in parts of the Pontypridd and Newport districts. The Edmondia (Foraminifera) Marine Band is widespread and generally contains abundant foraminifera, including *Agathamminoides*, *Glomospira*, *Glomospirella*, *Hyperammina* and *Tolypamina*. Apart from in the vicinity of the east crop, the Shafton (Lower Cwmgorse) Marine Band occurs throughout the coalfield, but it is best developed in the Gwendraeth valley where it is dominated by *Dunbarella macgregori*. Similarly missing in the vicinity of the east crop is the otherwise widespread Cumbriense (Upper Cwmgorse) Marine Band, at the Coal Measures-Warwickshire Group boundary; this is richly fossiliferous with the nautiloid *Huanghoceras postcostatum* and ammonoids *Anthracoceras cambriense* and *Politiceras kitchini*. It is the highest marine band in the Westphalian succession in Britain and, in the south-west of the coalfield, it is overlain by green-grey, feldspathic, lithic sandstone, which marks the first major influx of southerly derived Pennant Sandstone Formation sands into the basin. The lithic sands appeared earliest in the south-west, between Cynheidre and Margam, spread diachronously north-eastwards, and reached the north-east edge of the basin after deposition of the Brithdir Coal.

The Pennant Sandstone Formation facies are organised in large-scale cycles, fining upwards from erosively based sandstone into siltstone and mudstone. The sandstone is cross-bedded, conglomeratic at the base, with coal rafts, log clasts, siltstone and ironstone clasts. They represent alluvial deposition in highly sinuous channels, and the overlying mudstone and siltstone represents floodplain deposits. Clasts of Devonian phyllite and spilitic basalt confirm derivation from the south. The formation is subdivided by coal seams into the Llyfni, Rhondda, Brithdir, Hughes, Swansea members, which together with the overlying Grovesend Formation are dominated by sandstone and form the interior plateau of the coalfield. Thin mudstones form 'slack' features in the steep valley sides. The lowest Llyfni and Rhondda members have been referred to the Upper Coal Measures Formation in the main part of the basin. The principal coal seams are the Rhondda No. 1 and No. 2, Brithdir, Cefn Glas and Mynyddislwyn. The latter and two higher coals (Small Rider and Big Rider) have an abundance of *Leaia* in their roofs. The correlation of the Mynyddislwyn seam, in the east, with the No. 3 Llantwit and Swansea Four Feet seams suggests an eastward-developing unconformity, caused by continuing movement along the Usk Axis.

In early Westphalian D times, uplift along the Usk Axis resulted in a lowering of the water table and oxidation of the sediments in the vicinity. Thin coals in the Llynfi and Rhondda members fail towards the east crop, and east of the Taff valley, the red beds of the Deri Formation progressively replace the grey measures of the Pennant Sandstone. Red, purple and green mudstones and siltstones,

commonly with rootlets and pedogenic fabrics, are interbedded with mature quartz sandstone that is pebbly in places and probably derived from the Usk Axis. These changes are most apparent in the uppermost, Grovesend Formation, which is lithologically different from those below. The strata are preserved in the Gowerton Syncline where they are predominantly grey mudstones, with coals, seatearths and ironstones. To the east, in the Caerphilly Syncline, the strata are markedly thinner, devoid of coal seams, and include red and purple mudstones and a flora of possible Stephanian age. The lithologies indicate suppression of the alluvial valley environment of the underlying Pennant sandstones and re-establishment of the delta plain. The reddened strata reflect a change of environment from the Coal Measures to 'New Red Sandstone' although it is possible that a considerable thickness of late Carboniferous strata over south Wales has been removed.

The Westphalian strata in Pembrokeshire occupy the core of the syncline between Carmarthen Bay and St Brides's Bay and a small fault-bound outcrop between Newton and Newgale. The faulted southern boundary of the main outcrop juxtaposes Coal Measures Group strata against Precambrian, Silurian and Lower Carboniferous rocks. The northern boundary, with Namurian strata, is less severely disrupted.

In the spectacular cliff sections between Amroth and Wiseman's Bridge, folded and faulted strata within the *communis*, *modiolaris* and *similis-pulchra* zones are exposed. The basal bed is a pale weathered, laminated ankeritic siltstone with abundant specimens of the nonmarine bivalve *Anthracosia regularis*. The overlying strata include at least eleven seatearth-coal seam associations and nine mussel bands, indicating a succession of floodplain deposits that accumulated in swamps and freshwater lakes in a coastal plain environment. These are overlain a complex of contiguous minor channels with fining-upwards sandstone to siltstone infills and numerous soft-sediment disruption structures; the complex reflects the advance of a west and north-westerly flowing river system. The uppermost coal is overlain by the Amman Marine Band, which here is a thin mudstone with ammonoids and brachiopods. The overlying sequence is well exposed to the vicinity of Wiseman's Bridge, and comprises three coarsening-upward cycles capped by thin coals; they are typically coastal plain, swamp, fresh water and brackish lake deposits laid down during marine regression.

On the north side of Waterwynch Bay, the *Gastrioceras subcrenatum* Marine Band is overlain by an alternating siltstone-mudstone sequence, displaying part of a coarsening-upward regressive cycle. Synsedimentary deformation structures are common, including small-scale faults, slump folds and convolute lamination, and indicate the water saturated state of the sediments. In St Bride's Bay, Lower Coal Measures are exposed in the cliffs between Settling Point and Broad Haven, although locally, as about The Sleekstone, the sequence is intensely faulted. Sandstones in the cliffs and foreshore on the north-west side of Nolton Haven, comprise an overall fining-upward, fluvial channel-fill cycle similar to those of the typical Pennant facies farther east. Similarly, the orientation of cross-bedding, ripple marks and minor channels all indicate transport to the west and north-west, as determined in the main basin.

In north Wales, the main Westphalian outcrop lies between Point of Ayr, at the northern edge of the Dee estuary, and Ruabon, in the south. These strata dip eastwards beneath the younger rocks of the Cheshire plain and re-emerge, farther to the east, in the Lancashire and Staffordshire coalfields. To the west, Westphalian strata crop out through the Trias cover in the Vale of Clwyd and in the Malltraeth syncline, in south-west Anglesey.

The succession has been subdivided into the Pennine Coal Measures Group overlain by the Warwickshire Group ([P916195](#)). The Pennine Coal Measures Group is lithologically similar to the Coal Measures Group of south Wales; it is subdivided into Lower and Middle Coal Measures formations by the Vanderbeckei (Llay) Marine Band. The Warwickshire Group is a sequence of red

and purple mudstones with a few thin limestones, coals and grey mudstones that was deposited in an oxidising environment of an upper delta or alluvial plain.

The basal *Gastrioceras subcrenatum* Marine Band of the Pennine Coal Measures Group, 1 m of dark mudstone with an ammonoid-pectinoid facies, lies between the leaves of the Gwespyr Sandstone in north Flintshire and immediately above the Aqueduct Grit in Denbighshire. Seven marine bands occur higher in the sequence, and of these the Llay Marine Band (*A. vanderbeckei*) and the Warras Marine Band (*A. hindi*), defining Langsettian-Duckmantian (Westphalian A-B) and Duckmantian-Bolsovia (Westphalian B-C) boundaries, respectively, are the most significant stratigraphically. In Flintshire, the Coal Measures, up to 650 m thick, contains some 18 workable steam coal seams of which the Main Coal, the Wall and Bench Coal and the Yard Coal can be traced across most of the district and are the most important. Locally, thick sandstones occur within the dominantly shaly sequence near Buckley, the Hollin Rock succeeds the Hollin Coal and replaces most of the beds up to the base of the Buckley Fireclay Group but wedges out to the west and east. In Flintshire, the Buckley Fireclay Group, at the top of the Pennine Coal Measures Group, comprises compact, fine-grained quartzose and softer feldspathic sandstones. The white and grey sandstones are superficially stained purple, red and yellow. They grade into fine siliceous, purple, black and grey calcareous mudstone (marl), which is the main source of the raw material used in the manufacture of fire- and acid-resisting bricks and tiles. Elsewhere, beds of fine-grained clayey sandstone (ganister) are worked for brick making.

The red measures of the Warwickshire Group are traceable southwards from near Flint in the Dee estuary, to Ruabon and farther into the Shropshire Coalfield near Oswestry. In the southern part of this outcrop, the upward succession comprises the Etruria Formation, Halesowen Formation and the Salop formations. The base of the group is markedly diachronous, ranging from mid-Duckmantian in the Flintshire coalfield to Bolsovia in the Denbighshire coalfield. The Etruria Formation is restricted to the south of Wrexham; it is up to 300 m thick, and consists mainly of red or purple mudstone, mottled yellow, with a few thin beds of grey to black mudstone, carbonaceous smears and thin sandstones. In the upper part there are *Spirobis* limestones, but the only other fossils recorded are plants, ostracods, fish and rare mussels. The Halesowen Formation consists mainly of grey mudstone, sandy mudstone and sandstone with red and purple bands and mottling in places; a cyclical pattern can be discerned in places, but the coals are very thin. At Pont y Cyfflogyn, a limestone at the base is overlain by a marine band, which probably lies close to the Bolsovia-Westphalian D boundary. Apart from a possible occurrence in the Vale of Clwyd, the formation has not been determined north of Caergwrle. The Salop Formation forms a wide outcrop from Llay, north of Wrexham, to Oswestry. It comprises red, purple and green mottled mudstone and grey feldspathic sandstone, which seem to overstep the underlying formations ([P916195](#)). Particularly distinctive components are marl breccias and mudstones with abundant hematite grains. In the Vale of Clwyd, similar red beds, resting unconformably on Dinantian limestones have been correlated with the Salop Formation. Less common are grey measures with thin coals and thin limestones. The only fossils determined are plants, *Spirobis* and tetrapod footprints.

The relationship of the red measures to the underlying coal measures, and the possible unconformity at the base of the Etruria and Salop formations, have been subjects of considerable discussion. Comparison with the sequences farther east suggest that the relationships are most easily explained by interpreting the red measures as a facies that is diachronous; the Etruria Formation in Denbighshire is the lateral equivalent of the Buckley Fireclay Group of south Flintshire. On Anglesey, Westphalian strata crop out on the north-west side of the Berw Fault, in the area of Malltraeth, south-west of Llangefni; the outcrop is largely obscured by glacial deposits and alluvium. The detail of the sequence is derived mainly from shafts and boreholes from 19th century exploration. For much of the outcrop, the strata overlie Dinantian limestone, but in the south-east

they rest on Precambrian. The sequence consists of 450 m of grey measures (Pennine Coal Measures Group) with a thick cross-bedded coarse-grained sandstone at the base, referred to the 'Millstone Grit', overlain by some 200 m of red beds (Warwickshire Group). Marine shales within the sandstone contain a fauna that compares closely with the *Gastrioceras listeri* Marine Band in Flintshire. The overall sequence is typically cyclic with as many as 13 coals, four over 1 m thick, which reputedly were mined intermittently from the 15th century to the late 19th century. Mussels from a bed in the middle of the sequence suggests the lower part of the *Carbonicola communis* Zone. The Warwickshire Group, consisting of red mottled and grey mudstone and red, locally conglomeratic sandstone may rest unconformably on the grey measures, but the evidence is inconclusive. In a narrow outcrop along the Menai Straits, red, pale-green mottled mudstone (Ferry Beds), which unconformably overlies Visean limestone, has been assigned a Westphalian age on lithology. The mudstone is similar to that south-east of Port Dinorwic, which is associated with a distinctively massive boulder bed, crowded with subrounded clasts of locally derived sedimentary and volcanic rocks set in an argillaceous matrix, and with only the most imperceptible indication of horizontal bedding. The mudstone is bound to the south-east by the Dinorwic Fault, and is intensely folded within the Menai Straits Fault System at the northeast edge of the outcrop.

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