Permian—Triassic of Wales

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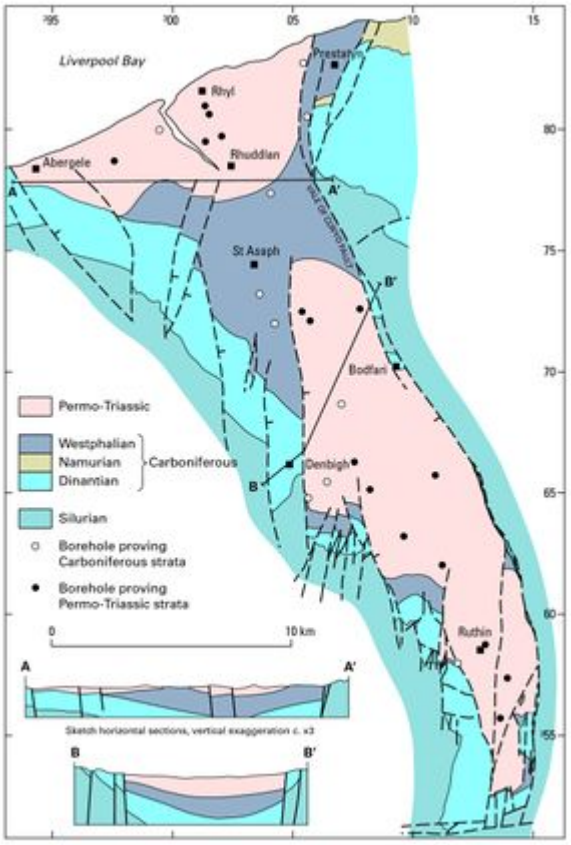
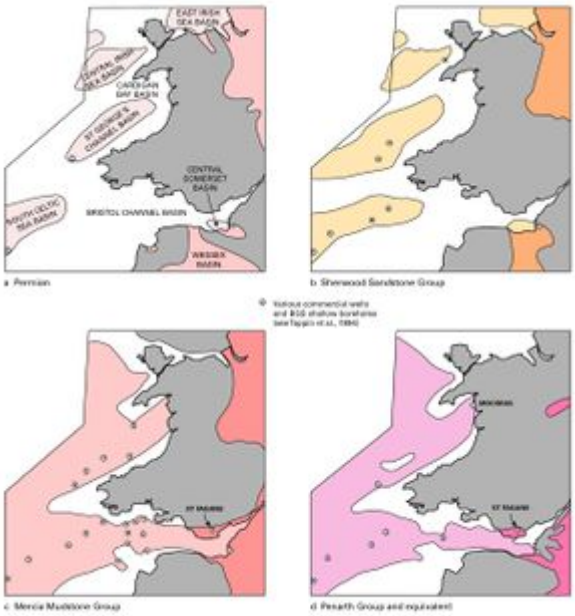


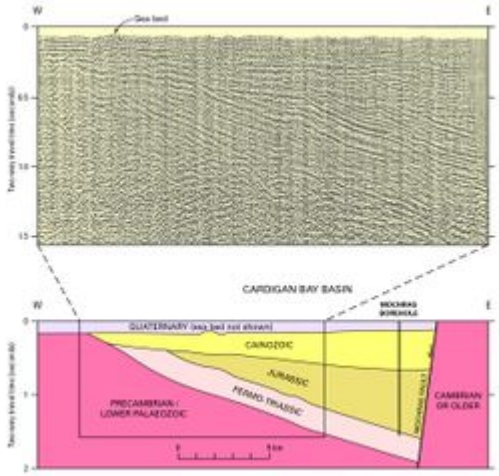
Vale of Clwyd, sketch map of the geology (adapted from Warren et al., 1984). P916185.

Vale of Clwyd viewed from the south-east. The fault-defined eastern margin of the Vale of Clwyd separates Triassic and Carboniferous strata from the Silurian outcrop of the Clwydian Hills (MFH

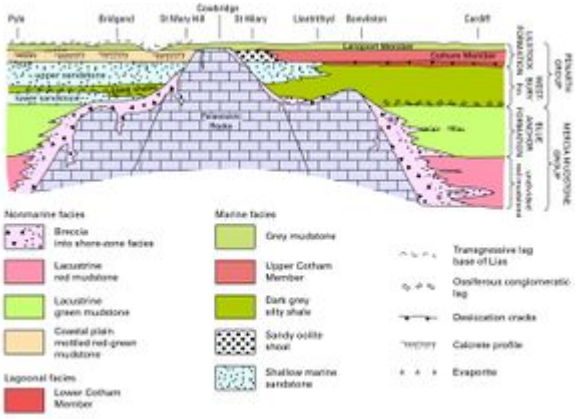
P662432).



Distribution of Permian and Triassic strata around Wales (adapted from Tappin et al., 1994). P916200.



Seismic reflection profile across part of Cardigan Bay Basin with interpretation extended to the Mochras Fault (Tappin et al., 1994). P916201.

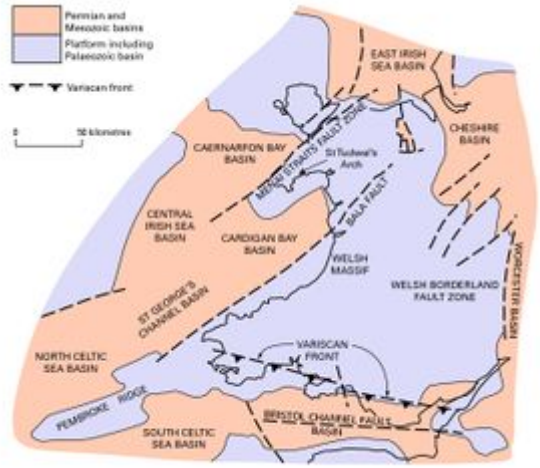


Schematic cross-section through the Triassic

sequence of the Vale of Glamorgan, not to scale (after Wilson et al., 1990). P916202.

Fissure in High Tor Limestone (Dinantian) infilled with Triassic sediment, Ogmore by Sea (MFH P662433).

Triassic blocky scree deposits resting unconformably on the High Tor Limestone (Dinantian), Ogmore by Sea. P662434.



Mesozoic basins in relation to the Welsh Palaeozoic massif (after Tappin et al., 1994). P916198.

During Permian–Triassic times, most of the area of the British Isles was a desert, with areas of rugged hills, as across Wales, and marginal areas of lower ground. Through Permian times, a marginal shallow sea, Zechstein, lay to the north-east, close to the current position of the North Sea, and it progressively encroached the landmass so that by mid-Triassic times, the Welsh landmass was almost surrounded by water. The Mesozoic era began with the removal of extensive areas of the exposed Carboniferous rocks and, at the same time, there was widespread oxidation of the desert surface. The earliest sediments were locally derived, reddened, waterlaid conglomerates and breccias that were probably generated in alluvial fans. The 'New Red Sandstone' represents a molasse facies to the Variscides, comparable with the Devonian, Old Red Sandstone, molasse facies to the Caledonides. Evidence of the fauna and flora in early Permian times is extremely poor, probably due to its low preservation potential and original low biodiversity in the desert environment. In mainland Wales, reconstruction of the early Permian geography is difficult because of the limited outcrop. However, offshore exploration has determined a fault-controlled basin in Cardigan Bay, and another in the east Irish Sea. Periodically, hypersaline lakes were established in these basins.

The occurrence of Permian rocks in north-east Wales has not been positively proved, but two outcrops of red sandstone in the Vale of Clwyd (P916185); (P662432) have been assigned a Permian age. Along the vale, geophysical surveys have determined three sedimentary basins that are bound on the east by the Vale of Clwyd Fault, which downthrows some 1500 m to the west. On the west side of the outcrop, between Abergele and Rhuddlan, red sandstone (Kinnerton Sandstone Formation) oversteps on to Carboniferous limestone and marks the edge of a small, fault-bound basin that extends northwards into Liverpool Bay (P916200)a. The friable, red, predominantly aeolian sandstones contain cemented layers with siltstone beds and mud-flake breccias of fluvial origin. An offshore borehole near Llandudno proved 65 m of unconsolidated red sand, with Upper Permian (Kazanian to Tatarian) spores, which has been considered to be equivalent to the Kinnerton Sandstone Formation.

Farther south, in the Denbigh–Ruthin area, exposures of red sandstones are scarce. Some of the more competent, cemented sandstones have been quarried, for example those from Foel Ganol were used in the construction of Ruthin Castle. The false-bedded sandstones are aeolian crescentic dune deposits, and palaeocurrents indicate westerly directed winds. The sand grains are subangular, faceted, coated with limonite and locally show secondary over-growths of quartz. Feldspar is a ubiquitous accessory mineral and ilmenite is the dominant heavy mineral; rutile, tourmaline and

zircon are common and garnet is less so. The rich mineral assemblage contrasts sharply with the paucity of the assemblages in the Carboniferous sandstones. Similar sandstones, also assigned to the Kinnerton Sandstone Formation, crop out on the western edge of the Cheshire Basin; the sequence oversteps the Carboniferous in eastern Denbighshire to rest on Ordovician strata near Oswestry and Llanymynech. To the south-west of Anglesey, Permian strata have been inferred in the Central Irish Sea Basin (P916200)a. In a borehole at the southern margin of St George's Channel Basin, calcareous mudstone and muddy sandstone, overlying Westphalian strata, have been assigned to the Permian, based on their geophysical signature.

Biostratigraphical evidence of Triassic age is variable and generally sparse. Macrofossils are scarce, but they do indicate that diverse assemblages occur. Plant spores and pollen are more widespread and allow some regional correlation. Three major lithostratigraphical units have been determined. They are, in ascending order, the Sherwood Sandstone, Mercia Mudstone and Penarth groups.

From the elevated edge of eastern Denbighshire and Flintshire, it is easy to envisage the development of the New Red Sandstone molasse facies that occupies the Cheshire Basin to the east. The lowermost, early Triassic, dominantly sandstone sequence (Sherwood Sandstone Group) with a local development of pebbly and conglomeratic sandstone (Cheshire Pebble Beds Formation, formerly the Bunter Pebble Beds) at its base, crops out close to the border, near Oswestry (P916200)b. The sandstones are typically well cemented, medium to coarse grained with scattered quartzitic pebbles. The internal bedforms suggest deposition in confined channel systems of low-sinuosity rivers; interbedded friable sandstones with faceted grains have been interpreted as wind-blown sand on gravel bars. All the palaeocurrent evidence indicates that the river systems drained persistently to the north-northwest, through the Cheshire Basin.

The top of the Sherwood Sandstone Group and the lower part of the overlying Mercia Mudstone Group are dominated by blocky red mudstone with interlaminated siltstone and mudstone. Halite that is extensively exploited in the Cheshire salt industry also occurs offshore within the Mercia Mudstone Group. The halite indicates that there were ephemeral lakes and the thickest deposits occur in the vicinity of syndepositional faults. The sandstones were deposited in a continental fluvial environment with rivers flowing northwards into the area of Liverpool Bay (P916200)c. Fine-grained, aeolian sandstones within the sequence record north-easterly prevailing winds, probably during drier winter seasons. Vertebrate tracks have been recorded.

The Mercia Mudstone Group forms the main outcrop in the extension of the Cheshire Basin in Liverpool Bay, north-east of Anglesey. To the south, elements of the three lithostratigraphical groups occur in both the St George's Channel and Cardigan Bay basins. The Sherwood Sandstone Group is generally finer grained than the onshore equivalent, possibly reflecting a more distal depositional environment. In the centre of the basins, the Mercia Mudstone Group strata lie conformably on the Sherwood Sandstone Group and four lithological units, with variable proportions of mudstone, siltstone, fine-grained sandstone and halite, dolomite and gypsum have been distinguished. Using geophysical logs, these units have been correlated with equivalent sequences in onshore boreholes. The evaporites were precipitated in coastal marine sabkhas. The thickest sequence, some 1700 m, penetrated by a borehole at the southern edge of St George's Channel Basin (Well 103/2–1), compares with a maximum of only 160 m in the Vale of Glamorgan. The lithologies suggest more basinal conditions than their onshore continental equivalents. The St George's Channel and Cardigan Bay basins are bound on the south-east side by the seaward extension of the Bala Fault Zone, and the asymmetry of the basin infill indicates syndepositional activity.

The first clear indication of the extent of these offshore Mesozoic sequences was provided by the Mochras Borehole (P916201), which was drilled between 1969 and 1971, on Shell Island, near Llanbedr, to the south of Harlech. During Triassic times, as today, the site lay close to the western

edge of the Welsh landmass. At the bottom of the borehole, at a depth of 1906 m, some 32 m of Triassic sedimentary rocks have yielded a miospore assemblage of Norian to late Rhaetian age. The Triassic sequence has been divided into the Terrigenous Formation, which consists of pale red-brown calcareous sandstone and dark brown shales, overlain by the Carbonate Formation, consisting of grey-green, dolomitised carbonate with some hematitic sandy beds, and suggesting deposition in a playa-lake environment; it is not closely comparable with the Rhaetic facies of south Wales.

Triassic rocks in south Wales are largely restricted to the Vale of Glamorgan, but small patches of red calcareous mudstone in some of the Gower bays and a larger outcrop of red breccia and conglomerate at Port Eynon are probably Triassic karstic remnants. Similar, red-stained breccias within Dinantian limestones in south Pembrokeshire and the Vale of Glamorgan are also possible sites of Triassic collapse cavities. In the Vale of Glamorgan, the lowermost Triassic strata are predominantly brownish red calcareous mudstone and siltstone) (P916202) that locally pass laterally into a 'marginal facies' of conglomerate, breccia and sandstone. The transition was controlled by the topography, which was dominated by the effects of erosion on the contrasting lithologies within the Cardiff–Cowbridge Anticline. The Carboniferous limestone formed ridges and small hills, and the softer Lower Old Red Sandstone along the axis was the site of a valley in the main basin to the south-east. The Mercia Mudstone Group in south Wales is probably of Norian age. The red mudstone is typically massive and dolomitic with common gypsum nodules and veins. Thin bands of greenish grey mudstone, with mottling, mudcracks and raindrop imprints, occur in places and, where they pass into the marginal facies, they contain thin calcareous sandstone and siltstone beds. The marginal conglomeratic facies is dominated by clasts of Dinantian limestones. Generally, exposures are poor but good coastal cliff sections occur between Barry and Sully islands, and between Ogmore by Sea and Kenfig Pool, where the basal unconformity and Triassic sediments in fissures and caverns in the limestones are commonly well displayed (P662433).

The red mudstone is overlain by green and grey-green mudstone, in places thinly laminated with thin dolomitic limestone beds (Blue Anchor Formation), which locally pass laterally into a conglomeratic marginal facies (P916202). Red mudstone bands are rare and gypsum nodules are common at a few horizons. Fish, plant and reptilian remains have been recovered from strata near the top of the formation, and sparse palynomorph assemblages have Rhaetian associations. The 14 m section at Lavernock Point displays a range of lacustrine lithologies, and desiccation cracks and evaporites indicate periodic drying out. The plant debris and spores in the upper part of the sequence, and the change in colour from red to green, indicate a change from arid to humid conditions probably associated with increasing marine influence, which culminated in the late Triassic marine transgression.

The Rhaetian marginal facies deposits have been divided into continental and lacustrine shore-zone subfacies. The continental subfacies of red conglomerate, breccia and sandstone, with few siltstone and mudstone beds and nodular calcretes has been subdivided into four lithofacies. The lacustrine subfacies consists predominantly of well sorted breccia, calcareous sandstone, siltstone and mudstone with subordinate nodular dolomites and, in proximity to the mudstones, both fenestral and cryptalgal carbonates. The breccias and conglomerates, with mainly Carboniferous limestone clasts (P662434), are well sorted and pass laterally, in as little as 10 m, into red mudstone. Platforms backed by low cliffs are cut into both subfacies; on the west side of Little Island, adjacent to Barry Island, five such platforms occur in a vertical section of 6 m. The marginal conglomeratic subfacies is interpreted as an alluvial fan deposit, and the ill-sorted angular breccias resemble modern scree. Matrix-supported conglomerates and thinly bedded graded sandstones are interpreted as the deposits of concentrated to dilute grain flows. These facies are most easily related to deposition in a major lake that dried out from time to time, with prolonged periods of subaerial exposure. In the

lacustrine subfacies, the lateral gradation from scree deposits through shore-zone clastics to red mudstone reflects the passage from a littoral to a sublittoral environment. The platforms indicate variations in the lake level and erosion by wave action. Between Barry and Sully, screes and local sheet flood and stream flood deposits are associated with shore-zone facies in the uppermost part of the sequence.

The Blue Anchor Formation is overlain by about 12 m of dark grey and grey mudstone with subordinate sandstones, siltstones and limestones (Penarth Group), which passes into a more restricted marginal facies. The strata were deposited during the mid to late Rhaetian marine transgression that persisted into early Jurassic times. In the cliff sections about Penarth Head, at St Mary's Well Bay and north of Lavernock Point, the group overlies an erosion surface corresponding to a significant shoreline recession following deposition of the Blue Anchor Formation. The lowest strata, the Westbury Formation, consist of dark grey, fissile, pyritous mudstone with a few thin beds of limestone and calcareous sandstone. Six depositional cycles have been recognised, each with a basal fine-grained sandstone that fines upwards into mudstone with bivalve-rich layers; bivalves include Rhaetavicula contorta, Chlamys valoniensis and Protocardia rhaetica. South of Penarth, between Lavernock Point and St Mary's Well Bay, thin limestones occur with the mudstones, and contain a restricted bivalve fauna, dominated by Liostrea bristovi. These are overlain by a thin fossiliferous, locally conglomeratic coarse-grained sandstone commonly referred to as a bone bed (Storrie's fish bed). The bed represents a strand-line deposit of the main marine transgression, which probably engulfed most of the Vale of Glamorgan. The foraminifera, marine ostracods, the brachiopod Orbiculoidea, echinoid fragments, ophiuroids, cirripedes and various marine invertebrates indicate a diverse community in a shallow marine, low-energy environment. The presence of relatively coarse lithologies and uncemented shell accumulations suggest more turbulent phases, possibly storm induced.

At the top of the Rhaetian sequence, the Lilstock Formation consists of grey and grey-green mudstone with few siltstone, sandstone and limestone beds. It has been divided into the Cotham Member overlain by the Langport Member (P916202). The junction between the Westbury Formation and the Cotham Member is sharp and locally channelled, up to 40 cm deep, indicating uplift and consequent shallowing. The basal calcareous, pale grey silty mudstone was probably deposited in a restricted marine lagoonal environment, and contains abundant dark mudstone clasts torn from the substrate. The mudstone matrix contains a diverse fauna with Cardinia and abundant 'Gervillia' praecursor, together with most of the Rhaetian bivalve taxa. However, up-sequence, the faunas decline and the presence of the foraminifera Dentalina, Euguttulina liassica, Lingulina tenera and Nodosaria and the ostracod Darwinia liassica indicate fresh-water influxes. At the top of the member, a coarse-grained, locally ooidal sandstone infills large polygonal desiccation cracks, up to 8 cm wide.

The Langport Member comprises porcellanous limestone overlain by calcareous mudstone with thin beds of fine-grained sandstone, siltstone and limestone. The pale grey, white-weathered, porcellanous limestone beds are separated by thin mudstone partings. Identifiable bivalves in the limestones include Modiolus, Dimyopsis and Liostrea hissingeri and the mudstones contain foraminifera, ostracods, echinoid, fish and plant debris. The facies records the final marine inundation of the lagoonal environment of the Cotham Member. The overlying calcareous mudstone was deposited in a shallow marine, offshore environment, and the few beds of thin sandstone and argillaceous limestones, some of which are graded, were probably storm generated. The top of the Penarth Group is sharply overlain by 'paper shales' of the St Mary's Well Bay Member, which straddles the Triassic–Jurassic boundary, at the base of the Blue Lias Formation.

To the west of the Vale of Glamorgan, the basal Triassic unconformity can be traced across Swansea Bay and close to the south coast of the Gower. However, the thickest Triassic sequence is contained

within the Bristol Channel Basin (P916198), bound on its north side by the Central Bristol Channel normal fault zone, an extensional reactivation of a Variscan thrust. The Mesozoic infill of the basin, which was profoundly influenced by the active tectonic extension, thickens west of Lundy Island. The Sherwood Sandstone, Mercia Mudstone and Penarth groups have all been proved, and the lithologies have been determined mainly from the geophysical logs and their comparison with onshore wells. The 960 m of the Mercia Mudstone Group within the basin, compared with about 160 m in the Vale of Glamorgan, is the clearest testimony to syndepositional fault movement. The sequence, predominantly of mudstone and siltstone with a thick central zone of halite, was deposited in basinal conditions some distance from the continental facies of south Glamorgan.

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