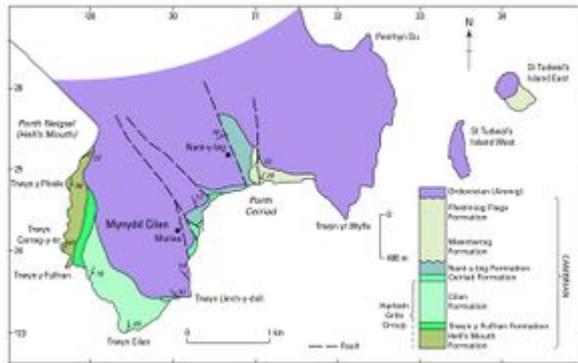


Arenig Series, Ordovician, Wales

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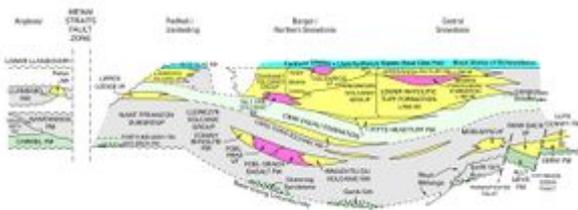
From: Howells, M F. 2007. [British regional geology: Wales](#). Keyworth, Nottingham: British Geological Survey.



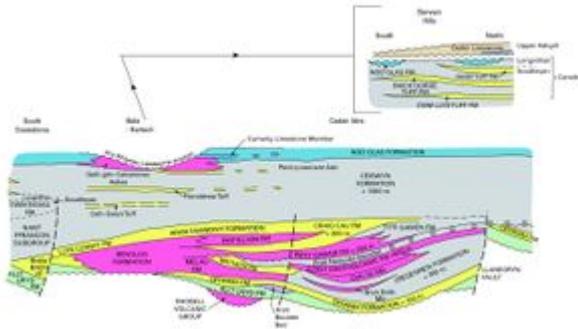
St Tudwal's peninsula, Llyn, sketch map of the geology (adapted from Young et al., 2002). P916151.



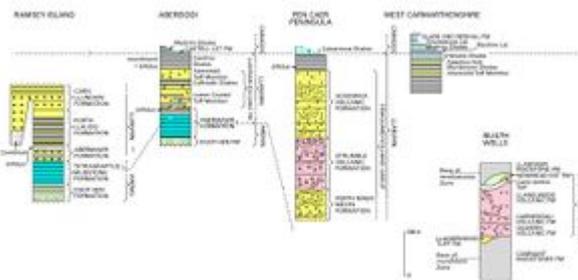
Unconformity at the base of the Arenig, Trwyn Llech y doll, St Tudwal's peninsula, Llyn. Arenig sandstones in the cliffs dip gently eastwards and rest on more steeply dipping siltstones of Middle Cambrian age. P662402 from Young et al., 2002.



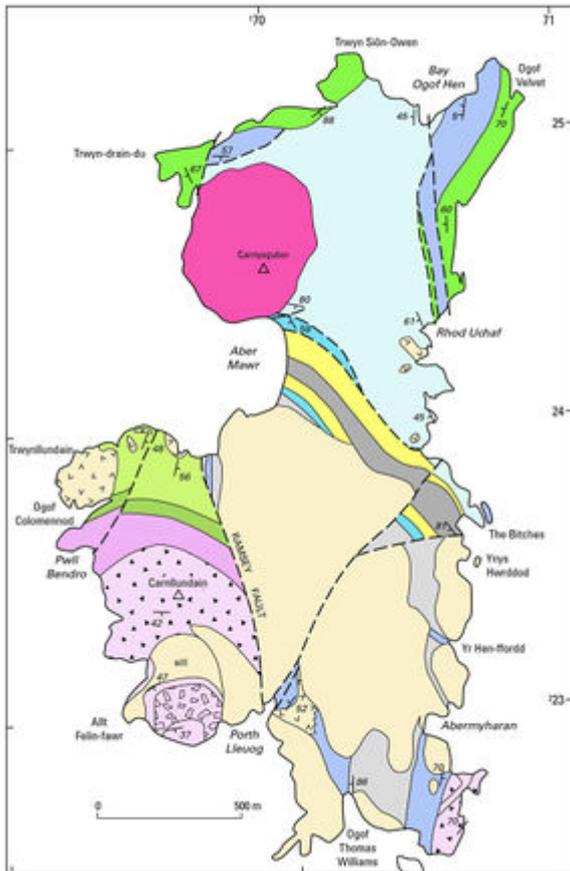
Cartoon (not to scale) illustrating a generalised vertical sequence of the Ogwen Group and equivalents (Arenig — Caradoc) across northern Snowdonia, Llŷn and Anglesey (adapted from Rushton and Howells, 1999). P916154.



Cartoon (not to scale) illustrating a generalised vertical sequence of the Ogwen Group and equivalents (Arenig — Caradoc) across southern Snowdonia and the Berwyn Hills (inset) (adapted from Rushton and Howells, 1999). P916155.



Generalised vertical sections of the Ordovician strata of north Pembrokeshire, west Carmarthenshire and Builth Wells (adapted from several sources). P916156.



Simplified geological sketch map of Ramsey Island (adapted from Kokelaar et al., 1984). P916157.

The Arenig Series in Wales is a transgressive sedimentary sequence that followed a eustatic regression and possible local uplift at the end of Tremadoc times. It is divided into three stages, Moridunian, Whitlandian and Fennian (P916227). It was first defined at Arenig Fawr to the north-east of the Harlech Dome, but subsequent biostratigraphical work has shown that there the series is incomplete, with most of the Whitlandian and Fennian stages missing. The most complete section is in south Wales where basal sediments, similar to those of the Tremadoc Series, continued to accumulate. Elsewhere, Arenig rocks crop out around the margin of the Harlech Dome, in Snowdonia, in Llŷn and on Anglesey.

The magnitude of the basal Arenig unconformity is most apparent to the north of the Harlech Dome where Arenig beds overstep on to the Precambrian Padarn Tuff Formation near Bangor, and on to the Monian Supergroup near Red Wharf Bay on Anglesey. Similarly, on Llŷn, Arenig sedimentary rocks overstep almost the whole of the Cambrian sequence in the width of St Tudwal's peninsula (P916151), and similar strata overlies the Precambrian Sarn Complex in the vicinity of Aberdaron. This basal Arenig unconformity (P662402) gives an indication of the minimum age for the final juxtaposition of the terranes adjacent to the Menai Straits Fault System. The intense erosion reflected in the unconformity caused dramatic changes in sedimentation across the boundary. Relatively deep-water, pelagic sediments of the Tremadoc were replaced by shallow-water, coarse-grained and locally conglomeratic sand in the lowermost Arenig.

The basal Arenig sandstones are well developed, but variable in lithology and thickness throughout most of the north Wales outcrops (P916157) (P916155). They represent fan delta and shoreface deposits, and even where there is no other evidence of an angular unconformity, the *Neseuretus* trilobite biofacies indicates shallow water. In the Vale of Ffestiniog, the distinctive Garth Grit is a

massive bedded, white quartzitic sandstone that is locally bioturbated and conglomeratic. It is probably a beach or sublittoral deposit. About Rhyd it is up to 130 m thick, but thins eastwards through a more flaggy, volcanoclastic sandstone facies to Blaenau Ffestiniog, and farther to the slate quarries at Croes yr Ddwy Afon where it is intensely bioturbated and chloritic, and forms the hanging wall of the main slate extraction. The clasts are mainly of vein quartz, rhyolite, andesite and siltstone; many are coated with a black, phosphatic encrustation that was once thought to be a bryozoan, '*Bolopora undosa*', but now is known to be an oncolitic accretionary precipitate of chemogenic or bacteriogenic origin. Similar encrustations are recognised on clasts in the basal Arenig sandstone (Graianog Sandstone) in Cwm Graianog, high above the Nant Ffrancon valley. These basal sandstones contain the trace fossils *Phycodes* and *Teichichnus*, and are overlain by a sequence of mudstone, ripple-marked sandstone and, in places, thin, bioturbated, ooidal ironstones. In the sandstone beds, trails of a foraging trilobite, *Cruziana*, are associated with the burrows *Skolithus*, and the mudstone contains the graptolites *Azygograptus* and *Didymograptus*.

Across Llŷn, conglomerate with clasts of Precambrian rocks is common at the base of the Arenig sequence. At Wîg, near Aberdaron, the conglomerate that overlies the Sarn Complex passes up into siltstone, bioturbated sandstone and dark grey mudstone with phosphatic nodules (Wig Bâch Formation; [P916154](#)). The mudstone has yielded the trilobite *Merlinia selwynii* (Salter) and the graptolite *Ayggograptus eivionicus* Elles, indicating an early Arenig age for the transgression at this locality. Eastwards across the peninsula, the base of the Arenig rests progressively on younger strata. T P Crimes, in his detailed studies of the trace fossils, distinguished eight facies in this sequence, which he attributed to transgressive-regressive pulses within the intertidal zone. Basal phosphatic and ferruginous conglomerates, with '*Bolopora undosa*', and coarse-grained sandstones grade up into medium-grained sandstones and siltstones, with a *Cruziana* ichnofacies, which in turn grade into finer grained sandstone and mudstone with a *fodinichnia* ichnofacies. The gradation reflects a progressive shift from a nearshore to an offshore setting. At Nant y Gadwen, the formation consists of siltstone and mudstone with trilobites and graptolites that indicate a fairly complete Arenig sequence and relatively deep-water conditions. At Porth Meudwy, coarse-grained turbiditic sandstones and conglomerates (Porth Meudwy Formation), probably mass flow deposits, are of probable late Arenig age. The sedimentary structures indicate dominant north-east and south-west flow, possibly parallel to a shoreline that was close to western Llŷn and may have been fault controlled. Thin welded tuffs on the north side of Mynydd Rhiw indicate the earliest stages of volcanic activity (Rhiw Volcanic Group), which lasted from late Arenig into Llanvirn times. North of Trwyn Talfarach, a suite of dolerite sills form the dominant feature. At the base of the tuffs is a manganese bed with rhodocrosite, rhodonite and pyrolusite, and a pisoidal ironstone.

The thickest Arenig sequence, up to 1500 m, with a basal, locally conglomeratic sandstone overlain by mudstone (Carmel Formation), is recorded on Anglesey, about Mynydd y Garn, on the north-west side of the Coedana Complex outcrop; the thickness may be accentuated by folding. The main outcrop extends from Rhosneigr, on the south-west coast, to Dulas Bay and Carmel Head, in the north, with smaller outcrops inland from Red Wharf Bay. The coarsening of the basal sandstones towards the north indicates a possible source in that direction. North of the Carmel Head Thrust, the conglomerates are typical beach deposits, possibly remobilised, and they are overlain by coarse-grained, cross-bedded sandstones with brachiopods and trilobites that indicate the nearshore *Neseuretus* biofacies. The clasts in the conglomerates are entirely of local, Precambrian origin. The basal deposits probably prograded southwards across the Precambrian substrate, from Whitlandian to late Fennian times. Locally derived conglomerates with many angular clasts persist into the uppermost Arenig (Treiorweth Formation). The associated Nantannog Formation comprises mudstone scattered with a similar range of Precambrian clasts, and marked facies change suggests remobilisation. Generally, it overlies the Treiorweth Formation, but in places it replaces it to lie directly on the Carmel Formation. The brachiopod faunas similarly reflect a high-energy

environment, and indicate that inundation occurred during Fennian times.

About the Harlech Dome, the Arenig strata are broadly referred to the Allt Lwyd Formation at the base of the Aran Volcanic Group ([P916155](#)). The formation can be traced with marked thickness variations from the Moelwyns in the north to Cadair Idris in the south. Coarse-grained sandstones, similar to the Garth Grit farther north, are laterally impersistent at the base. In the historical type area about Arenig Fawr, the sandstones are overlain by alternating beds of dark grey siltstone and light grey, fine-grained, bioturbated sandstone. The lithologies suggest a shallow water environment, and interdigitated volcanoclastic sandstones contain a shelly fauna characteristic of the inshore *Neseuretus* biofacies. Most of the sequence is lower Arenig (Moridunian), but some localities suggest a mid Arenig, *Didymograptus simulans* Biozone age. Southward, the main part of the formation comprises well-featured, medium- to thick-bedded, coarse-grained feldspathic sandstone, separated by thinly bedded, flaggy sandstone and silty mudstone. Local irregularities in the sandstone bases and *Chondrites*- and *Skolithus*-type bioturbation are common. The feldspathic sandstone, with abundant feldspar-phyric basalt clasts similar to the Rhobell Fawr Group, increases in abundance south-eastwards towards Aran Fawddwy, where the Aran Boulder Bed (up to 300 m thick) at the top of the Allt Lwyd Formation contains similar clasts of altered andesite or basaltic andesite. To the east, the Aran Boulder Bed oversteps onto the Mawddach Group, and to the south-west passes laterally into a crudely graded conglomerate. The boulder bed and associated conglomerate are interpreted as an alluvial fan complex, with both fluvial and debris flow deposits.

In south Wales, early Arenig tectonism associated with the development of the basin resulted in a series of fault blocks, which were eroded and transgressed prior to the deposition of conglomerates and coarse-grained, cross-bedded sandstones (Ogof Hên Formation; [P916156](#)). In general, Tremadoc strata are absent throughout Pembrokeshire, and the unconformity is most graphically displayed at Whitesand Bay where the basal sandstone infills incised Cambrian strata. On Ramsey Island, the basal Arenig pebbly sandstone with 'Bolopora undosa' rests with slight angular unconformity on the Lingula Flags Formation of the Merioneth Series ([P916154](#))([P916155](#)). The basal sandstone grades up into laminated and cross-laminated sandstone and siltstone, with burrows and trilobite tracks. The overlying mudstone contains a rich shelly fauna of early Moridunian age. Whitlandian strata on Ramsey Island were probably removed by disruption and soft-sediment sliding prior to deposition of black graptolitic mud, offshore in dysaerobic bottom waters. Such conditions persisted into late Fennian times when mud deposition was interrupted by distant volcanic activity, with the emplacement of fine- to medium-grained rhyolitic volcanoclastic turbidites as thin to thick beds within the black mudstone (Aber Mawr Formation). The mudstone contains abundant extensiform graptolites, and passes up into the Lower Llanvirn.

In the Abereiddi area, the basal coarse sandstones, which transgress Upper Cambrian (Merioneth) strata, grade up into micaceous mudstone and feldspathic sandstone turbidites. The sequence has yielded a rich shelly and graptolite fauna of Whitlandian age and the overlying darker grey shale contains blind or nearly blind trilobites of the atheloptic association plus mesopelagic trilobites of the cyclopygid biofacies, which imply water depths of probably more than 300 m. Farther east, at Treffgarne, sandstone turbidites and debris-flow deposits, which unconformably overlie the Trefgarn Volcanic Group, grade up into blue-grey, tuffaceous, cross-laminated sandstone and micaceous shale with dendroid and extensiform graptolites. In the Whitland area, equivalent strata have yielded a Whitlandian fauna and have been interpreted as turbidites and channelled mass-flow deposits passing into shallower water wave-influenced sandstones. The distribution pattern of this facies suggests a shoreline to the south, possibly controlled by fault-block movement of the basement in the Haverfordwest area. The overlying sequence of mudstone and siltstone reflects progressive deepening, and graded turbidites at the base of the Fennian indicate possible tectonic reactivation of the southerly source area. However such activity was brief, as the Fennian strata of hemipelagic

dark grey fissile and blocky mudstone (Pontyfenni Formation) yield rich trilobite and graptolite faunas, indicating that open marine conditions prevailed over south-west Wales at that time. In latest Arenig times, the deposition of pale grey mudstone is attributed to falling sea level as a result of eustatic regression.

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