

Llanvirn Series, Ordovician, Wales

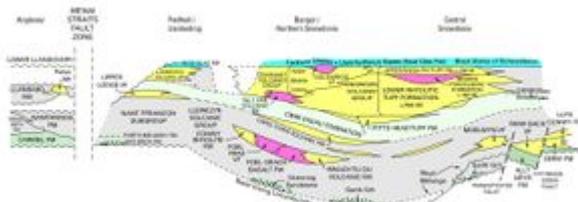
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[Jump to navigation](#) [Jump to search](#)

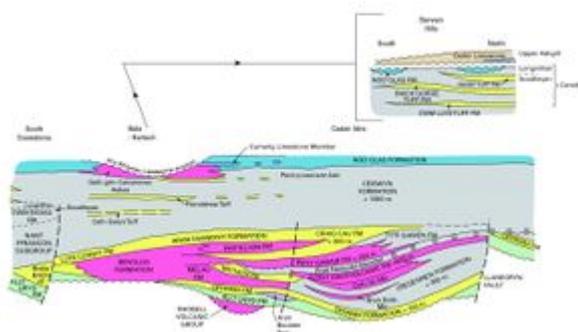
From: Howells, M F. 2007. [British regional geology: Wales](#). Keyworth, Nottingham: British Geological Survey.

Global Series	Global Stages	Series	Stages/Substages	Graptolite biozones	Ma
Llanvirn	Hirnantian	Arenig	Hirnantian	<i>Glyptograptus pinnatifidus</i> <i>Clonograptus aff. subaerolatus</i>	445
			Leintwardinian	<i>Dicellograptus unicus</i>	
			Castellian	<i>Dicellograptus complanatus</i>	451
			Fungilian	<i>Nemagraptus linearis</i>	
	Katian	Chazyan	Chazyan	Diconograptus digrammus	461
			Actonian		
			Marthaocokian		
			Wobolokian		
			Longillian	Diplograptus foliaceus (multifidus)	
			Soudleyan		
	Sandbian	Arenig	Costanian	Nemagraptus gracilis	
			Willehyan		
Nant	Darriwilian	Sandbian	<i>Haledograptus tentaculatus</i>	c. 466	
		Aberystwythian	<i>Didymograptus meridiocis</i> <i>Didymograptus arcticus</i>		
	Stage 3	Arenig	Fennian	<i>Eupanograptus frons</i> <i>Isograptus codonius gibberulus</i>	
			Whitelandian	<i>Didymograptus similans</i>	
Llanfyllin	Floian	Arenig	<i>Didymograptus varicosus</i> <i>Isograptus phyllograptoides</i>	478 c	
	Tremadocian	Tremadoc	<i>Clonograptus tenuis</i> <i>Strobilopora fabeliformis</i>	488	

Ordovician series. P916227.



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.



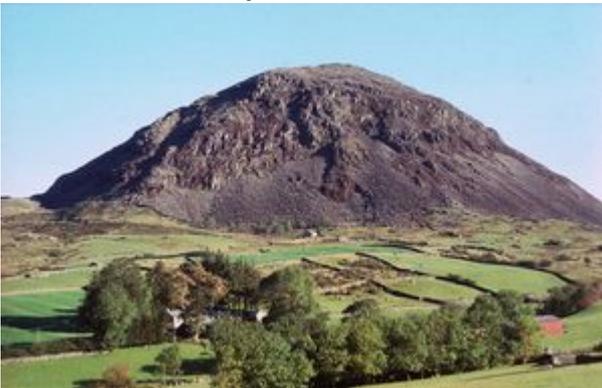
Cadair Idris scarp viewed across the Mawddach estuary. Middle to Upper Cambrian in the lowermost slopes pass up into the Ordovician Aran Volcanic Group in the ridges across Bryn Brith, to the left of centre. Acidic and basic volcanic rocks with intercalated sedimentary rocks and associated intrusions crop out in the main scarp. P662403 C D R Evans.



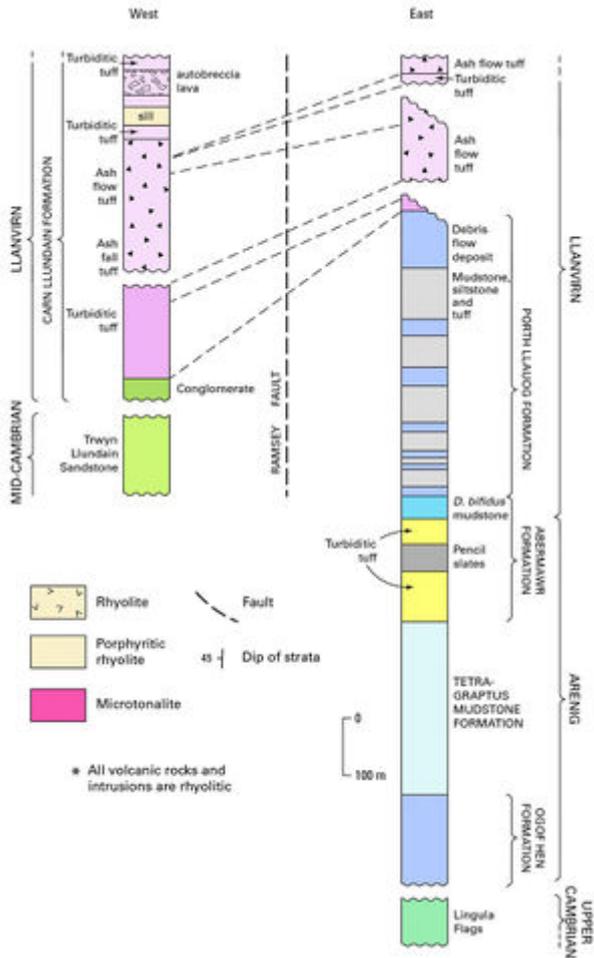
Acid tuff with foliation accentuated by siliceous recrystallisation, Offrwm Volcanic Formation, Mynydd-y-gader. P662404.



Bedded basic tuff overlain by coarse basaltic debris flow, Cefn Hir Member, Cregennen Formation, Pared y Cefn Hir. P662405.



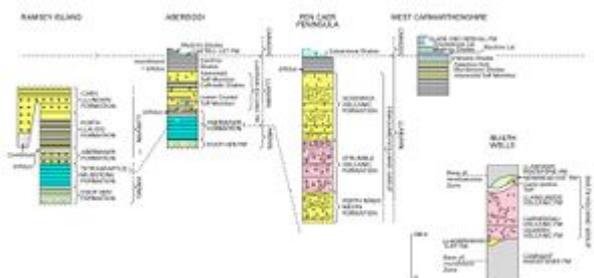
Manod Bach, north of Ffestiniog. A stock-like intrusion of quartz latite composition with extensive autobrecciation (MFH P662406).



Summary of lithostratigraphy, Ramsey Island (adapted from Kokelaar et al., 1984). P916158.



Layered gabbro exposed on Carn Llidi (C D R Evans; P662407).



Generalised vertical sections of the

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

Following the end Arenig regression, a blanket of mud with a deep water biofacies, which covered most of Wales and its borders, reflected a period of marine transgression in Llanvirn times. The series is most completely preserved in south Wales and it is there, in Pembrokeshire, that the type section was established. For most of north Wales, Llanvirn strata are extremely restricted, either the result of nondeposition or, more probably, of removal by erosion.

There is a rich trilobite fauna with large-eyed cyclopygids being particularly distinctive, and the series is subdivided into a number of graptolite biozones: *D. artus* (formerly *D. bifidus*), *D. murchisoni* and *Hustedograptus teretiusculus* ([P916227](#)). The Llandeilo Series was formerly a constituent part of the Ordovician of Wales; it included the *Hustedograptus teretiusculus* Biozone and part of the *Nemagraptus gracilis* Biozone. Redefinition of the chronostratigraphy now includes the *H. teretiusculus* Biozone in the Llanvirn, and the *gracilis* Biozone is the lowest biozone of the Caradoc Series.

The volcanic activity initiated in late Tremadoc and Arenig times evolved into a major geological event during the Llanvirn. Llanvirn volcanic rocks crop out in western Llŷn, about the Harlech Dome in southern Snowdonia and between western Pembrokeshire and Builth Wells along the southern crop. The volcanism developed in a back-arc basin from subduction of Iapetus Ocean beneath the northern, leading edge of Avalonia.

Between Porth Neigwl (Hell's Mouth) on southern Llŷn and Llanfairfechan on the coast to the east of Bangor, there is a thick sequence (up to 1500 m) of blue-grey, mudstone and siltstone with laterally impersistent fine-grained sandstones (Nant Ffrancon Subgroup; [P916154](#)); local pisoidal ironstones indicate brief periods of shoaling. The sequence is relatively well exposed in the lower parts of both the Nant Ffrancon Pass and Llanberis Pass, and there is no evidence for non-sequences or unconformities in either section. However, in southern Snowdonia, between the Cwm Pennant and the Trawsfynydd fault zones, Nant Ffrancon Subgroup rocks of Caradoc age rest directly on Arenig or older strata. Elsewhere, in Llŷn and around the eastern and southern flanks of the Harlech Dome only strata of *Aberiddian artus* and *murchisoni* Biozone age are present. Only in Cwm Pennant, south-west of Snowdon, is there any suggestion that Llandeilian rocks may be present, and their general absence is correlated with a widespread mid-Ordovician unconformity.

On Anglesey, Llanvirn rocks outcrop in the central region and contrast sharply with those through most of Arfon. They comprise a sequence of graptolitic mudstone with thick wedges of matrix-supported conglomerates and medium- to coarse-grained sandstones. These coarse deposits, with mainly Precambrian and Monian Supergroup clasts, reflect the continuation of the tectonic activity that influenced the Arenig sedimentation on Anglesey, and are interpreted as having been deposited from debris flows transported over short distances on an irregular sea floor; a wedge of these deposits, up to 650 m thick, is banked against an easterly dipping fault scarp. Rich assemblages of brachiopods and less common trilobites have been determined from the sandstones, and the mudstones have yielded graptolites of the *Didymograptus artus* and *D. murchisoni* biozones.

On Cadair Idris and north of the Mawddach estuary, acid tuffs with thin tuffites of the Offrwm Volcanic Formation are the first major expression of the volcanism (Aran Volcanic Group) that dominated southern Snowdonia from Llanvirn through to early Caradoc times ([P916155](#)); ([P662403](#)). The acid tuffs, both welded and nonwelded, are massive-bedded and contain quartz and feldspar crystals and pumice fragments; foliation is locally accentuated by siliceous recrystallisation ([P662404](#)) and interbeds of fine-grained, devitrified dust tuffs are common. The formation thins

markedly eastwards. South of Dolgellau, it oversteps the Arenig sequence to rest on upper Cambrian (Merioneth) strata. Around Tonfannau, several acidic ash-flow tuffs are interbedded with mudstone. The dearth of coarse terrigenous deposits and shallow-water structures suggest that the tuffs were deposited in a relatively deep, probably subsiding basin. A few thinly bedded tuffaceous sandstones indicate reworking of pyroclastic debris into debris flows and turbidites from shallower parts of the basin. The mudstones have yielded a graptolite fauna of early Llanvirn (artus Biozone) age.

The overlying Cregennen Formation comprises dark grey mudstone with impersistent basic tuffs and tuffites, few acid tuffs and some pillowed basalt. The Brin Brith and Cefn Hir members form prominent features between Arthog and Llynau Cregennen, particularly across Pared y Cefn Hir, but they merge to the east, and thin and wedge out westwards towards Arthog ([P916155](#)). The members are typically composite and reflect considerable complex reworking of both acid and basic volcanic debris into flows ([P662405](#)). Coarse-grained tuffites become finer grained and more thinly bedded upwards and may have been deposited in broad migrating channels; thinner, finer grained tuffaceous deposits are interpreted as low-concentration turbidites. The numerous tabular and contorted clasts of bedded tuff within the coarser deposits suggest collapse and erosion of channel margins. Graptolitic mudstones have yielded an artus Biozone fauna at many localities. The uppermost, Llyn y Gafr Volcanic Formation consists mainly of basalt lavas and bedded basic tuffs, with a few acid tuffs and intercalated graptolitic mudstones. Correlation is imprecise because of marked lateral facies variation and, locally, the intensity of basaltic intrusions. The thick accumulation of pyroclastic breccias near Llyn Gafr comprises blocks of highly vesicular basalt with a sparse matrix of comminuted basaltic debris, and probably represents an accumulation close to a vent. The massive and pillowed lavas represent the first major effusive volcanic episode in southern Snowdonia; the intercalated mudstones, together with the absence of evidence of shallow-water reworking, suggest accumulation well below wave base. However, the abundance of scoriae and cusped fragments in the basic tuffs also suggest periodic explosive activity. North of the Bala Fault, the basaltic tuffs and thin pillowed basalts of the Melau Formation are possibly lateral equivalents, and contemporaneous acidic activity is represented by an acidic ash-flow tuff and breccia (Brithion Formation) derived from the collapse of a rhyolite dome at Creigiau Brithion on the edge of Aran Fawddwy. The eroded top of the dome suggests temporary emergence.

North of the Harlech Dome and within the Nant Ffrancon Subgroup, acid ash-flow and fine-grained dust tuffs with high level synvolcanic intrusions ([P662406](#)) and extrusions of locally autobrecciated diorite and rhyolite (Rhiw Bach Volcanic Formation) crop out from Llyn Morwynion (east of Ffestiniog) to the north-east of Blaenau Ffestiniog. Locally, the tops of the diorite sheets show evidence of shallow marine reworking into laterally impersistent beds of volcanoclastic sandstones. In contrast, the relationships of the rhyolites, for example at Carreg y Fran in Cwm Teigl and Graig Goch north-east of Llynau Gamallt, are distinctively more intrusive. The volcanic rocks are hosted within dark blue-grey, sparsely graptolitic mudstone of artus Biozone age, which has been extensively quarried and mined for slates in the complex of quarries from Llechwedd to Manod Mawr.

On Ramsey Island, volcanism and sedimentation were profoundly influenced by the north-south, Ramsey Fault ([P916157](#)) ([P916158](#)). To the east of the fault, debris flow deposits with clasts of rhyolite and Cambrian rocks are interbedded with mudstone and minor siltstone (Porth Llauog Formation). The debris flows were controlled by repeated activation of the Ramsey Fault, which destabilised large masses of volcanoclastic debris to produce both high- and low- density turbidity currents. To the west of the fault, temporary uplift and emergence resulted in littoral conditions, and conglomerates rest unconformably on Cambrian rocks. The conglomerates form the basal member of the Carn Llundain Formation, a thick succession of graded and laminated tuff turbidites with three thick acidic ash-flow tuffs, locally with well-developed columnar jointing, in which ragged pumice

clasts are moulded about lithic clasts and crystals. The tuffs are interpreted as deposits entrapped close to a vent by rapid subsidence, and the eruption and emplacement are considered to have taken place under water. High-level intrusion of autobrecciated rhyolite was facilitated by fluidisation of the unlithified sediments. Throughout this volcanic activity the background sedimentation was dominated by black mudstone, and shallowing and emergence was extremely local and temporary.

On the Pembrokeshire mainland, evidence of broadly contemporaneous volcanic activity is preserved near Aber-eiddi and Fishguard, and its distribution was, to some extent, constrained by the Fishguard-Cardigan Fault Belt. In the Aber-eiddi-Abercastle area, the historical type area for the Llanvirn series, the Llanrian Volcanic Formation comprises thick rhyolitic tuffs and coarse- and fine-grained volcanoclastic deposits. These are separated by black graptolitic mudstone from overlying pumiceous lapilli tuffs (Aber-eiddi Tuff Member, previously termed Murchisoni Ash) formed by the youngest volcanic episode in the district ([P916156](#)). The tuffs were mantled by black pelagic mud with a rich, mid to late Llanvirn fauna of *murchisoni* and *teretiusculus* Biozone age. A rich shelly fauna near the top of the overlying Castell Limestone Formation indicates the transition into a shallower setting, spanning the Llanvirn-Caradoc boundary.

Another volcanic centre lay to the east in the vicinity of Fishguard and Strumble Head, and the sequence (Fishguard Volcanic Group) is spectacularly exposed in the sea cliff sections across Pen Caer between Pwll deri and Pen Anglas. The earliest activity produced rhyolite and rhyodacite lavas (locally pillowed) and breccias (Porth Maen Melyn Formation) that are overlain by pillowed basalts and hyaloclastites with intercalated volcanoclastic turbiditic sandstones (Strumble Volcanic Formation) on the north side of Porth Maen Melyn. The fluid basic magmas were emplaced mainly as interdigitating pillowed and sheet flows with the minor tuffs and hyaloclastites indicating periodic explosive activity. The final phase of rhyolitic activity (Goodwick Volcanic Formation) resulted in the extensive emplacement of welded and nonwelded ash-flow tuffs and thick rhyolite lavas, with flow-banded and perlitic cores and autobreccia carapaces. The formation is well-exposed in the cliff section between Goodwick and Penfathach. The primary volcanic elements are associated with much reworked volcanoclastic material, both in debris flow deposits and in the background silty mudstone. Interbedded graptolitic mudstones indicate a mid Llanvirn age close to the *artus-murchisoni* biozonal boundary. The sequence can be traced eastwards into Mynydd Preseli and, farther, into possible feather-edges near Narberth.

A striking feature of the Llanvirn sequence through western Pembrokeshire is the complex of dolerite, gabbro and dioritic intrusions, with subordinate microgranites and microtonalites, which were clearly coeval with the volcanic activity. They intruded the volcanic pile and associated unlithified mud, and extend west of the outcrop of the volcanic rocks. Perhaps the most prominent are the layered gabbroic complexes of Carn Llidi and St David's Head ([P662407](#)), which are probably the same intrusion on the limbs of a north-east trending syncline. Both outcrops display internal layering of gabbroic facies that can be crudely correlated; the marginal quartz-gabbro is considered to be the undifferentiated magma and the other varieties were largely generated by in situ magmatic differentiation. The intrusive suite is also present on the islands of Bishop and Clerks, some 5 km west-north-west of Ramsey Island, and on Mynydd Preseli, south-east of Fishguard, from where the Stonehenge bluestone were excavated.

In eastern Pembrokeshire and Carmarthenshire, blue-black graptolitic mudstone sedimentation persisted through early and mid Llanvirn times (*artus* and *murchisoni* biozones). Younger silicified tuffs (Asaphus Ash; [P916156](#)) with interbedded siltstone, commonly with the asaphid trilobite *Basilicus tyrannus*, are correlated with the late Llanvirn *teretiusculus* Biozone. The overlying flaggy sandstone, siltstone and dark grey mudstone with few volcanoclastic siltstones (Hendre Shales) lie within the *teretiusculus* and *gracilis* biozones, and therefore span the Llanvirn-Caradoc boundary.

Towards the east, deep water graptolitic mudstone passes laterally, near Llandeilo, into shallow marine sediments deposited close to the basin margin. The lowermost, early Llanvirn, blue-black and grey shales, with bands of rhyolitic tuff, grade up into sublittoral conglomerate, sandstone and rhyolitic tuff with subordinate mudstone and argillaceous limestone (Ffairfach Group). The group contains a rich shelly fauna. The overlying fossiliferous succession of shallow marine, fine- to medium-grained sandstones with impure limestones (Lower Llandeilo Flags) reflects a major upward transgressive cycle. A Williams interpreted the succession as shoreface coarse sands passing through intertidal to subtidal sands and silts, to shallow shelf mud deposited below wave base.

About the Tywi valley, volcanoclastic debris in the sequence was derived by shallow water reworking of lavas and pyroclastic deposits from the approximately contemporaneous Builth volcanic complex to the north-east. The lowermost dark grey graptolitic mudstone (Camnant Mudstone Formation) was deposited in fairly deep water and is overlain by acid tuffs, coarse agglomeratic tuffs, and spilitic and pillowed porphyritic andesite lavas with local high-level keratophyric intrusions (Builth Volcanic Group; [P916156](#)). The sequence was the subject of the classic interpretation by O T Jones and W J Pugh. In particular, they recognised that andesitic boulder beds and coarse feldspathic sandstones (Newmead Formation) were laid down as beach deposits around exhumed sea stacks and cliffs during the emergence of small volcanic islands. The volcanic rocks are overlain by grey mudstone with a few tuffaceous beds and thin argillaceous limestones (Llanfawr Mudstone Formation); the richly fossiliferous mudstone indicates that the sequence extends up into the *gracilis* Biozone at the base of the Caradoc.

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Contents

Introduction

[History of geological research](#)

[Geotectonic setting](#)

Precambrian and ?Cambrian

[Monian Composite Terrane](#)

[Coedana Complex](#)

[Blueschist Terrane](#)

[Monian Supergroup](#)

[Avalon Terrane](#)

[South-west Wales and the borders](#)

Cambrian

[Comley Series](#)

[St David's Series](#)

[Merioneth Series](#)

Ordovician

[Tremadoc](#)

[Arenig](#)

Llanvirn

[Caradoc](#)

[Ashgill](#)

[Ordovician volcanism](#)

Silurian

[Llandovery](#)

[Wenlock](#)

[Ludlow](#)

[Přídolí](#)

[Caledonian orogeny](#)

Devonian

[Lower Old Red Sandstone](#)

[Lochkovian](#)

Pragian—Emsian

Upper Old Red Sandstone

Carboniferous

Dinantian

Tournaisian

Visean

Silesian

Namurian

Westphalian

[Coal](#)

[Variscan orogeny](#)

[Mineralisation](#)

[Mesozoic](#)

[Permian—Triassic](#)

[Jurassic](#)

[Lower Jurassic](#)

[Middle Jurassic](#)

[Upper Jurassic](#)

[Cretaceous](#)

[Lower Cretaceous](#)

[Upper Cretaceous](#)

[Oil and gas](#)

Cainozoic

[Palaeogene—Neogene](#)

[Quaternary](#)

[Pleistocene](#)

[Holocene](#)

Geology and man

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Category:

- [Regional Geology of Wales](#)

Navigation menu

Personal tools

- Not logged in
- [Talk](#)
- [Contributions](#)
- [Log in](#)
- [Request account](#)

Namespaces

- [Page](#)
- [Discussion](#)

Variants

Views

- [Read](#)
- [Edit](#)
- [View history](#)
- [PDF Export](#)

More

Search

Navigation

- [Main page](#)
- [Recent changes](#)
- [Random page](#)
- [Help about MediaWiki](#)

Tools

- [What links here](#)
- [Related changes](#)
- [Special pages](#)
- [Permanent link](#)
- [Page information](#)

- [Cite this page](#)
- [Browse properties](#)

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