

# Geology of the Llanidloes area: Geological description - Late Ordovician and Silurian

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## Late Hirnantian to early Telychian slope-apron succession

The marked, rapid rise in sea level that followed the Late Ordovician glacial maximum is recognised across the Welsh Basin. It began during the late Hirnantian and continued into the Silurian, leading to the widespread re-establishment of mudstone-dominated slope-apron facies. The onset of this Hirnantian postglacial deepening is recorded by the **Bryn-glâs Formation (BGF)**, a mudstone succession up to 300 m thick that sharply overlies the Pencerrigteuion Member and is unfossiliferous and commonly thinly laminated, but contains units of slumped mudstone (Cave and Hains, 1986<sup>[1]</sup>; Davies et al., 2009<sup>[2]</sup>). Locally, in the westernmost inliers, the Pencerrigteuion Member is overlain by the **Lluest-y-Graig Member (LyG)**, a sequence of thinly interbedded turbiditic mudstone and sandstone up to 50 m thick, which represents a basal division of the Bryn-glâs Formation.

The Bryn-glâs Formation is succeeded by the late Hirnantian to Aeronian **Cwmere Formation (CeF)**, which crops out in a complex pattern of folds around the flanks of the Ordovician inliers. It consists of 220 m to 550 m principally of thinly interbedded turbiditic and anoxic hemipelagic mudstones, generally in units about 5 cm thick, with thin beds and laminae of turbiditic siltstone and sandstone at intervals throughout. At its base is the **Mottled Mudstone Member (MMb)**, comprising up to 25 m of pale grey burrow-mottled mudstone ([Plate P775110](#)) that, in its lowest part, includes units of laminated hemipelagite containing latest Hirnantian *persculptus* Biozone graptolites ([Plate P775109](#)). The Mottled Mudstone Member sharply overlies the Bryn-glâs Formation and records the subsequent, postglacial recolonisation of the basin prior to the creation of a deep thermally stratified water column and the widespread deposition of the anoxic facies (Davies et al., 2009<sup>[2]</sup>).

In the west of the district, around the Bryn Mawr, Mynydd-y-groes and Plynlimon inliers, the Cwmere Formation is largely replaced by the **Glaslyn Formation (Gly)**, a succession of abundant, thin, parallel- and cross-laminated turbiditic sandstone arranged in characteristic Bouma-type units, interbedded with turbiditic and hemipelagic mudstone. The sandstones form up to 50 per cent of the succession and are typically 1 to 3 cm thick, although they may locally reach thicknesses of 30 cm. The formation thins eastwards, splitting into two leaves that interdigitate with the Cwmere Formation around the flanks of the Van Inlier. The lower leaf crops out around the eastern side of the inlier, where it replaces the lower 30 to 60 m of the Cwmere Formation, including the uppermost part of the Mottled Mudstone Member; the upper leaf thins eastwards and passes into the Cwmere Formation north and south of the inlier. The Glaslyn Formation records deposition from mixed sand and mud turbidity currents, and was probably deposited as a number of small turbidite lobes that amalgamated on the margin of the Rhuddanian slope apron.

Marine regression during the Aeronian introduced the **Claerwen Group** (Davies et al., 1997<sup>[3]</sup>),

which sharply overlies the the Cwmere Formation ([Plate P775111](#)). It comprises a slope-apron facies of predominantly oxic, pale grey-green, colour-banded turbiditic and hemipelagic mudstone, thinly interbedded on a scale of 2 to 3 cm, with subordinate thin siltstones and sandstones. The turbiditic and hemipelagic mudstones are mostly burrow-mottled, and there are horizons of diagenetic phosphate nodules at intervals. Individual turbidite units commonly display thin (1 mm or less) silt laminae at their bases, and were generally deposited from low-density, fine-grained turbidity currents. Thin units of anoxic mudstone, which occur in places throughout the succession, are thought to record brief transgressive pulses in response to fluctuations of the Gondwanan ice sheet (Page et al., 2007<sup>[4]</sup>). The Claerwen Group envelops earlier formations around the margins of the Ordovician inliers and crops out over much of the area around Llanidloes. It is comprises the **Derwenlas Formation (DIF; up to 140 m thick)** and the overlying **Rhayader Mudstones Formation (Rhs; up to 550 m thick)** separated by a widespread anoxic unit, the **Monograptus Sedgwickii Shales Member (lh<sup>s</sup>)**, at the base of the latter formation ([Plate P775112](#)). This anoxic level correlates with a major sequence boundary in shelfal areas bordering the Welsh Basin, and equates with a well-documented global marine transgression (Davies et al., 2013<sup>[5]</sup> and 2016<sup>[6]</sup>; Johnson, 2010<sup>[7]</sup>) which probably began during the late Aeronian *convolutus* graptolite Biozone; graptolites of the latter have been recorded in anoxic units within the upper part of the Derwenlas Formation.



**Plate P775111** Rusty weathering anoxic mudstones of the Cwmere Formation overlain in the upper part of the scarp by more resistant bioturbated mudstones of the Derwenlas Formation, Uwch-y-coed [SN 8300 9502].



**Plate P775112** Feature (slack) formed by *Monograptus Sedgwickii* Shales Member at the base of Rhayader Mudstones Formation (right of picture), with the underlying Derwenlas Formation exposed in left foreground, Uwch-y-coed [SN 8300 9513].

The Rhayader Mudstones Formation is succeeded diachronously by the **Devil's Bridge Formation (DBF)** and **Foel Fadian Formation (FoF)**, two broadly comparable early Telychian divisions of thinly interbedded, Bouma-type, turbidite sandstones and mudstones ([Plate P775113](#)), which crop out in the south-west and north-west of the district respectively. The sandstones are parallel and cross-laminated, between 1 and 5 cm thick, and form up to 30 per cent of the succession; widely scattered thicker sandstone beds range up to 30 cm. The interbedded turbidite mudstones are generally pale green-grey, colour banded and somewhat thicker. They are commonly capped by a thin burrow-mottled hemipelagic mudstone, although parts of each succession include laminated hemipelagites containing graptolites indicative of the *turriculatus* (s.l.) Biozone. Deposition of both the Devil's Bridge and Foel Fadian formations is thought to result from the overall increase in sediment supplied to the basin in response to tectonic uplift of the source areas during the Telychian (Davies et al., 1997<sup>[31]</sup>; Soper and Woodcock, 1990<sup>[81]</sup>). Palaeocurrent indicators suggest that the Devil's Bridge Formation was derived from south-easterly quadrants whereas those of the Foel Fadian Formation are indicative of a north-westerly source. Both source areas lay outside the Llanidloes district. The Devil's Bridge Formation thickens to over 500 m in the extreme south-west, coincident with the basinward thinning of the underlying Rhayader Mudstones Formation. At its maximum development within the district the Foel Fadian Formation is 430 m thick, and it appears to thin in a general eastward direction. The reason for these thickness variations is equivocal, although the distribution of both formations was influenced by a sea-floor topography that may have been affected by contemporaneous movement on component structures of the Central Wales Lineament which runs through the western part of the district (Davies et al., 1997<sup>[31]</sup>; see below).



**Plate P775113** Thinly interbedded turbidite sandstones and mudstones of the Foel Fadian Formation, Foel Fadian [SN 8236 9554].

### **Telychian sandstone-lobe succession**

The deposition of slope apron mudstones mostly ended during the early Telychian when a series of large-scale, sand-dominated turbidite-lobe systems (*sensu* Mutti and Normark, 1987<sup>[9]</sup>) entered the Welsh Basin from the south. This marked increase in the grade and volume of sediment supplied to the basin has been linked to plate collision and uplift of the sediment source areas (Soper and Woodcock, 1990<sup>[8]</sup>; Woodcock et al., 1996<sup>[10]</sup>). The distribution of the sandstone-lobe systems within the southern Welsh Basin reveals a pattern of eastwards migration, which is related to the successive reactivation of intrabasinal faults ([Figure P930912](#)). These deposits are represented by formations that comprise the **Cwmystwyth Grits Group**. The first appearance of this southerly sourced sediment within the district is recorded by the **Blaen Myherin Mudstones Formation (BMM)** and **Caerau Mudstones Formation (CaM)**. These partly contemporaneous formations represent muddy fringing facies to the main sandstone-lobe systems, and are characterised by alternations of thin- to medium-bedded, dark grey turbidite mudstones and either laminated or

bioturbated hemipelagites. The Blaen Myherin Mudstone Formation is up to 350 m thick and crops out in the west of the district, where it gradationally overlies the Devil's Bridge and Foel Fadian formations, west of the Central Wales Lineament. The Caerau Mudstones Formation, up to 600 m thick, crops out in the central parts of the district, east of the Central Wales Lineament, and generally overlies the Rhayader Mudstones Formation.

The Blaen Myherin and Caerau mudstones formations are indistinguishable and can only be differentiated where they are separated by the sandstone-lobe facies of the **Rhuddnant Grits Formation (Rdd)** or its fringing facies, the Glanyrafon Formation (see below). The Rhuddnant Grits Formation crops out in the south-west and north-west of the district, and comprises up to 1500 m of abundant, medium to very thick (up to 1 m), commonly amalgamated beds of coarse-grained, feldspathic, mud-rich sandstone ('high-matrix sandstone'), interbedded with subordinate thin-bedded, Bouma-type turbidite sandstone-mudstone couplets and packets of mudstone. The high-matrix sandstones range from very muddy types that grade into sandy mudstones and in which the regional cleavage is typically well developed, to harder, less muddy, normally graded beds. They commonly contain a variety of larger clasts including granules, small pebbles and rip-up clasts of sandstone and mudstone. Northward-directed flute and groove casts on the bases of certain beds indicate derivation from the southerly source. These sandstones have been interpreted as the products of high density sediment gravity flows, varying from slurry-like debris flows to highly concentrated turbidity currents. They were probably fast-moving and deposited their entrained sediment suddenly when flow velocity waned; contorted rip-up clasts, convolute lamination and dish structures are evidence of the rapid dewatering that occurred as the flows 'froze' in situ. The high-density turbidites were able to travel considerable distances beyond the limits of the Bouma-type flows, and into the mudstone belt that formed the distal fringing facies of the turbidite system (Davies et al., 1997<sup>[3]</sup>; Lowe, 1982<sup>[11]</sup>); thus, feature-forming packets with high-matrix sandstone and commonly sandy mudstone beds occur locally within a succession predominantly of turbiditic mudstones in the north-west of the district (**Rdd(md)**). Regional studies (Clayton, 1992<sup>[12]</sup>; Davies et al., 1997<sup>[3]</sup>; 2006<sup>[13]</sup>; Smith, 2004<sup>[14]</sup>) have shown that the Central Wales Lineament was an intrabasinal structure, which was active during deposition of the Rhuddnant Grits and largely confined them to its western side, where the thickest part of the succession crops out. The grits appear to sidelap against the structure and the youngest strata, of early *crispus* Biozone age, lie immediately to the east where they interdigitate in a complex manner with the succeeding **Glanyrafon Formation (Glr)**. The latter crops out widely in the south of the district around Llangurig, and in the north between Staylitttle, Carno, Trefeglwys and Llandinam; further outcrops lie along Nant Feinion, south of Llandinam. It comprises a succession, in places up to 750 m thick, of thinly interbedded Bouma-type turbidite sandstone-mudstone couplets. The sandstones are both parallel and cross-laminated, and form 10 to 50 per cent of the succession, generally in beds about 5 cm thick, but locally up to 30 cm. The interbedded mudstones include both oxic and anoxic types, in which the hemipelagite is respectively either burrowed or laminated. In contrast to the Rhuddnant Grits, the Glanyrafon Formation was deposited from relatively slow-moving, low-concentration turbidity currents that were less confined by basin topography and therefore able to spread laterally, beyond the limits of the higher density flows, to form a sandy fringing facies of the turbidite system. The formation gradationally overlies and locally interfingers with the system's muddy fringing facies (Blaen Myherin Mudstones and Caerau Mudstones formations) and intervenes between the sandstone lobe facies of the Rhuddnant Grits and younger Pysgotwr Grits formations (see below).

The **Pysgotwr Grits Formation (Ptr)** crops out in both the north and south of the district, where it separates two units of the Glanyrafon Formation (distinguished as **Glr'** and **Glr''** respectively). It consists of bundles of high-matrix sandstone, comparable to those of the Rhuddnant Grits, but with noticeably coarser-grained, thicker (up to 2 m) and more massive beds, which alternate with packets of thin-bedded sandstones and mudstones ([Plate P775114](#) and [Plate P775115](#)). East of the Central

Wales Lineament, where the Rhuddnant Grits are largely absent, the Pysgotwr Grits lie about 350 m to 400 m above the base of the Glanyrafon Formation. However, the formation thins eastwards and is absent to the east of the Tylwch Anticline; in this area, the Glanyrafon Formation is undivided. The eastwards disappearance of the Pysgotwr Grits Formation has been interpreted as evidence of sidelp against an active Tywi Lineament and the contiguous Tylwch Anticline (Davies et al., 1997<sup>[3]</sup>).



**Plate P775114** Thick-bedded high-matrix sandstones interbedded with thin turbidite sandstones and mudstones, Pysgotwr Grits Formation, Trannon [SN 8914 9576].



**Plate P775115** Flute casts on base of turbidite sandstone, fallen block, Pysgotwr Ggriots Formation, Trannon [SN 8919 9578].

### **Late Telychian to early Wenlock slope-apron succession**

A period of tectonic quiescence in the late Telychian led to the re-establishment of oxic slope-apron sedimentation within the basin, characterised by deposition of the **Dolgau Mudstones Formation (Dgu)** (the Tarannon Pale Shales of earlier workers e.g. Wood, 1906<sup>[15]</sup>). This distinctive olive-green and purplish red mudstone facies (**Plate P775116**) is up to 300 m thick, commonly silt-laminated and mostly bioturbated, but in places contains subordinate thin beds of laminated hemipelagic mudstone, recording brief episodes of anoxicity that were a precursor to a period of sustained anoxic deposition associated with the early Wenlock Ireviken Event (Gelsthorpe, 2004<sup>[16]</sup>; Jeppsson, 1997<sup>[17]</sup>; Munnecke et al., 2003<sup>[18]</sup>). The formation mainly crops out in the northern and eastern parts of the district. In the Trannon area, in the north, packets of thin-bedded turbidite sandstone and siltstone appear in the highest parts of the formation.



**Plate P775116** Purple and green banded and mottled (oxic) turbidite mudstones, Dolgau Formation, Trannon [SN 8955 9565].

The earliest Wenlock strata are represented by the predominantly anoxic **Nant-ysgollon Mudstone Formation (Nyg)**, which sharply overlies the Dolgau Mudstones. Most of the formation has been assigned to the *centrifugus* Biozone (Davies et al., 1997<sup>[3]</sup>), with the base of the Wenlock located within the lowest few metres of anoxic mudstone. The formation comprises a succession of dark grey, graptolitic, laminated hemipelagic mudstones, with subordinate colour-banded and burrow-mottled turbiditic mudstones and local slumped units. It is about 60 m thick on the flanks of the Pegwyn Hills in the south-east of the district, but thickens north-westwards to at least 140 m in the area around the Trannon Syncline, where it contains abundant thin beds and laminae of turbidite sandstone and siltstone (**Nyg(sa)**; [Plate P775117](#)). The distribution of this sand- and silt-rich facies was possibly controlled by intrabasinal topography and structure, as it appears to be confined within a north-south belt that extends onto the adjacent Dinas Mawddwy district. It represents a precursor to the major influx of turbiditic sandstone that is associated with the onset of Wenlock tectonism within the Welsh Basin (Davies et al., 1997<sup>[3]</sup>).



**Plate P775117** Rusty weathering, laminated (anoxic) hemipelagic mudstones interbedded with thin turbidite sandstones and siltstones, Nant-ysgollon Mudstone Formation, Esgair Hir Forest [SN 9002 9362].

### **Early Wenlock sandstone-lobe succession**

The renewal of tectonism in the early Wenlock coincided with the deposition of the **Penstrowed Grits Formation (PdG)**, which has its type locality at Penstrowed Quarry [SO 0680 9100] in the east of the district. The formation crops out mostly in the east, and as outliers within synclinal cores in the north of the district. It is up to 900 m thick and comprises thick beds of high-matrix sandstone, interbedded with thinner Bouma-type turbidite sandstones and mudstones in which the hemipelagic component is generally laminated ([Plate P775118](#)). The high-matrix sandstones are feldspathic, micaceous, and commonly contain variable amounts of bioclastic material; flute and groove casts on their bases indicate derivation from southerly source areas. On a regional scale, the Penstrowed Grits Formation thins eastward against a contemporary palaeoslope which lay to the east of the district, probably along the line of the Pontesford Lineament (Dimberline and Woodcock, 1987<sup>[19]</sup>); supporting evidence for this is obtained from slumped units at certain levels within the

formation, with folds that are overturned westwards. However, biostratigraphical evidence (Davies et al., 1997<sup>[3]</sup>) suggests that the formation also sidelaps in a westerly direction, and the idea has developed of a fault-controlled depression (the 'Montgomery Trough') within which the Penstrowed Grits turbidite lobe system expanded laterally (Cave and Hains, 2001<sup>[20]</sup>; Cave, 2008<sup>[21]</sup>; Cummins, 1959<sup>[22]</sup>; Davies et al., 1997<sup>[3]</sup>).



**Plate P775118** Massive, basal sandstone of the Penstrowed Grits Formation overlying Nant-ysgollon Mudstones Formation, north-east of Carno [SN 9850 9784].

## Wenlock to Ludlow slope-apron succession

The **Nantglyn Flags Formation (NgF)** overlies the Penstrowed Grits Formation in the east of the district, and marks the gradual re-establishment of slope-apron sedimentation during a tectonically quiescent period that extended from the mid to late Wenlock (*riccartonensis* Biozone) into the Ludlow. It comprises up to 750 m of dark grey turbidite mudstones with subordinate siltstones and thin sandstones, thinly interbedded with laminated hemipelagic mudstones; thin units of slumped mudstone occur sporadically throughout. In the north-east of the district the **Gregynog Mudstone Member (GyM)**, a thick succession (up to 180 m) of slumped and otherwise disturbed anoxic mudstones and sandstone-mudstone turbidites, represents the lowermost division of the Nantglyn Flags Formation, although it incorporates lithological elements of both this and the underlying Penstrowed Grits Formation (Cave, 2008<sup>[21]</sup>). Slumping was probably initiated by instability along the Pontesford Lineament which, at this time, formed the eastern margin of the Montgomery Trough. In the vicinity of Aberhafesp, the Gregynog Mudstone Member passes laterally into undisturbed Nantglyn Flags. Late Wenlock (Homeric) marine regression is recorded by the widespread deposition of bioturbated, oxic slope-apron mudstones that comprise the **Mottled Mudstone Member (MMu)** of the Nantglyn Flags Formation. Two discrete oxic units (**MMu'** and **MMu''**), separated by an anoxic interval 60 to 70 m thick, have been recorded within the district which suggests that regression was a more complex event than has been previously thought. These poorly bedded oxic mudstones, which appear about 200 to 300 m above the base of the formation, are generally calcareous, pale greenish grey and colour-banded with grey dark burrow mottles and a sparse, indigenous fauna of brachiopods, trilobites and bivalves.

Deposition of the anoxic Nantglyn Flags resumed in the late Homerician, and continued until early Ludlow times when they were succeeded by sandstone-rich facies of the **Bailey Hill Formation (Bai)**, which appears to have accumulated in a north-south orientated intrashelf trough or corridor that expanded laterally as the supply of resedimented sand increased throughout the Gorstian (Cave and Hains, 2001<sup>[23]</sup>). Over 200 m of the formation is present at outcrop in the extreme east of the district. It comprises a succession of buff-coloured, thin- to thick-bedded, fine-grained sandstones and siltstones, locally rich in bioclastic material, interbedded with thin laminated hemipelagic mudstones; slumped units occur at certain levels. A local basal division, the **Dingle Mudstone Member (DiM)**, consists of up to 40 m of homogenous grey mudstone with subordinate beds and lenses of fine-grained sandstone and siltstone. The Bailey Hill Formation has long been regarded as a basinal facies (Bailey, 1969<sup>[24]</sup>; e.g. Cummins, 1959<sup>[22]</sup>), its turbiditic origin having been re-emphasised by Cave and Hains (2001)<sup>[25]</sup>. However, sedimentary structures, bedforms and concentrations of shell detritus within the sandstones led Tyler and Woodcock (1987)<sup>[26]</sup> to argue that the formation was partly emplaced as a series storm sheet deposits below a strongly stratified water column.

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