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The geology of the area around Lampeter, Llangybi and Llanfair Clydogau

1:10 000 sheets SN54NW, 54NE, 55SE, 64NW & 65SW

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BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/04/064

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Foreword

This report is the published product of a survey made by the British Geological Survey (BGS) of the geology of 1:10 000 Series Sheets SN54NW, 54NE, 55SE, 64NW and 65SW, as a component of 1:50 000 scale series sheet 195 (Lampeter). The survey of sheet 195 is co-funded by the Wales Assembly Government. The boundary between sheet 195 1:50 000 scale series sheet 194 (Llangranog) lies 700m inside the western edge of sheet SN54NW.

The superficial geology of the that part of the Teifi Valley which lies within the report area south of Lampeter was surveyed by J. R. Davies in 1995-6, whilst the superficial geology of that part of the Teifi Valley which lies within the report area north of Lampeter was surveyed in September 2002 by T. H. Sheppard. These successions have been described in BGS Technical Report WA/97/35 and BGS Internal Report IR/03/097 respectively. This report details the bedrock geology of the district and describes those Quaternary successions which lie in the uplands outside the Teifi Valley.

All localities cited fall within the SN National Grid square, which prefixes the given grid references.

The majority of localities cited in the text are within private ownership and visiting permissions must be sought from the relevant landowner.

Since the writing of this report, the geology of the western part of SN54NW has been revised by R A Waters and includes new data acquired during the survey of the Llangranog (194) 1:50 000 Sheet in Summer 2004. As a consequence, some of the stratigraphical relationships represented on the mapface may differ from those described within. The Sheet Explanation for Lampeter should be consulted where discrepancies arise.

Frontispiece: View from the hills above Careg y Bwlchi, looking westward towards the Teifi Valley.

Contents

Summary

The country around Lampeter, Llangybi and Llanfair Clydogau comprises late Ordovician Ashgill to Silurian Llandovery-age bedrock overlain by a widely distributed cover of superficial deposits. The bedrock strata largely comprises sandstones, siltstones and mudstones deposited by turbiditic flows in the deep waters of the Welsh Basin. The major units recognized are the Yr Allt Formation, comprising dark pelagic mudstones and disturbed or dewatered sandstones, the Mottled Mudstone Member of the Cwmere Formation, the sandstone-dominant Rhyddlan Formation, the mudstone-dominant Clarewen Group, the rhythmitic Devil's Bridge Formation, the mudrock-dominant Blaen Myherin Mudstones Formation and the generally coarse-grained rocks of the Cwmystwyth Grits Group. Outliers of the Borth Mudstone Formation are also recorded. The bedrock is deformed by a series of anastamosing faults which trend south-west to north-east. Major faults include the Rhysgog Fault, the Teifi Escarpment Fault, and the Falcondale Lake Fault. Fold axes follow the same trend, the folds dominantly having a vergence to the south-east with the eastern limbs of anticlines frequently overturned and fold closures sheared out by faults. Superficial deposits are dominated by tills, which form fans soliflucted from upland sheets down into the main river valleys of the region. Other drift deposits are largely confined to these trunk valleys. The geomorphology of the area reflects the glacial sculpting and exaggeration of bedrock structural lineaments.

1 Introduction

The country around Lampeter, Llangybi and Llanfair Clydogau comprises 125 square kilometres of rural upland. The major river system of the area, the Afon Teifi, divides the country into two areas: the high plateau of the Cambrian Mountains east of the Teifi Valley, and the rolling, dissected hill country westward towards the coast. The ground rises east of the Teifi towards a series of southwest-northeast trending craggy hills, the highest of which is Esgair Fraith (247m OD), before falling rapidly into the Twrch Valley at the foot of the escarpment known as Craig Twrch.

The bedrock of the area is composed of Ordovician Ashgillian to Silurian Llandoverian pelagic and turbiditic mudstones together with turbiditic to debritic sandstones, siltstones and conglomerates, the stratigraphic units recognised being those of Davies *et al* (1997). These rocks are overlain by Quaternary deposits of Devensian age. The Teifi valley is filled with thick successions of till and gravel, largely representing the deposits of valley glaciers (Waters *et al.*, 1997; Sheppard, 2003); tills deposited during ice-sheet formation in association with the Devensian glacial maximum occur across the upland plateau of the Cambrian Mountains and rolling hills westward of the Teifi Valley. Periglacial head is locally important in the west. The Holocene is represented by alluvial deposits in the valley floors, and limited peat developments in the uplands.

2 Ordovician

2.1 YR ALLT FORMATION

The oldest rocks known in the area are those assigned to the late Ashgillian Yr Allt Formation (Davies *et al.*, 1997) (Figure 1) which is around 1km thick. Only one exposure is known in the district, in a farm yard and track [50303 46678] at Rhiwson Isaf Farm some 2.5Km west of Llanwnen. The rocks are massive, black to very dark grey silty mudstones up to several metres in thickness, interbedded with hard, very high matrix (i.e. dilute HMS) sandstones up to 10cm in thickness which are often contorted and disturbed. Sandstones occur in bundles approximately 2-3m in thickness. The very high-matrix nature of the sandstone suggests deposition as a highly dilute debrite slurry; the contortion and disturbance of the sandstone beds attests to later dewatering and/or slumping. Cleavage in the mudstone is irregular. The facies is very similar to that described as the ‘silty mudstone facies’ of the Yr Allt by Davies *et al.* (1997); however, the base of the formation is not seen, and it is difficult to estimate its thickness.

2.2 CWMERE FORMATION

2.2.1 Mottled Mudstone Member

The Mottled Mudstone Member (Figure 1) represents the basal unit of the Cwmere formation preserved in this area. A prominent bioturbated hemipelagic unit, it is exposed in the highest part of the farm track at Rhiwson Isaf Farm. The member was first identified by Jones & Pugh (1916) in the Aberystwyth district where it ranges from 3 to 10m in thickness (Cave & Hains, 1986). It comprises dark to pale grey hemipelagic mudstone mottled by *Chondrites* burrows with a piped infill derived from interbeds of dark silty mudstone more reminiscent of the Yr Allt mudstone lithologies.

2.2.2 Strata above the Mottled Mudstone Member

Up to 50m of thinly-interbedded grey turbidite mudstones and dark, laminated hemipelagites (e.g. Davies *et al.*, 1997), assigned to the Cwmere Formation, are thought to be present in the area above the Mottled Mudstone Member. These strata straddle the Ordovician-Silurian boundary.

3 Silurian

3.1 RHYDDLAN FORMATION

The Cwmere Formation is succeeded in the hills northeast and northwest of the exposures at Rhiwson Isaf by a strongly sand-dominant succession (Figure 1), named the Rhyddlan Formation (new name). The thickness of these rocks is thought to be up to 250m. Exposure is poor but two outcrops are known: a small roadside quarry 300m south of Talardd near Llanwnen [51696 47500] and a larger roadside pit near Blaenwaun Uchaf (50608 49060) south-west of Cribyn.

At Talardd, the rocks comprise relatively strong (3-5cm thick) tabular, yellow-grey bouma-type laminated turbidite sandstones interbedded with thin (2-3cm), light grey turbidite mudstones. The outcrop is extremely weathered and orange staining indicates a high iron content; unusually, ferricretes are found in the regolith overlying these rocks. The light colour of the exposed rocks may thus reflect bleaching during weathering. The pit at Blaenwaun Uchaf provides a cleaner exposure, and here very massive, blocky, clean sandstones, up to 15cm thick, are interbedded with light grey turbidite mudstones, similar in lithology to those at Talardd, but seldom more than 2cm in thickness. The sandstones show only faint (probably upper flow regime) planar lamination, are probably translocative at least in part, and are very unlike any other facies exposed in the local area. Again, iron staining on joint planes is a prominent feature.

The origin of these rocks is uncertain but they clearly represent the invasion of hemepalagic, anoxic and iron-rich slope-apron muds by a sandy chute or lobe, in the area west of Lampeter during late Ordovician times. In parts of the Rhayader area, similar debris-channel or chute facies of the Caban Conglomerate Formation occupy the stratigraphical interval of the Cwmere Formation above the Mottled Mudstone Member, whilst in the Llanilar area parts of the Ystrad Meurig Grits Formation intervene between the Mottled Mudstone Member and the background turbidite mudstone facies of the Cwmere Formation (Davies *et al.*, 1997).

3.2 DERWENLAS FORMATION

The Derwenlas Formation of Davies *et al.* (1997) (Figure 1) is poorly characterised in the area. It intersects rockhead south of the Falcondale Lake Fault in a plunging anticline in the floor of the Teifi Valley. North of the fault it makes up much of the low, undulatory ground immediately beneath and west of the Granell Valley. Outcrop widths are up to 300m northwest of the Falcondale Lake Fault and together with steep dips (up to 65 degrees) suggest a thickness of around 250m, comparable to the 190m recorded by Davies *et al.* (1997) in the Llanilar-Rhayader area, although the succession may be thicker southeast of the Falcondale Lake Fault.

A quarry exposure at Cefnrhuddlan Uchaf Farm [50348 44998] reveals a succession of medium to dark-grey turbidite mudstones which pass upwards into a greenish-grey mudstone, with thin (<5mm) turbidite silstone and rare 1cm sandstone interbeds. A 3m anoxic unit is dated to the Derwenlas-age *Convolutus* biozone by the presence of *Metaclimacograptus* cf. *hughesi*, *Campograptus lobiferus*, *Normalograptus* sp., and *Glyptograptus* sp (Williams, 2004).

3.3 RHAYADER MUDSTONES FORMATION

3.3.1 *Sedgwickii* Shale?

The base of the Rhayader Mudstones is taken at the occurrence of a prominent anoxic hemipelagic unit known as the *M. Sedgwickiii* shale (Jones and Pugh, 1916) (Figure 1), belonging to the graptolite biozone of that name (Davies *et al.*, 1997). This unit has been tentatively identified in a quarry at Beli-Cadarn Farm [52255 48322] near Llanwnen, where a 3m thick exposure reveals pale, oxic mudstones south of a normal fault which downthrows to the north, and exposes a hanging-wall succession of similar oxic mudstones with an anoxic unit around a meter thick near the base. Williams (2004) suggests that the latter represents either the *Convolutus* or perhaps more probably the *Sedgwickii* anoxic horizon, on the presence of *Metaclimacograptus undulatus, Stimulograptus sedgwickii*?, *Pristiograptus regularis, Campograptus lobiferus*?, and *Lituigraptus*. Siltstone and sandstone turbidite interbeds, although thin (2-3mm), are present, although they comprise well under 10% of the section.

3.3.2 Strata above the *Sedgwickii* Shale

The hillside above the quarry at Beli-Cadarn farm is transected by a farm track [52225 48358] with limited intermittent exposures. Oxic hemipelagic intervals persist, but the siltstone and sandstone turbidite interbeds recorded in the quarry show a progressive increase both in thickness and frequency up-section in the track, until the strata exposed at an elevation of 15m above the quarry are so sand-rich that they can no longer be assigned to the Rhayader Mudstones but must rather be attributed to the overlying Devil's Bridge Formation (A large quarry exposes the Devil's Bridge formation in the woodlands on the western hillside above Beli-Cadarn [52266 48295]). Although the anoxic unit at Beli-Cadarn is not identified with certainty, if it is the *Sedgwickii* Shale then the oxic-facies Rhayader Mudstone is anomalously thin here (perhaps no more than 15m of strata above a 1m anoxic unit).

3.4 DEVIL'S BRIDGE FORMATION

The Devil's Bridge formation of the area is lithologically similar to that described by Cave and Hains (1986) and Davies *et. al*. (1997) (Figure 1). The majority of exposures comprise clean, bouma-type laminated and rippled thin, tabular turbidite siltstones and fine sandstones alternating with thick, structureless turbidite mudstones on a decimetre scale. Thin oxic hemipelagic interbeds are preserved. Bioturbation is common within this formation, with endostratal ichnofabrics, largely burrow networks assigned to *Planolites, Chondrites, Nereites* and *Palaeophycus* often preserved as on the soles of turbidite sandstones.

The formation has by far the largest crop of any unit in the area, underlying a wide swath of the country west of the Teifi Valley and north of Llanwnen. Thickness is difficult to estimate (hill heights are only in the order of 200m or so, and the formation is devoid of internal markers with which to make meaningful estimates of sheet dip) but is likely in the order of several hundreds of metres; Davies *et al*. (1997) advance a range of 470 to 600m and the higher estimate seems more likely a minimum thickness for this area. Dozens of exposures are recorded and two sub-facies of the 'typical' Devil's Bridge (as described above) are known from the lower part of the succession south and west of Lampeter: a sand dominant facies A, and mud-dominant Facies B.

Facies A is seen to the northwest of the Teifi Valley in the Llanwnen district in the three quarries at Neuadd Fawr Farm, north of Dre Fach. The largest [53692 47516] lies on the roadside downslope from the farm itself, whilst a moderately large quarry [54020 47628] lies south-west of Neuadd Pond. A further small quarry [54200 47705] lies to the north-east of the pond. This latter exposure was investigated by Orr (1995), who studied the ichnofabrics and palaeoecology of the succession. Orr reported a pasichnial (semi-infaunal feeding; see Seilacher, 1964) assemblage of post-depositional moulds (rather than typical turbidite sole cast assemblages)

representing a deep-water *nereites* ichnofacies (Seilacher, 1964), although this seems somewhat debateable given the preponderance of fodichnial infauna (e.g. *palaeophycus*). The Neuadd Fawr quarries comprise largely fissile, grey-green pale oxic turbidite mudstones with interbedded sandstones of two types; thin (c.3 to 10cm) ripple- laminated bouma-type sandstones and thicker (up to 25cm in the largest exposure) bouma turbidite sandstones which exhibit planar (upper flow regime) lamination; sandstone content is up to 70%. This greenish, anomalously thick-bedded Devil's Bridge facies is again seen to the south-east of the Teifi Valley (in the Cwmann area) at Tynycoed Farm in a quarry [56745 45237] and cutting [56391 45221] behind the farmhouse. These exposures may possibly represent the early 'pathway phase' of the Devil's Bridge Formation (see Davies *et al.*, 1997), in which case the thinness of the underlying Rhayader Mudstones Formation in the Llanwnen area might be explained by the development and expansion of a coarse-grained sediment pathway shortly after *Sedgwickii* times. It is perhaps not coincidental that the Neuadd Fawr and Tynycoed exposures lie close to the north-western margins of the Falcondale Lake and Teifi Escarpment faults respectively; it might be tentatively suggested that these faults possessed a contemporary geomorphological expression with troughs forming on (what is now) the footwall side, locally forcing flow separation and channelizing (possibly in a non-orthogonal fashion) the coarser fraction of turbidity currents (that is, the Falcondale Lake and Teifi Escaprment faults became inverted during the Acadian Orogeny; cf. Soper *et al.*, 1987).

Facies B is seen sporadically, often close to the contact between the Devil's Bridge and the underlying mudrocks of the Rhayader Mudstone Formation, and as such may represent gradational passage beds between the Rhayader Mudstone and 'blanket' Devil's Bridge lithofacies outside the confined tract of the pathway phase (Facies A). It typically comprises relatively thin (<4cm) ripple-laminated siltstones and sandstones with anomalously thick (up to 15cm) turbidite mudstone interbeds. Good exposures occur in quarries [53975 45476] at Pencarreg, and a cutting [55900 47500] 400m west of Aber-dauddwr Farm. Both localities occur in the area between the Falcondale Lake and Teifi Escarpment faults (i.e. a potential submarine interfluve, or sediment-starved area) and this provides some support for the suggestion of fault-controlled facies distribution during the earliest Devil's Bridge times.

The upper (blanket) facies, typical of the Devil's Bridge Formation throughout the area north and east of Lampeter, is well demonstrated in a large roadside quarry [59294 51414] at Betws Bledrws. These rocks have a sandstone: mudstone percentage ratio of around 40:60 and, in contrast to the pasichnial assemblages of Orr (1995) at Neuadd Fawr, the abundance of *Nereites* is reduced in favour of fully-infaunal fodichnial structures; however, epifaunal to semi-infaunal activity is evidenced by rare examples of sweeping (presumably locomotive to feeding) traces which are in some cases reminiscent of *crossopodia* (cf. Crimes, 1992).

3.5 BORTH MUDSTONE FORMATION

The Borth Mudstone Formation of Cave (1975) (Figure 1) crops out in a series of inliers in the hillsides west and north of Lampeter from Pont Cwm Hendryd in the south to Betws Bledrws in the north. The largest inlier, which crops out in a low hill [54205 48664] between Pont Cwm Hendryd and Hen Feddau Wood [56500 49600], is exposed in a 2m deep forestry cutting [56207 49377] at Ty-Hen Wood. Here the rocks comprise massive oxic turbidite mudstones generally around 5 cm in thickness interbedded with rare rippled muddy turbidite siltstones up to 2cm in thickness. At Coed Gleision [58803 51922] the rocks comprise finely laminated siltstone and mudstone turbidites with lozenge-shaped phosphatic nodules up to 2 cm in thickness subparallel to bedding.

The Borth Mudstone Formation inliers all lie in the hanging-wall of the Falcondale Lake Fault and the thickness of Borth Mudstone preserved by downfaulting varies with the throw of the fault. The rocks have a shallow dip and although the top contact of the formation is not seen, preserved thicknesses range from perhaps less than 10m in the case of the northernmost inliers

near the inception of the Falcondale Lake Fault to perhaps as much as 50m or more in Ty Hen Wood where the fault has a much greater throw.

3.6 BLAEN MYHERIN MUDSTONE FORMATION

The Blaen Myherin Mudstone Formation of Jones (1909) and Davies *et al.* (1997) (Figure 1) occurs in two isolated inliers, the largest of which lies near the core of the Central Wales Lineament, deep within the Cwmystwyth Grits Group at Esgair Coch farm [62696 46192]. Here a large quarry cut, some 10m high and near 100m long, exposes a c. 20m succession of oxic, turbiditic mudstones interbedded with abundant anoxic hemipelagic layers. Sandstone occurs only as very rare casts of sole structures. Graptolite assemblages include *Stimulograptus halli*, *Monograptus marri*, *Petalolithus* sp. and *Streptograptus plumosus*, indicating a position in the upper *Utilis* Biozone close to the *Johnsonae* Subzone boundary (Williams, 2004). Although the upper part of the Devil's Bridge Formation occupies the *Utilis* Subzone (*sensu lato*) to the immediate north of the area, failures of the sand-dominant turbidite system are known to occur some 20km to the north (Davies *et al.*, 1997), where the lower part of the Blaen Myherin Formation lies within that Subzone. Two thin beds of high-matrix sandstone occur within the uppermost part of the section, and are likely to be conformable with exposures of similar rocks a little to the north-east; these units therefore represent the downward extension of the basal part of the Rhuddnant Grits Formation to the *Utilis-Johnsonae* boundary at this locality. However, in the only other known inlier of Blaen Myherin in a former roofing-slate quarry near the summit of Bryn Mawr [60300 47055], the uppermost thick mudstones are succeeded by a succession of typical bouma-turbidite sandstone-mudstone rhythmite couplets with high-matrix sandstones not encountered until some 5m above the top of the Blaen Myherin. The thickness of the Blaen Myherin Mudstone Formation is unknown as the base is nowhere exposed; it has only a small crop width on the map, and may not substantially exceed the thickness exposed at Esgair Coch (c. 20m).

3.7 RHUDDNANT GRITS FORMATION

The Rhuddnant Grits Formation of Jones (1909) and Davies *et al.* (1997) (Figure 1) occupies much of high plateau of the Cambrian Mountains, east of the Teifi valley. The Rhuddnant Grits essentially comprise an interleaved succession of massive, highly resistant, often structureless dilute debrite silty sandstones ('high-matrix sandstones, or HMS) and ripple-laminated bouma-type turbidite sandstones, siltstones and mudstones of a lithofacies largely similar to that of the 'blanket phase' Devil's Bridge Formation facies. The Rhuddnant Grits are divided into two provinces by the Rhysgog Fault.

3.7.1 Rhuddnant Grits West of the Rhysgog Fault

3.7.1.1 LLYN TEIFI MEMBER

The lowermost part of the Rhuddnant Grits succession is occupied in the Llanilar and Rhayader districts by a thick, debrite sandstone dominant-succession up to a kilometre thick known as the Llyn Teifi Member (Davies *et al.*, 1997), which in the Lampeter area is confined in a tract between the Teifi Escarpment and Rhysgog faults (Figure 1). The Llyn Teifi member is a HMS-dominant package, comprising, north of the area in the Llanilar and Rhayader districts, up to a kilometre of stacked and amalgamated high-matrix sandstone beds on a decimetre to metre-scale interbedded with subordinate mixed rhythmite-HMS bundles (Davies *et al.*, 1997). In the Llanilar district it has a wide crop in the type area near Llyn Teifi [78000 68000], but the crop thins southward into the Lampeter area and just south of Tregaron becomes confined between two significant faults, the Teifi Escarpment Fault in the west and Rhysgog Fault in the east. The member maintains a crop width of over 2km south towards Llanfair Clydogau, with good

sections through a succession dominated by high-matrix sandstones up to 1m thick seen in the bed of Nant Clywedog [62880 51114]. Dips to the east, however, are consistently shallow (around 20-30 degrees) across the crop, and there may be less than 500m of the Llyn Teifi Member exposed in this tract.

South of Llanfair Clydogau the crop of the Llyn Teifi Member between the Teifi Escarpment and Rhysgog Faults narrows to 1.4km east of Cellan. This narrowing co-incides with a progressive overturn of the 30°E dip to 60-80°W in overturned strata near the Rhysgog Fault and a steep 40-60°W dip near the Teifi Escarpment Fault; the resultant form is an overturned anticline which exposes strata below the Llyn Teifi Member in its core, which forms the high hillside of Bryn Mawr. Although some section may be lost against the confining faults, these steeper dips produce crop widths between 350 and 500m, suggesting that the Llyn Teifi Member is decidedly less than 500m thick in this area (i.e. only half the Llanilar-Rhayader thickness is preserved). There is also a subtle facies change southward, with thinner (<50cm) high-matrix sandstones interbedded with thicker (c. 20cm) rhythmitic intervals, e.g. the small quarry at Bryn Mawr Farm [60805 46440]. The Llyn Teifi Member is last seen in the footwall the Hathren Fault, an important cross fault which runs in the floor of the Eiddig valley between the Teifi Escarpment and Rhysgog faults, at Hendai Farm [59888 46123], although some crop in the hanging-wall is inferred before the unit plunges into the subsurface.

Current vectors (Davies *et al.*, 1997) suggest a south to south-westerly provenance for the Llyn Teifi Member in the Llanilar area, which seems at odds with the progressive thinning and decrease in coarse-clastic material southwards. The thinning of the member, however, between the Teifi Escarpment and Rhysgog faults must indicate either a lack of accommodation up-depositional tract (i.e. sediment bypass) or that the Llyn Teifi depocentre was located west of the Teifi Escarpment Fault in the Lampeter area, and the succession is now lost to erosion. That the coarse-clastic depocentre was located elsewhere is borne out by the diminished high-matrix component in the southernmost exposures of the Llyn Teifi Member at Bryn Mawr and Hendai.

3.7.1.2 Strata above the Llyn Teifi Member

Rocks of the western province Rhuddnant Grits higher than the Llyn Teifi Member occur only on the hanging-wall (south) side of the Hathren Fault. Only one exposure of near in-situ high-matrix sandstone blocks in a poorly-exposed scarp at Rhiwlas Farm [59854 45540], is known. The upper contact with the Glanyrafon Formation is not preserved in the area, and thickness cannot be effectively measured.

3.7.2 Rhuddnant Grits East of the Rhysgog Fault

In contrast to the more complex stratigraphy west of the Rhysgog Fault, the eastern province of the Rhuddnant Grits Formation maintains a constant character of <10m-scale bundles of high-matrix sandstone interbedded with 5-10m bundles of bouma mudstone-sandstone turbidite rhythmites and subordinate thin high-matrix sandstones. These rocks have an outcrop width of up to 1.5km and both conformably overlie the inlier of Blaen Myherin Mudstone Formation at Esgaircoch and conformably underlie the Glanyrafon Formation in the Pant-Teg Plantation [63700 47700]. The Llyn Teifi Member is not present in the eastern province. Outcrops are relatively abundant; good exposures of both high-matrix dominant and rhythmite-dominant facies are seen in the crags around Blaen Hathren [61500 46100].

Thickness estimates are difficult. The crop is some 1.5km wide, and dips are generally steep; thicknesses may be in the order of 1km or more, comparable to those reported by Davies *et al.* (1997) for the Llanilar district.

3.8 GLANYRAFON FORMATION

The Glanyrafon Formation of Davies *et al* (1997) (Figure 1) is not well exposed within the area, although its presence is inferred from terrain analysis and stratigraphic context. The formation is lithologically very similar to the Devil's Bridge Formation, being comprised of interbedded bouma-type turbidite sandstone and massive, oxic turbidite mudstone couplets. Davies *et al* (1997) divided the Glanyrafon Formation into an 'upper' and 'lower' part, the division between the two parts being drawn at the occurrence of the interleaved Pysgotwr Formation. Where the latter is not present, the Glanyrafon Formation remains undivided. The Pysgotwr Formation persistently overlies the Glanyrafon in the area, and therefore only the 'Lower Glanyrafon' of Davies *et al.* (1997) is inferred. The main crop of the formation is confined to a tract of low-lying, boggy ground beginning in the Pant-Teg Plantation and trending northwest along the strike of the Pysgotwr crop at Esgair Fraith. However, east of the Pysgotwr crop in the western wall of the Twrch valley, sporadic outcrops are known, the best of which is behind the farmhouse [63916 46119] at Esgair Crwys Farm.

Thicknesses are difficult to estimate, but are in the order of 40 to 50m of Lower Glanyrafon in the western wall of the Twrch valley. This is thinner than recorded for the Lower Glanyrafon west of the western part of the Central Wales Syncline succession in the Llanilar district by Davies *et al*. (1997) and may reflect the southward expansion of the Rhuddnant Grits or underlying formations.

3.9 PYSGOTWR GRITS FORMATION

The Pysgotwr Grits Formation of Davies (1933) and Davies *et al.* (1997) (Figure 1) crops out in a series of craggy hills trending southwest-northeast from Alltgoch Farm [62800 46000] to Esgair Fraith. The base of the formation is taken at the first entry of high-matrix sandstones above the Glanyrafon. The Pysgotwr Formation is lithologically similar to the high-matrix sandstone dominant elements of the Rhuddnant Grits Formation, but individual high-matrix sandstone beds are thicker (up to 2m or more), coarser (many are granule conglomerates) and notably feldspathic to arkosic. Bundles of such sandstones, several tens of metres thick, are interbedded with rhythmite-dominant successions generally less than 10m thick. Conglomerate horizons are not unusual within the Pysgotwr Grits, although only one conglomerate is known from the succession in the area. This takes the form of a c. 5m thick bed of quartzitic conglomerate and interbedded greywackes, exposed in the crags of Craig Twrch [64800 47800]; the pebbles are well-rounded lower Palaeozoic quartzites, probably derived from a shelf shoreface.

The top of the formation is not seen in the district, but preserved thicknesses are at least 50m, thickening to the north-east.

4 Devensian

Thick successions of glacigenic deposits, putatively considered representatives of the last glacial maximum (late late-Devensian event, c. 20Ka) in South Wales (e.g. Sheppard, 2003; Davies *et al.*, 1997), are present throughout the area, with particularly thick fills found in the Teifi valley, which has been treated separately (Waters *et al.*, 1997; Sheppard, 2003). In this report, only Devensian successions outside the trunk valley and its principal tributaries are considered.

4.1 TILL

Tills form a near-ubiquitous cover across most of the upland plateau west of the Teifi valley, and a thinner but no less ubiquitous veneer across the rolling hillsides to the west. Thicker sheets are present within tributary valleys.

The upland tills of the Cambrian plateau are exclusively grey-blue to oxidized brown diamicton, and generally composed of subangular gravel to cobble clasts of local, lower Palaeozoic sandstone supported by a clayey, often overconsolidated matrix. A prominent characteristic of the plateau is the development of down-valley fans or lobes of till in dissected valleys. At the upland head, these fans are fed from a sheet of till deposited in a wide, shallow depression representing the catchment area of the tributary. The till deposit then narrows and necks down into the tributary valley, presumably reflecting a deep, perhaps glacially overdeepened, rockhead floor. The most distal part of the system is a delta-shaped spread of debris entering the trunk valley. At the downslope end of this fan, the tills become progressively cleaner and eventually pass imperceptibly into gravels. As a whole, these deposits represent prominent valley-marginal deposystems and substantial contributors of glacigenic material to the trunk valley. The large fan feeding from the plantations around Coed Llwynifan, down the Ffwrdd Cynon valley, and emerging as a till, debris and gravel spread at Pentre'r-Felin and Cellan is a good example (see frontispiece). These fans and spreads probably owe their origin to a spectrum of processes ranging from Devensian subglacial to paraglacial, periglacial and post-glacial slope processes.

West of the Teifi Valley the tills are seldom thick, often intercalated with sand and gravel lenses, and are of a subtly different facies, with a reduced clay and increased silt or sand content in the matrix, and a reddy-brown to orange colouration. This probably reflects derivation from iron-rich sandy bedrock such as the Devil's Bridge and Rhyddlan formations, rather than deposition by a different ice mass. Clast assemblages at all localities are exclusively local Palaeozoic sandstones and there is no evidence of erratic clasts which might indicate an Irish-Sea ice provenance. The tills are, however, not generally overcompacted, and probably indicate deposition by a thinner ice sheet than that which capped the Cambrian Plateau. In this area gravels occur interbedded and intercalated with much of the diamict tills; however these deposits are unworkable for gravel and represented as diamict on the map. Occasional pockets of gravel are found in the valleys west of the Teifi, and often at substantial elevations on the valley sides; for instance, at Pantyrhywch [52550 48660] at 165m OD (40m above the Granell, 65m above the Teifi) and Blaun Waun Ganol [50777 48724] at 200m OD (75m above the Granell, 100m above the Teifi). These likely formed during recession on the flanks of a decaying ice sheet impounded in the Granell Valley.

4.2 ICE CONTACT SAND AND GRAVEL

Ice contact sand and gravel deposits are generally coarse, open to sandy gravels and silty sands, with well rounded gravel to boulder-size clasts of local lower Palaeozoic sandstone derived largely from the Cwmystwyth Grits Group. East of the Teifi only a small deposit of ice-contact gravel is inferred in the Twrch valley, forming a well-drained bench beneath the church at Llanycrwys [64516 45422]. More extensive deposits, probably derived from the reworking and washing of till material provided by the debris fan at Cellan, are seen in the Teifi valley between Glan Teifi and Trebannau farms. No good exposures are known in these gravels, but they are recorded in a series of boreholes at the site of the Cellan sewage works [60249 49040].

4.3 HEAD

The veneer of till present across the area provides an ideal parent material for head development. Much of the upper part of the till is represented on the map is thus likely to be soliflucted but is retained within that category for convenience ('Till and soliflucted till'). East of the Teifi, head deposits shown on the map represent the 'mudstone-chip head' facies of Davies *et al.* (1997) and

are derived from bedrock parent material. No good sections are known. In the west, wide, broad sheets of material which have clearly move downslope from the flanks of rounded bedrock hills probably contain both soliflucted till and mobilised bedrock scree. As such, they have been distinguished from till deposits. Again no good sections are known.

4.4 PEAT

Peat forms a cover of organic material over much of the flat-lying upland plateau east of the Teifi Valley. Peat bogs in the area are largely active and vegetation includes rushes and sphagnum moss. Large, extensive flats occur westward of Bryn Hirfaen Farm [62100 46700] and on the higher parts of the Pysgotwr crop at Llyn Bach [63400 46100]. West of the Teifi the impact of agriculture on the landscape has been considerably greater, and although occasional remnants are preserved at localities such as Ffinant Uchaf [51900 46400], it is probable that a former peat cover has been lost to deforestation and agricultural improvement.

4.5 TERRACE DEPOSITS

Terrace deposits, comprising low benches of alluvium of Holocene age interpreted as abandoned or partially abandoned parts of the river floodplain, are known from the Teifi Valley, and the mouths of the lowland tributary Cledlyn and Granell valleys only; these deposits are described by Waters *et al.* (1997) and Sheppard (2003).

4.6 ALLUVIUM AND ALLUVIAL CONES

Alluvium, comprising Holocene-age gravels, sands and sandy silts of fluvial origin, is largely confined to the wide floodplains of the Teifi and Dulais rivers in their respective valleys. The majority of the tributary valleys draining the Cambrian Mountains plateau east of the Teifi are entrenched and possibly actively downcutting; these tributaries form cones at their mouths where they enter the trunk valley rather than floodplains on the tributary valley floor. The larger tributaries of the Teifi to the west, such as the Cledlyn and Granell, have moderately wide valley bottoms floored with alluvium and reach a confluence with the Teifi as the floodplains merge. Alluvium in the area is described in more detail by Sheppard (2003).

5 Geological Structure

5.1 FAULTS

The bedrock geology of the area suffered deformation from late Silurian to mid-Devonian times during the Acadian Orogeny (Soper *et al.*, 1987; Davies *et al.*, 1997). The overall structure of the area is defined by a strongly developed south-west to north-east trending system of anastamosing faults. In all cases except one these faults downthrow to the south-east, and this south-eastward younging reflects an overall sheet dip between two important lineaments (Davies *et al.*, 1997); the Teifi Anticline, the core of which lies in the area west of Llanwnnen, and the Central Wales Syncline, part of the core of which is represented by the crop of the Pysgotwr Formation at Esgair Fraith. The density of faulting along the Pysgotwr crop reflects the relative concentration of deformation along these lineaments (Davies *et al.*, 1997).

5.1.1 Named structures

Three important strike faults (together with one cross-fault) have been identified and named during the mapping exercise, and because all three clearly influence sedimentary thicknesses,

must be faults which were extant and active during the Ordovician and Silurian (the period of 'enhanced subsidence' of Davies *et al.* (1997)). Sedimentary patterns clearly indicate the inversion of these faults during the Acadian Orogeny (Soper *et al.*, 1987). All three faults exhibit their maximum throws in the south of the area.

The Falcondale Lake Fault lies in the western part of the area, and trends south-west to north-east with a geomorphological expression in a series of aligned scarps and slacks from Rhiwson Uchaf Farm west of Llanwnen to Derry Ormond Park [59100 52400] north of Betws Bledrws. It takes it's name from the prominent fault gouge and scarp at Falcondale Lake [56917 49957] north-west of Lampeter, and is at least 12km long, progressively increasing in throw southwards; its maximum recorded throw is at the western extremity of the ground surveyed, and it thus must continue as a significant structure for some distance beyond the present area. In the South-west between Rhiwson Isaf and Silian it can be mapped as a single, discrete displacement; however in the hillsides west of Betws Bledrws it breaks into a series of splays, which possibly indicates the presence of an unmapped anastamosing fault set in the floor of the Dulais valley. Whatever the cause of the breakdown of the lineament, the fault cannot be traced north of Derry Ormond Park.

Although sedimentary patterns in the basal Devil's Bridge Formation suggest that the fault downthrew to the north-west during the Llandovery (see above), the Falcondale Lake Fault is inverted and now downthrows to the south-east, in the north preserving small outliers of Borth Mudstones amongst its splays. Here the throw on the fault is probably only in the tens of metres. A more substantial outlier of Borth Mudstone, at least 50m thick, is recorded in Ty Hen Wood, suggesting a larger throw on the Falcondale Lake Fault. West of Llanwnen, however, the fault throws the Ordovician Yr Allt Formation against the Devil's Bridge Formation, which must indicate a throw in excess of 500m.

The Teifi Escarpment fault is an important structure which, as the name suggests, is responsible for the prominent eastern scarp wall of the Teifi valley, characteristically between Llanfair Clydogau and Llandewi Brefi. It runs the length of 1:50 000 series sheet 195 from north to south, is at least 25km long, and downthrows to the south-east.

From the southern margin of sheet 195 to its intersection with the Hathren Fault near Nant Eiddig [57800 54600], the Teifi Escarpment Fault downthrows strata of the Rhuddnant Grits Formation above the Llyn Teifi Member against the Devil's Bridge Formation in the area east of Pencarreg [53800 45500]. Thus, like the Falcondale Lake Fault, the Teifi Escarpment Fault has its maximum downthrow in the south of the area, with an estimated throw in excess of 300m.

North of its intersection with the Hathren Fault at Nant Eiddig, the Teifi Escarpment Fault dowthrows the Llyn Teifi Member against the Devil's Bridge Formation; this reduction in throw to about 100-150m suggests that the Hathren Fault cross-cuts the Teifi Escarpment Fault and itself has a throw of at least a hundred metres. The Teifi Escarpment Fault continues to throw the Llyn Teifi Member against the Devil's Bridge Formation for much of the length of the Teifi valley. It retreats from the valley edge at Llandewi Brefi and makes a prominent fault-gouge slack at Prysg Farm [66600 55400]; a little further north its diminished throw is evidenced as it lets in the Blaen Myherin Mudstone Formation on the downthrow side. A little further north it peters out to a displacement in the Devil's Bridge Formation and cannot be traced north of Tregaron.

The Rhysgog Fault is the most easterly of the three named faults, being expressed as a series of south-west to north-east trending slacks in the relatively desolate ground at the heads of the Hathren, Fwrdd Cynon and Clywedog valleys. The fault plane is mineralised, and the fault takes its name from lodes identified and mined in the bed of the Rhysgog stream [68000 53800]. The fault extends for much of the length of sheet 195, and is at least 20km in length. Like the Falcondale Lake and Teifi Escarpment faults, it downthrows to the south-east, but for most of its length it acts as a confining structure for the Llyn Teifi Member, the absence of which is proven west of the Rhysgog; the fault must therefore have downthrown a trough to the north-west during the Llandovery.

South of the Hathren Fault, the Rhysgog Fault offsets strata above the Llyn Teifi Member of the Rhuddnant Grits, and its throw is not known. However, for most of its length between the Hathren Fault and Llandewi Brefi, it downthrows the upper part of the Rhuddnant Grits Formation against the Llyn Teifi Member. A little south-east of Tregaron, the Llyn Teifi crop crosses the fault, indicative of an eastward overspill of the coarse-sediment pathway in Llandovery times in association with a reduced throw on the fault plane. The Rhysgog continues as a displacement within the Llyn Teifi Member to the northern boundary of Sheet 195.

5.1.2 Unnamed structures

Two important faults or fault groups remain presently un-named. In the east below Esgair Fraith and trending south-west to Allt Goch Farm, two faults rapidly downthrow the Rhuddnant Grits agains the Esgaircoch inlier (Blaen Myherin Mudstone Formation) and the Pysgotwr Grits against the Rhuddnant Grits respectively; the combined throw must total several hundred metres. Another major fault occurs in the north-west corner of SN54NW near Blaenwaun Uchaf. This is the only fault known with a north-westerly downthrow, and as it juxtaposes rocks of Cwmere Formation-age against the Borth Mudstones, it perhaps has a throw of 500m.

5.2 FOLDS

Folding patterns are sub-parallel to faulting, with the majority of fold axes orientated south-west to north-east, and this trend is mirrored in the regional plunge of the strata. Thus, folded successions within individual faulted blocks or slivers young to the north-east. Although at an outcrop-scale folding is relatively complex and without substantial regional importance, at a sub-regional scale, a marked eastward vergence leads to the overturning of the eastern limbs of anticlines which frequently dip steeply to the west; a good example is the vergence of the folded Llyn Teifi Member between the Hathren Fault and Fwrdd Cynon. Overturning seems to be most prevalent where tectonic pressures increase in the noses of fault closures; for instance, the Llyn Teifi Member of the Rhuddnant Grits is almost everywhere overturned in the Cellan area where it occurs in a fold closure between splays of the Teifi Escarpment Fault.

The regional sheet dip between the Teifi Anticline in the west and Central Wales Syncline in the east (Davies *et al.*, 1997) is recorded by the progressive south-eastward younging of the strata across the area west of the north-westerly downthrown fault near Blaenwaun Uchaf (see above). Although the prominent plunging fold in the floor of the Teifi Valley at Pencarreg might be considered as representing the core of the Teifi Anticline, the exposure of older strata in what is effectively a horst between the un-named fault at Blaenwaun-Uchaf and the Falcondale Lake Fault argues for the complex faulting and dissection of the anticline core in this area.

6 Geomorphology

Two distinct geomorphologies are present within the area: east of the Teifi Valley, the Cambrian Plateau is largely sculpted by subglacial erosion, whereas constructional (glaciofluvial and glaciolacustrine) geomorphologies dominate the Teifi Valley and the western hills.

6.1 SUBGLACIAL GEOMORPHOLOGY OF THE CAMBRIAN MOUNTAINS

The geomorphology of the Cambrian plateau west of the Teifi valley is largely shaped by extensive glacial erosion of south-west to north-east trending bedrock structures. Thus, many of the faults present within the bedrock successions are manifest at surface as south-west to north-east trending slacks in the ground. Typically, anticline cores resist erosion whilst syncline cores are denuded (although this in not necessarily the case when syncline cores are protected by

resistant rocks; synclines cored by Pysgotwr Grits, for instance, tend to resist erosion better than anticlines in the Glanyrafon Formation which enclose them). Thus low hills, typically termed 'esgairs', tend to represent anticlinal bedrock structures.

6.1.1 Drumlinoid features

Many of the hills are drumlinised by (presumably but not necessarily) late-Devensian ice; that is, they represent rock drumlins *sensu* Linton (1963). The drumlinisation is assymetrical, with the steeper (presumed lee) side being found to the south or south-west (e.g. Esgair Fraith). This geomorphology is, however, to be expected given the north-easterly plunge of the fold axes within the majority of the hills, and it is difficult to determine the relative degree of influence of ice and structure on the development of this geomorphology, which is the prevalent form throughout the southern Cambrian Mountains. Examples of drumlinoid features are best developed north of the area near Tregaron, where they may be attributable to fast-flowing ice streams (Ettienne *et al*, in press) but are found throughout the Cambrian plateau east of the Teifi (e.g. at Esgair Fraith and Bwlch Blaen Corn, [64000 47200]) whilst much of the ridge of Devil's Bridge Formation between the Dulais and Teifi valleys may similarly have been subglacially sculpted.

6.1.2 Meltwater channels

Meltwater channels are a prominent geomorphological feature of the Cambrian Plateau. In most cases they are developed along faults and thus orientated largely with bedrock lineaments. The three most prominent channels are located at 1) Bwlch Blaen Corn; 2) Allt Goch Farm [6300 46200]; and 3) north of Blaen Hathren [61800 46800].

The Allt Goch channel is presumably developed as a consequence of ice gouge and subsequent erosion of a major fault plane by meltwater trapped and pressurized at the glacial bed. The other two channels are less conventional in aspect; at Bwlch Balen Corn, the channel bifurcates, following the bifurcation of two minor faults within the Central Wales Syncline deformation. The channels thus trend north-northwest, and the interfluve between them is drumlinised with the lee face being on the northern side. This suggests the movement of meltwater against the regional structural trend, and is probably attributable to hydraulic jacking of subglacial water 'up and over' the esgair line of the Pysgotwr crop towards areas of lower basal pressure westward towards the Teifi Valley. Similarly, the meltwater channel at Blaen Hathren is orientated directly east-west and is over 1km in length, exploiting the Hathren cross-fault. The hills around it are drumlinised with the lee face westward, further suggesting east to west transport of meltwater away from the high ground towards the Teifi Valley.

6.2 WESTERLY CONSTRUCTIONAL GEOMORPHOLOGIES

The constructional geomorphology of the Teifi Valley itself is described by Sheppard (2003), and the area west of the Teifi has largely the same geomorpholgical expression of the glacial and post-glacial infilling of pre-extant fluvial tributaries. In most cases, tributary valley floors are infilled with a substantial thickness of till (e.g. the Granell valley) whilst ice-contact gravels are locally important near confluences with the trunk Teifi Valley. At higher elevations, most of the rounded hills in the western part of the area are veneered with a sandy, orange, relatively poorly consolidated till veneer. Only one putative moraine structure has been recorded outside the trunk Teifi Valley, consisting of a mass of ice-contact gravels forming a substantial small hill west of Falcondale Lake [57400 49500].

7 Made Ground and Economic Geology

Made ground is very unimportant in this rural, undeveloped area. It is restricted to small areas of concreting and infilling around farmyards; the only representation of made ground on the mapface is at Llwyn-cnau farm [60000 49300], where the farmyard has been built up significantly.

Similarly, the area has a modest economic history. Aggregate extraction has been sporadic and largely for agricultural or low-level industrial uses (e.g. quarrying of the Esgaircoch inlier for hardcore by Tristar Horseboxes). Only the Coedmore Hall quarry seems to have been an organised attempt at commercial quarrying, constituting a roofing slate quarry which, unsurprisingly given that the ‘slates’ in question are in fact sandstones, seems to have rapidly failed. Several abandoned mineshafts, presumably very ancient and probably not very productive lead mines, have been mapped during the present survey, such as those at Cwm Gaer [62700 48000] and Lanlas Fawr [60400 47700] farms. Both are associated with fault plane mineralisation in the Llyn Teifi Member of the Rhuddnant Grits Formation. The more substantial lead and silver mine workings at Llanfair Clydogau represent the most significant element of the area’s economic geology; details of these workings and their history may be found in Hall (1971) and redescribed in notes by John Aspden.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

CAVE, R. 1975. Glan-Fred Borehole, Dol-y-Bont. P.7 in Institute of Geological Sciences IGS boreholes 1974. *Report of the institute of geological sciences*, No. 75/7.

CAVE, R. AND HAINS, B. A. 1986. *Geology of the country between Aberystwyth and Machynlleth.* Memoir of the British Geological Survey, Sheet 163 (England and Wales). (London: H.M.S.O.)

CRIMES, T P. 1992. Changes in the trace fossil biota across the Proterozoic_Phanaerozoic boundary. Jouurnal of the Geological Society of London, 149, 637-646.

DAVIES, K A. 1933. *The Geology of the country between Abergwesyn (Breconshire) and Pumpsaint (Camarthenshire).* Quarterly Journal of the Geological Society of London, Vol. 89, 172-201.

DAVIES, J R, FLETCHER, C J N, WATERS, R A, WILSON, D, WOODHALL, D G and ZALASIEWICS, J A. 1997. *Geology of the country around Rhayader and Llanilar*. Memoir of the British Geological Survey (England and Wales). (London: H.M.S.O.)

ETTIENNE, J. L, HAMBERY, M. J, GLASSER, N. F. and JANSSON, K. N. *In press*. West Wales. In: LEWIS, C.A. (ed.), *The Glaciations of Wales and Adjoining Regions* (2nd edn).

HALL, G. W. 1971. Metal mines of southern Wales. 95pp.

JONES, O T. 1909. *The Hartfell-Valentian succession in the district around Plynlimon and Pont Erwyd (North Cardiganshire).* Quarterly Journal of the Geological Society of London, Vol. 65, 463-537.

JONES, O T. and PUGH, W J. 1916. The geology of the district around Machynlleth and the Llyfnant Valley. *Quarterly Journal of the Geological Society of London*, 71, 343-385.

Linton, D L. 1968. The forms of Glacial erosion (Presidential Address). Institute of British Geographers (transactions and papers), 33, 1-28.

ORR, P. J. 1995. A deep-marine ichnofaunal assemblage from Llandovery strata of the Welsh Basin, West Wales, UK. Geological Magazine, Vol. 132, 267-285.

SEILACHER, A. 1964. Biogenic sedimentary structures. In: IMBRIE, J. and NEWELL, N. (Eds), Approaches to Palaeoecology, 296-316. New York: John Wiley.

SHEPPARD, T H. 2003. *The Pleistocene and Holocene Geology of the Upper Afon Teifi Valley*. British Geological Survey Internal Report No. IR 03 097. Keyworth: British Geological Survey, 22pp.

SOPER, N. J., WEBB, B. C. and WOODCOCK, N. H. 1987. Late Caledonian (Acadian) transpression in north-west England: geometry and geotectonic significance. Proceedings of the Yorkshire Geological Society, Vol. 46, 175-192.

WATERS, R A, DAVIES, J R, WILSON, D and PRIGMORE J K. 1997. A geological background for planning and development in the Afon Teifi catchment. British Geological Survey Technical Report WA/97/35. Keyworth: British Geological Survey.

WILLIAMS, M. 2004. Graptolites from the neighbourhood of Llanybydder and Lampeter, south central Wales. British Geological Survey Internal Report No. IR 04 011R. Keyworth: British Geological Survey, 10pp.

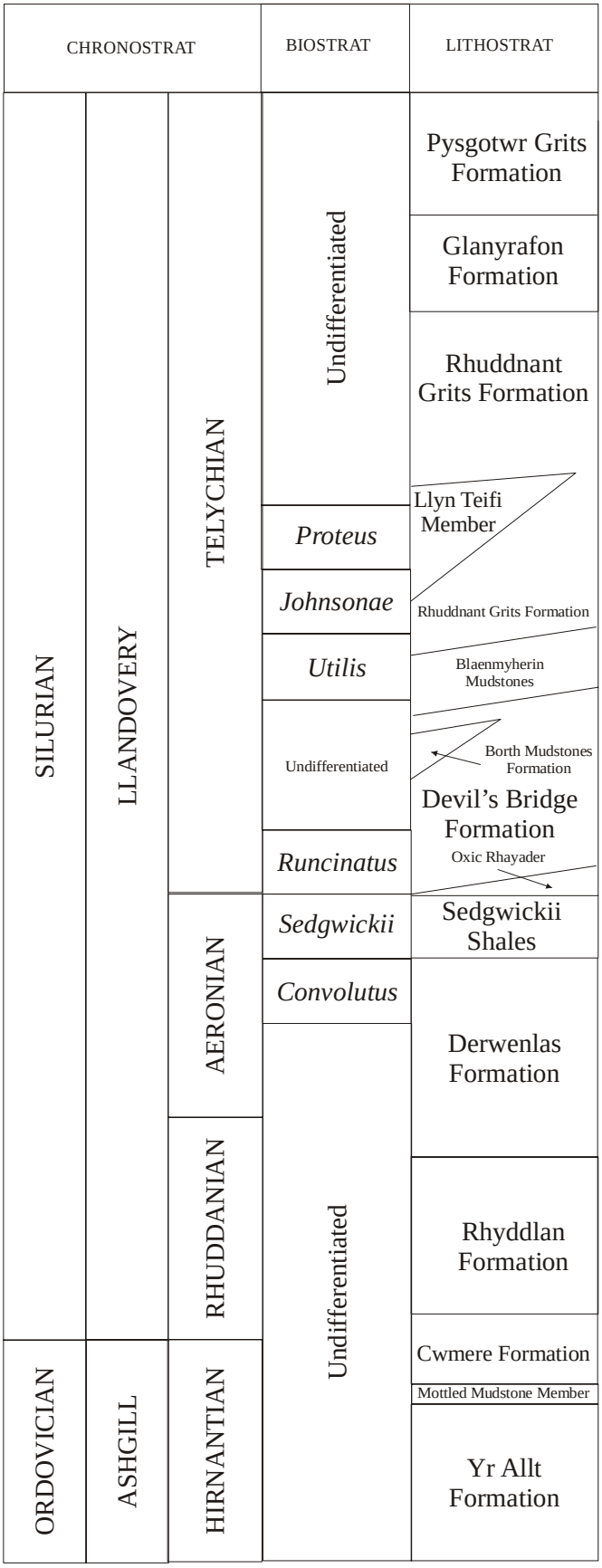

FIGURE 1. Chronostratigraphical, biostratigraphical and lithostratigraphical divisions of the bedrock geology (drawn relatibe to biostratigraphic chronology not lithostratigraphical thickness).