Geology of the Llanidloes area: Introduction

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This Sheet Explanation provides a summary of the geology of the district covered by Geological 1:50 000 Series Map Sheet 164 (Llanidloes), published in 2010 as a Bedrock and Superficial Deposits edition. The district mostly lies within the county of Powys, but includes small parts of Ceredigion in the extreme west and south-west. Much of the western part of the district is occupied by the deeply dissected uplands of the Cambrian Mountains, a designated Area of Outstanding Natural Beauty. In this area the land rises to 740 m on the flanks of Plynlimon (Pumlumon Fawr), the highest summit in the range. It falls away towards the eastern part of the district into rolling countryside that includes the important catchment of the River Severn (Afon Hafren) and its tributaries, the largest of which are the rivers Carno, Trannon, Cerist, Clywedog and Dulas. A major reservoir (Llyn Clywedog) occupies the upper reaches of the Clywedog valley, its purpose being to regulate river discharge and groundwater levels within the catchment. The south-western part of the district is drained by the River Wye (Afon Gwy) and its tributaries, that flow south-eastwards via Llangurig. The sources of both the Severn and Wye are situated on the eastern flanks of Plynlimon within the western part of the district.

The town of Llanidloes is the main centre of population, with smaller settlements at Llangurig, Carno, Trefeglwys, Caersws and Staylittle; the Newtown conurbation impinges on the eastern part of the district. Much of the district is given over to beef and dairy farming, although sheep are reared in the remote upland areas in the west and extensive forestry plantations have been developed in places. The Ordovician and Silurian rocks of the district have been exploited locally, in the past, as a source of building material and, recently, commercial quantities of sandstone aggregate have been excavated at Penstrowed Quarry [SO 0680 9100]. The district includes part of the Central Wales Mining Field from which substantial volumes of lead and zinc ore were extracted during the 19th and early 20th centuries. A number of former mine sites are still visible, notably along the Van, Nant-y-ricket, Dylife, Dyfngwm and Llanerchyraur lodes (Jones, 1922[1]; IGS, 1974), and the historic Bryntail Mine, below the Clywedog Dam has been restored as a site of industrial archaeological interest.

The district is underlain by a succession of Late Ordovician (Ashgill) to Silurian sedimentary rocks, over 5 km thick, deposited between 450 and 420 million years ago in the Early Palaeozoic Welsh Basin (**Figure P930911**). The basin developed on a fragment of the ancient supercontinent of Gondwana, known as Eastern Avalonia (e.g. Pickering et al., 1988[2]), that drifted northwards to collide with the continents of Baltica and Laurentia during the Late Ordovician and Silurian (Soper and Hutton, 1984[3]; Soper and Woodcock, 1990[4]; Woodcock and Strachan, 2000[5]). To the east and the south of the basin lay the Midland Platform, a relatively stable shallow marine shelf that was subject to periodic emergence. The basinal sediments are predominantly deep marine turbiditic facies that were introduced into the district by density currents from southerly, south-easterly and north-westerly quadrants. Coeval shallower-water 'shelfal' sediments were deposited north and east of the district, and locally impinge on its northern margins. Thickness variations within the major sedimentary units suggest that, at times, syndepositional fault movements were an important control on their distribution. During late Silurian (Ludlow) times, shallowing of the basin occurred, and sandstones, variably interpreted as a turbiditic (Cave and Hains, 2001[6]) or storm-generated facies (Tyler and Woodcock, 1987[7]), were laid down over the eastern part of the district and adjacent areas. The shallowing was a result of tectonic reconfiguration of the basin, a precursor to the late Caledonian (Acadian) Orogeny that affected the region during the late Early Devonian, around 400 million years ago.

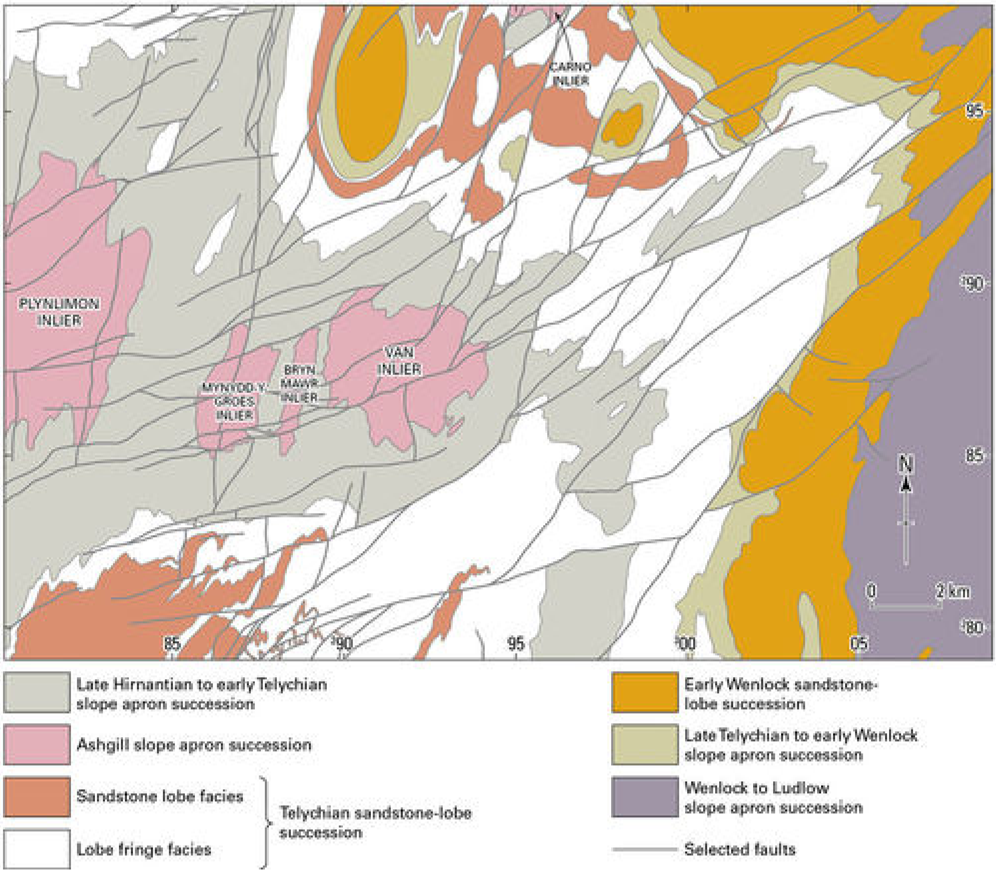

Figure P930911 Simplified bedrock geology of the district.

During the orogeny the basinal sediments were folded on a variety of scales, faulted and developed a regional cleavage. Many of the pre-existing syndepositional fault structures were reactivated at this time; they probably underwent further displacements during the subsequent Variscan and Alpine orogenic cycles. The array of east-north-easterly trending mineralised faults, along which many of the lead–zinc mines occur, appear to have been initiated during the early Carboniferous (Fletcher et al., 1993[8]).

The broad drainage pattern of the region was probably established during the early to mid Cenozoic (Brown, 1960[9]; Jones, 1951[10], 1955[11]), and modified during the Quaternary, when the British Isles were subject to a series of major glaciations. Quaternary superficial (drift) deposits mantle the solid formations over wide areas. They comprise Pleistocene sediments, deposited during the last major glaciation, and as periglacial materials that formed in the cold period immediately following ice retreat, and more recent alluvial deposits and peat. Any evidence of earlier ice advances is lacking, having been removed or obscured by the last glaciation (Late Devensian) around 20 000 years ago. At this time, ice sourced from the Welsh uplands covered the area, moulding the landscape to its present form. As the ice began to melt around 14 500 years ago, periglacial processes and meltwater reworked the previously deposited materials into a distinctive suite of landforms and deposits. Periglacial modification, under intense freeze-thaw conditions, continued until about 12 000 years ago when the climate began to ameliorate and peat started to form in upland areas. The glacial landforms were further modified during this period (the Holocene) as the present-day drainage pattern was superimposed on the remnants of the Tertiary system.

The first systematic investigations of the district by the Geological Survey were undertaken in the 19th Century; they were published as Old Series One-inch Sheets 56, 57, 59 and 60 Between 1848 and 1850. Since that date relatively little geological work has been undertaken. The structure and stratigraphy of the Tarannon area in the north of the district was broadly established by Wood (1906)[12], and that of the area around Llanidloes by W D V Jones (1944)[13]. The sedimentology of the late Silurian strata has been investigated by Dimberline (1987)[14], Dimberline and Woodcock (1987)[14], Smith (1987a)[15] and Tyler and Woodcock (1987)[7]. Detailed accounts of the geology of adjoining districts are given in Cave and Hains (1986[16], 2001[6]), and Davies et al. (1997)[17], and regional syntheses of the sedimentology and structure have been provided by Cherns et al. (2006)[18], Smith (1987b[19], 2004 [20]), (1990a, b, 2000), and Woodcock *et al*. (1988[21]; 1996[22]; 2000[5]).

The first detailed account of the lead mining and mineralisation within the district was given by O T Jones (1922)[1], and subsequent studies include those of Bick (1975[23]; 1977[24]) and Ball and Nutt (1976)[25]; recent work includes that of James (2006)[26]. The Quaternary deposits of the district have not been studied in detail, but the Pleistocene evolution of mid-Wales has been described in several regional syntheses (Bowen, 1973[27], 1974[28], 1999[29]; Lewis and Richards, 2005[30]), and a number of studies have concentrated on the geology, hydrology and geochemistry of rivers within the Severn catchment (Jones et al., 2006[31]; Leeks et al., 1988[32]; Neal et al., 1986[33]; 1990[34]; 1997[35]; Newson, 1976[36]).

Bedrock facies and sedimentation

The majority of the Ordovician and Silurian rocks of the district are re-sedimented, having been deposited by a range of mass-flow processes, resulting from submarine slope failure and avalanching along the margins of the Welsh Basin (Davies et al. 1997[17]). They include massive, dewatered units in which fluid escape and liquefaction has destroyed any original sedimentary structure, and slumps in which the original bedding fabric is highly deformed but still visible. Such units, collectively termed **'disturbed beds'**, are often tens of metres thick and have undergone in situ disruption or moved in a relatively intact manner for variable distances downslope. They are commonly interbedded with **debrites**, comprising massive, pebbly mudstones, conglomerates and matrix-supported sandstones, locally several metres thick, that are regarded as the products of fluid, but relatively cohesive (i.e. non-turbulent), debris-flows (Lowe, 1982[37]; Pickering et al., 1986[38]). Disturbed beds and debrites are both major components of the upper part of the Ordovician succession of the Welsh Basin, and occur at intervals within Silurian strata. However, large parts of the Silurian succession are composed of thinner and more regularly bedded mudstones and sandstones which record deposition from successive sediment-laden density flows that carried material, often for considerable distances, into the basin. The flows comprised turbulent mixtures of sediment and water, and deposited their sediment load as they decelerated and fanned out across the floor of the basin; thus, the coarser material (pebbles and sand) was deposited first followed, at a distance, by the finer (silt and mud). Each of these 'classic' **turbidite** units (Bouma, 1962[39]) exhibits a characteristic fining-upward sequence of sand into mud with a range of internal sedimentary structures indicative of a progressively waning flow velocity. They are commonly stacked in repetitive successions, hundreds of metres thick. Although individual flows may have been deposited in a matter of hours or days, successive flows may be separated by intervals ranging from months to tens or even hundreds of years. Many variations of the model Bouma turbidite are represented within the Welsh Basin succession (summarised by Davies *et al*., 1997[17]), including both coarse- and fine-grained turbidites that were emplaced by flows of a very different nature (Lowe, 1982[37]; Stow and Piper, 1984[40]).

Late Ordovician and Silurian chronostratigraphy and UK graptolite biozones (after Zalasiewicz et al., 2009[41]). * included together in the *turriculatus* Biozone (sensu lato) of earlier literature (see Davies et al., 1997[17]; 2013[42]).

Period	Global Series	British Regional Stages	British graptolite biozones/subzones

Silurian	Pridoli			
	Ludlow	Ludfordian	*No younger biozones in UK*	
			Bohemograptus proliferation'	
			leintwardinensis	
		Gorstian	*incipiens*	
			scanicus	
			nilssoni	
	Wenlock	Homerian	*ludensis*	
			nassa	
			lundgreni	
		Sheinwoodian	*rigidus*	
			dubius	
			riccartonensis	
			firmus	
			murchisoni	
			centrifugus	
	Llandovery	Telychian	*insectus*	
			lapworthi	
			spiralis	
			crenulata	
			griestoniensis	
			sartorius (formerly included in the *crispus* Biozone)	
			crispus	*loydelli*
				galaensis
			*turriculatus**	*carnicus*
				proteus
				johnsonae
				utilis
			guerichi *	*renaudi*
				gemmatus
				runcinatus
		Aeronian	*halli*	
			sedgwickii	
			convolutus	
			leptotheca	
			magnus	
			triangulatus	
		Rhuddanian	*cyphus*	
			acinaces	
			atavus	
			ascensus-acuminatus	

Ordovician (*part*)	Hirnantian	Ashgill (*part*)	Hirnantian	*persculptus*	
				extraordinarius	
	Katian (*part*)		Rawtheyan	*anceps*	*pacificus*
					complexus

At the same time as the turbidites, debrites and disturbed beds were accumulating on the floor of the basin a constant fall-out of terrigenous sediment from suspension was taking place through the water column. These fine-grained **hemipelagic** mudstones commonly cap individual turbidite beds, and are interbedded with the various mass-flow units. Unlike the resedimented deposits, the hemipelagic material records more closely the environmental conditions that prevailed in the bottom waters of the basin at the time of deposition. Two distinct types of hemipelagite are present within the Welsh Basin. The first is a generally homogenous, pale greenish grey mudstone with darker burrow mottles that record deposition beneath oxygenated (**oxic**) bottom waters, when benthonic (bottom-dwelling) organisms were able to colonise the sediment successfully (**Plate P775110**). The second type is a dark grey, very thinly laminated, pyritic and graptolitic mudstone that lacks any evidence of burrowing, having been deposited under oxygen-depleted (**anoxic**) bottom conditions. The distribution of oxic and anoxic hemipelagite within the succession is one of the criteria by which the formational subdivision of strata in the Welsh Basin is achieved. Considerable thicknesses of strata contain one or the other type of mudstone, suggesting that either oxic or anoxic conditions were sustained across the basin floor for prolonged periods of time; at other times such periods were relatively brief, as indicated by rapid alternations of oxic and anoxic hemipelagic mudstone within the succession. The preservation of the fossilised remains of **graptolites** within the anoxic hemipelagite (**Plate P775109**) is critical in correlating the geological succession, and establishing the history of deposition within the Welsh Basin. The rapid evolutionary change of these planktonic colonial organisms during the Ordovician and Silurian allows the rocks in which they occur to be accurately dated, according to the established succession of UK graptolite biozones (see table; Zalasiewicz et al., 2009[41]).

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  Plate P775109 Mottled Mudstone Member (late Hirnantian) of the Cwmere Formation, Hafren Forest [SN 8416 8992]. Persculptus Biozone graptolites from the ‘*persculptus* Band’.

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  Plate P775110 Chondrites burrow-mottling in Mottled Mudstone Member above the '*persculptus* Band'; locality as Plate P775109.

The effects of global (eustatic) sea-level fluctuation competed with tectonism in controlling the type and distribution of sedimentary facies within the Welsh Basin during the Ordovician and Silurian. Two distinct types of turbidite system occur within the basin (Davies et al., 1997[17]). Slope-apron systems, mostly of mudstone, characterise the Ashgill (Ordovician) to early Telychian (Silurian) basinal successions, when eustacy was the dominant control. In contrast, mid to late Telychian and early Wenlock sedimentation was strongly influenced by tectonism that resulted from plate collision, when voluminous amounts of sand were deposited in the basin as a series of major turbidite lobe systems. Palaeocurrent data, together with geochemical and heavy mineral studies, indicate that the sediment supplied to these different systems was also of different provenance (Ball et al., 1992[43]; Morton et al., 1992[44]). Slope-apron systems are generally composed of material derived from the east, whereas the sandstone-lobe turbidite systems contain material derived from southerly sources.

The slope-apron facies mainly comprise wedge-shaped accumulations of turbiditic and hemipelagic mudstone, ranging from tens to hundreds of metres in thickness, which typically thin towards the centre of the basin. In general, the distribution of anoxic hemipelagite within these facies closely correlates with periods of global sea-level high-stand (Johnson et al., 1991[45]; Johnson et al., 1998[46]; Davies et al. 2016[47]), when marine transgression resulted in high phytoplankton productivity and an outflow of warm surface waters from expanded shelf areas. Oxidation of the organic material, and the creation of a thermally stratified water column which inhibited the transfer of oxygen from surface waters, led to oxygen-depleted bottom conditions that were unfavourable for burrowing organisms (Curtis, 1980[48]; Leggett, 1980[49]). During periods of regression, the effects of thermal stratification were reduced and bottom waters were replenished with oxygen from surface levels, allowing burrowing animals to colonise the sediment. A contemporaneous increase of silt content within the turbidite mudstones reflects rejuvenation of the hinterland and basinward migration of facies. Each major anoxic/oxic couplet therefore represents a transgressive/regressive sequence, forming a slope-apron system which, in adjacent shelf areas, equates with a coeval sequence bounded by major discontinuities (Davies et al., 1997[17]; Davies et al. 2016[47]).

The introduction of large-scale, sand-dominated turbidite systems to the Welsh Basin during the

Telychian and early Wenlock effectively masked the effects of a widespread eustatic transgression. The tectonic controls on the geometry of these turbidite lobe systems has been previously documented (Davies et al., 1997[17]; James and James, 1969[50]; Smith, 1987a[15], 2004[20]; Wilson et al., 1992[51]). Major syndepositional faults were important in confining the path on successive turbidite flows (**Figure P930912**), and the eastward-migrating focus of deposition thoughout the late Llandovery and Wenlock reflects the successive eastward reactivation of such structures (Davies et al., 1997[17]). The reasons for this are unclear, but may be related to the nature of plate collision and lithospheric stretching as Avalonia was progressively subducted beneath Laurentia (King, 1994[52]; Woodcock and Strachan, 2000[5]).

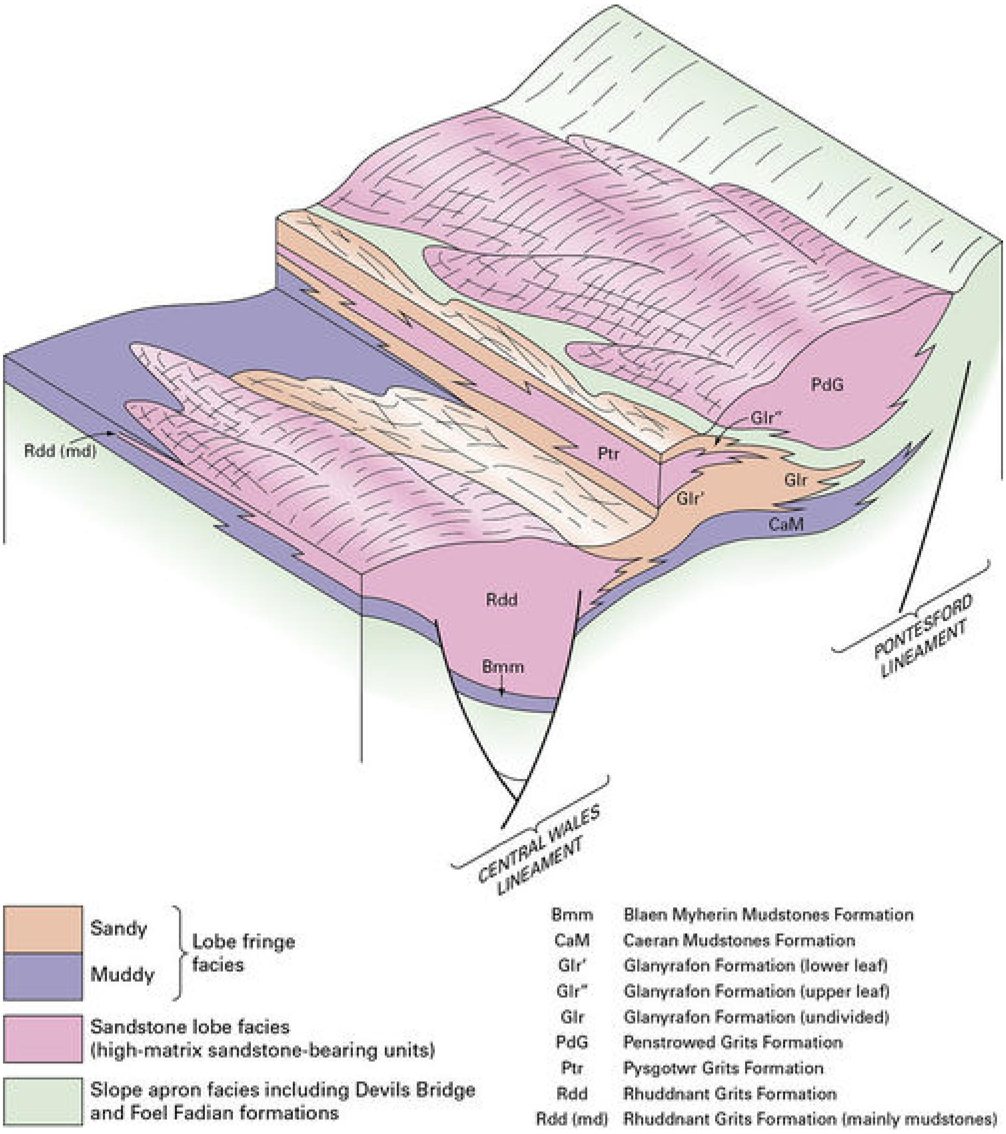

Figure P930912 Depositional model for the southerly derived sandstone lobe systems (after Davies et al. 2006).
Abbreviations: BMM Blaen Myherin Mudstones Formation; CaM Caerau Mudstones Formation; Rdd Rhuddnant Grits Formation; Rdd (md) Rhuddnant Grits Formation (mainly mudstones); Glr Glanyrafon Formation (undivided); Glr` Glanyrafon formation (lower tongue); Glr`` Glanyrafon Formation (upper tongue); Ptr Pysgotwr Grits Formation; PdG Penstrowed Grits Formation.

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