Carneddau and Llanelwedd

[SO 050 520]–[SO 075 549]

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Introduction

The Carneddau and Llanelwedd GCR site lies at the southern end of the Builth Inlier of Ordovician (Llanvim to Llandeilo) volcanic and sedimentary rocks (Figure 6.28). The volcanic rocks consist mainly of rhyolitic and basaltic tuffs, but there are basaltic, andesitic and dacitic lavas in various parts of the succession, most particularly at the top. Doleritic and dacitic intrusions also occur.

The history of research on the Builth Inlier extends back to general observations made by Murchison (1833, 1839, 1867, 1872) who noted that the largest 'trap' district in Radnorshire extends southwards from Llandegley to Builth Wells. The stratigraphy of the inlier was described by Elles (1940) but most emphasis in this work was on the sedimentary rocks. The detailed survey of Jones and Pugh (1941, 1949) was used by the Geological Survey in the compilation of a 1:25 000 scale geological map (1977). The whole of the Builth Inlier has recently been resurveyed by the British Geological Survey (BGS).

Petrological and geochemical studies of the volcanic rocks by Fumes (1978) and Smith and Huang (1995) indicated a range in composition, from basalt through andesite and dacite to rhyolite, which is wider than that which occurs generally in North Wales. The volcanic rocks appear to have mainly calc-alkaline geochemical affinities, although some tholeiitic flows are also present.

Description

The volcanic succession given in (Table 6.3) is based on the recent BGS resurvey of the Builth Inlier, with the stratigraphical units of Jones and Pugh (1949) for comparison.

The volcanic succession is underlain and overlain by mudstone-dominated sedimentary successions which crop out outside of the site area. The entire succession lies within the *Didymograptus murchisoni* Biozone.

The silicic ash-flow tuff at the base of the volcanic succession crops out along the eastern side of the site where it forms a subdued east-facing escarpment and is repeatedly offset by major E–W faults. It is composed of pumice fragments up to 3 mm across, along with glass shards and feldspar crystals, which can still be seen under the microscope despite intense quartz- and/or chlorite-dominated alteration. Much of the tuff appears to be bedded, but this is interpreted as a secondary feature resulting from the development of massive, resistant layers formed by intense silicification, and fissile, less-resistant layers produced by chloritization. True primary bedding is evident locally, however, where the uppermost *c.* 5 m of tuff is reworked. Erosion of the ash-flow tuff generated tuffaceous sands, composed of rhyolitic rock fragments, up to 2 m of which are locally preserved in erosional hollows at the top of the tuff.

The silicic tuff is sharply overlain by up to 100 m of massive lapilli-tuffs, emplaced as a series of debris-flow deposits. The lapilli-tuffs are composed of abundant poorly sorted fragments of basic volcanic rock up to 3 cm across, with scattered rhyolite fragments up to 15 cm across. Individual debris flow units are difficult to distinguish owing to poor exposure but they appear to be separated either by bedded tuffs, or by interbeds of dark-grey siltstone less than 10 cm thick. The massive lapilli-tuffs pass upwards into a series of turbidites, altogether about 50 m thick, each of which consist of normally graded beds of lapilli-tuff and/or tuff and which are well exposed near Maengowan Farm. Individual turbidites are sharp-based and range in thickness from 0.5 m to at least 4 m. The turbidites are overlain by up to 65 m of mudstones within which there are a number of interbedded tuff turbidites each less than 1 m thick. Within the lapilli-tuffs, tuffs and mudstones there are scattered pods of dacite lava (keratophyres of the Geological Survey 1:25 000 map, 1977) some of which are associated with hyaloclastite breccias.

An impersistent silicic ash-flow tuff occurs in the middle of the volcanic succession and is overlain by more basic lapilli-tuffs and tuffs. These were also emplaced as debris-flow deposits and turbidites, but they differ from those lower in the volcanic succession in that many individual flow units contain abundant feldspar crystals. Some of the tuffs are well bedded and display hummocky cross-stratification. An impersistent flow-banded dacite lava, 20 m thick, is well exposed immediately north of Caer Fawr.

(Table 6.3) Stratigraphy and lithologies of volcanic rocks of the Builth Inlier.

Lithology	**Stratigraphy (after Jones and Pugh, 1949)**	**Thickness (m)**
Silicic ash-flow tuff	Rhyolitic ash and ashy mudstones of the Cwmamliw Series	35
Sandstones and conglomerates of volcanic provenance	Sandstones of the Newmead Series, including the boulder beds	65
Feldspar-phyric basalt and andesite lavas, passing laterally into hyaloclastite breccia	Spilites, keratophyres and bouldery spilitic ash of the Builth Volcanic Series	250
Feldspar crystal-rich basic lapilli-tuffs and tuffs	Pebbly feldspar ash of the Builth Volcanic Series	50
Silicic ash-flow tuff		0–35
Basic lapilli-tuffs, tuffs and mudstones, with subordinate dacite and hyaloclastite	Red agglomerate, ash and shales of the Builth Volcanic Series	> 200
Silicic ash-flow tuff	Rhyolitic ash of the Llandrindod Volcanic Series	50

The tuffs and dacite lava described above are sharply overlain by a series of feldspar-phyric basalt lavas, with subordinate andesite lava, lapilli-tuffs and tuffs. The lavas reach up to 250 m thick at Llanelwedd where they are well exposed in a series of quarries (Figure 6.29), but they are only 150 m thick immediately to the north of the quarries. The lavas in the lowest 30 m are microporphyritic and the basal flow can be seen resting sharply on tuffs in a small disused quarry immediately SE of the main working quarry. Individual flows are 10–20 m thick and include up to 5 m of brown-weathering, clast-supported flow surface breccia. These lavas wedge out immediately north of the main quarry. In the eastern part of the main quarry the microporphyritic lavas are overlain by a series of feldspar-phyric basalt lavas, 40 m thick, with some individual flows up to 12 m thick. Flow surfaces are either brecciated or highly vesicular, but a few flows are separated by several metres of lapilli-tuff. In the NW and western parts of the main quarry massive feldspar-phyric basalt displays no obvious flow surface features and may therefore be intrusive. Two such sheets, 35–50 m thick, are separated by up to 8 m of blocky lapilli-tuff. This deposit, probably emplaced as an ash-flow tuff, contains abundant blocks of feldspar-phyric basalt along with many of gabbro and rhyolite. In the extreme west of the main quarry feldspar-phyric basalt, considered to be extrusive, locally displays pillow-like structures up to 2 m across defined by concentric layers of amygdales. Similar structures are seen locally where the lavas crop out north of the quarries. The highest lava, 35 m thick, crops out immediately west of the main quarry and is andesitic in composition (Fumes, 1978). It is locally flow-banded and distinctly brownish-yellow weathering at the top. In the NW part of the site area the feldspar-phyric basalt lavas overlie, and interdigitate with, massive poorly sorted hyaloclastite breccia composed of angular blocks of massive and vesicular feldspar-phyric basalt up to 0.5 m across. The finest-grained material consists of basalt fragments and feldspar crystals; the coarsest blocks are up to 2 m across.

The volcanic provenance of the sandstones and conglomerates at the top of the volcanic succession is indicated by the abundance of feldspar crystals and basalt clasts. The sandstones rest with marked unconformity on feldspar-phyric basalt and andesite lava. This unconformity was described in detail by Jones and Pugh (1949) who documented features such as fossil sea cliffs, stacks, wave-worn surfaces and screes, which they attributed to an ancient shoreline. Mapping of the unconformity clearly indicates that it has considerable relief. This may be at least 50 m in places, indicated by thickness variations across faults, notably the E–W Newmead Fault where the sandstones thin abruptly northwards from 85 m to 25 m. This may, however, be a result of contemporaneous faulting as well as relief on the unconformity. The lack of lavas or tuffs within the sandstones indicates that they are a product of post-volcanic sedimentation brought about by the erosion of pre-existing volcanic rocks.

There are few igneous intrusions within the site area. Many of the keratophyres shown on the 1:25 000 geological map (1977) have been re-interpreted during the recent BGS resurvey as dacite lavas, although the distinction between lavas and high-level intrusions has been difficult. A prominent E–W dolerite dyke adjacent to Tan-lan cuts across feldsparphyric basalt lavas and sandstones, and feeds a sill emplaced at the base of the overlying mudstones. The dyke increases in thickness to 80 m as it approaches the sill. The latter is exposed in a disused quarry at Tan-lan where a concordant contact with the mudstones is seen.

Interpretation

The silicic ash-flow tuff at the base of the sequence was produced during a violently explosive volcanic eruption, and the ash-flow probably travelled many tens of kilometres from its source. The location of the source is not known, but a coarse-grained facies found in northern parts of the Builth lnlier (Davies *et al.,* 1996)is consistent with a source still farther to the north. Evidence for subaqueous emplacement, including contacts with underlying mudstones and fossiliferous reworked tuffs at the top, is present mainly in parts of the inlier outside of the site area. It is considered that emplacement took place into an open-shelf environment and brought about marked shoaling following the emplacement of up to 50 m of ash-flow tuff. This led to the establishment of a shoreface zone possibly no more than 20 m deep within which the top of the tuff was reworked.

The basic lapilli-tuffs and tuffs also represent the products of explosive volcanism but this was probably less violent. The emplacement of the fragmented (pyroclastic) material as debris flow deposits and turbidites was probably contemporaneous with the volcanism as suggested by the angularity of the fragments and preservation of delicate glass shard structures. The increasing frequency upwards of finer-grained tuffs and interbedded mudstones suggests that there was a gradual reduction in frequency and duration of successive volcanic eruptions. The dacite pods are interpreted as viscous magma bodies emplaced within unlithified mud and ash, which in at least some instances broke through to the surface. The associated hyaloclastites formed by non-explosive quench fragmentation of magma in wet sediment and/or water.

Some of the mudstones mentioned above possibly accumulated during a short hiatus in volcanism that was terminated by the emplacement of another subaqueous silicic ash-flow. The impersistence of this tuff within the site area is interpreted as a result of emplacement in a shallow-water high-energy environment, and it is thought likely that immediately following its emplacement the tuff was eroded by strong (?)tidal currents; the remaining occurrences are the result of preservation in sheltered sea-floor depressions. The overlying feldspar crystal-rich lapilli-tuffs and tuffs represent the products of further contemporaneous basic explosive volcanism. However the shallow-water bedforms in some bedded tuffs suggest shoaling brought about by the continued accumulation of debris-flow deposits and turbidites. Dacite magmatism persisted.

The shoreface environment established as a result of shoaling was displaced by the northward spread of feldspar-phyric basalt lavas. Preexisting dacite lavas probably formed local topographical barriers limiting the extent of the earliest lavas. This is suggested by the abrupt termination of the basal microporphyritic lavas immediately north of the main quarry in proximity to a dacite lava. The feldspar-phyric basalt lavas have been interpreted as subaqueously emplaced (Jones and Pugh, 1949; Nicholls, 1958; Baker and Hughes, 1979; Metcalfe, 1990; Bevins and Metcalfe, 1993) on the basis of localized occurrences of interbedded black shales and pillows. However, they have also been interpreted as subaerial (Fumes, 1978), and this interpretation is preferred because of the nature of flow surfaces; lavas with brecciated surfaces are interpreted as as flows, whereas those that are highly amygdaloidal at the top are interpreted as pahoehoe flows. In addition, the pillows are re-interpreted as cross sections through lobate pahoehoe lava on the basis of the presence of concentric zones of amygdales and the absence of prominent chilled margins and radiating fracture patterns. The massive feldspar-phyric basalt sheets which lack flow surface features are interpreted as high-level synvolcanic intrusions (sills). The hyaloclastite breccias in the north of the site area are thought to be the products of quench fragmentation of the lavas as they encountered relatively deep water; however, the poorly sorted nature of the breccia is consistent with debris-flow deposition. The fact that the breccia is first encountered immediately beneath feldspar-phyric basalt lavas suggests that the earliest breccias were over-ridden by later lavas.

The immediate post-volcanic period in the site area was marked by marine erosion, which was accompanied by sandstone deposition and possibly also by faulting. A combination of erosion and faulting may have produced a cliffed coastline, the ultimate burial of which by sands could account for the relief on the unconformity, most evident across the Newmead Fault. The latest volcanism to affect the Builth Inlier did not leave any deposits within the site area. This volcanism resulted in the subaqueous emplacement of a further silicic ash-flow tuff, comprising the Cwmamliw Series of Jones and Pugh (1949). The pile of feldspar-phyric basalt lavas appears to have acted as a barrier preventing the southward spread of this ash-flow tuff into the Carneddau and Llanelwedd site area.

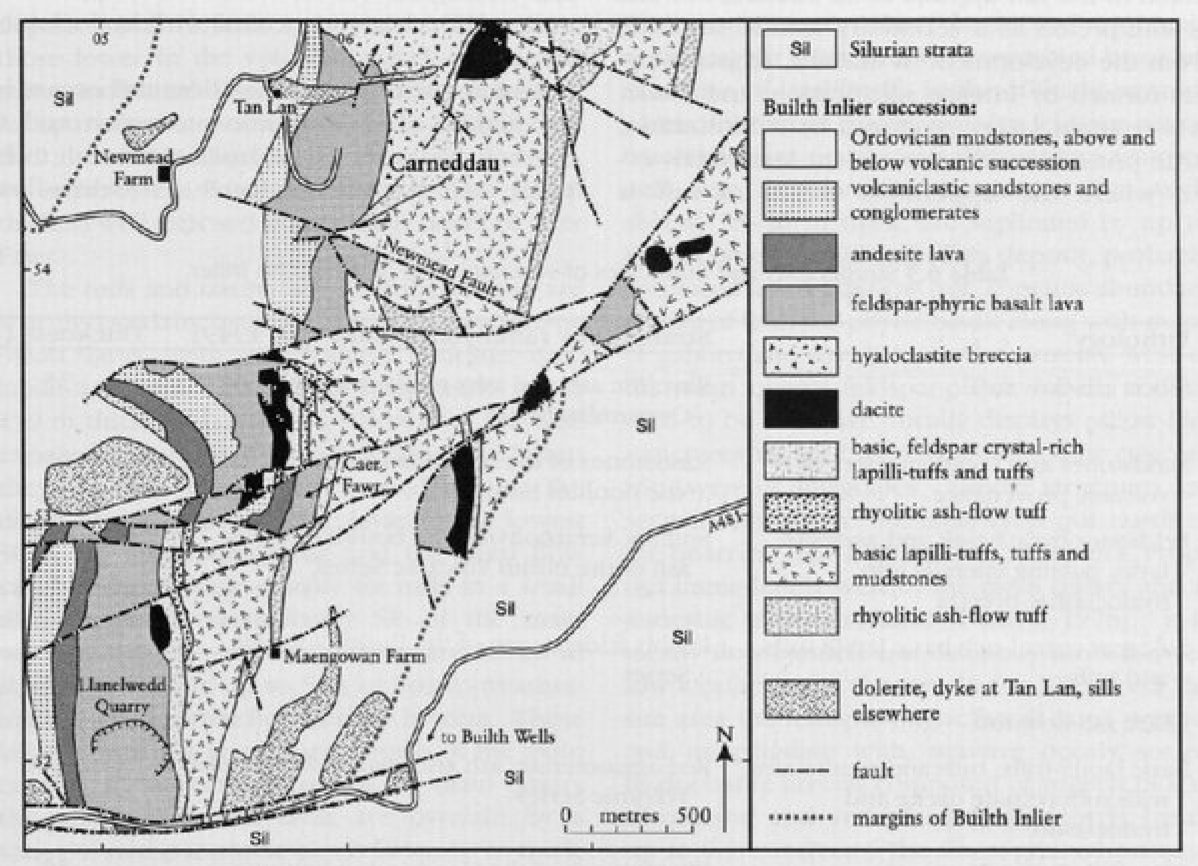
Fumes (1978) investigated the geochemistry of the volcanic rocks of the site area, although this work remains unpublished. Kokelaar *et al.* (1984b) reported that the lavas have calc-alka-line affinities, while the more detailed investigations of Metcalfe (1990) and Smith and Huang (1995) identified the presence of tholeiitic lavas interbedded with those of calc-alkaline affinity.

Conclusions

The volcanic rocks of the Builth Inlier, most of which are seen within the Carneddau and Llanelwedd GCR site, are of national importance for their value in reconstructing the plate tectonic history of both Wales and the British Isles during Ordovician times. The extensive outcrops provide detailed successions through the thickest sequence of Ordovician volcanic rocks at the margin of the Welsh Basin. The sequence has mainly calc-alkaline affinities, in contrast to volcanic rocks of Llanvirn age in north Pembrokeshire (see the Pen Caer GCR site report), which are chiefly tholeiitic. Silicic ash-flow tuffs at the base and near the middle of the volcanic succession represent the onset of separate volcanic cycles characterized by more basic explosive activity and finally basaltic lavas. The best exposures are those of the late-stage lavas seen in the Llanelwedd quarries. The continued working of the main quarry, leading to constantly changing exposures, has resulted in divergent views as to the subaqueous or subaerial emplacement of the lavas.

Finally, the site is of historical interest in that it is in part the area studied in detail by Jones and Pugh (1949), which led to the presentation of one of the first detailed palaeogeographical reconstructions of an ancient volcanic environment.

References



(Figure 6.28) Map of the southern part of the Builth Inlier.

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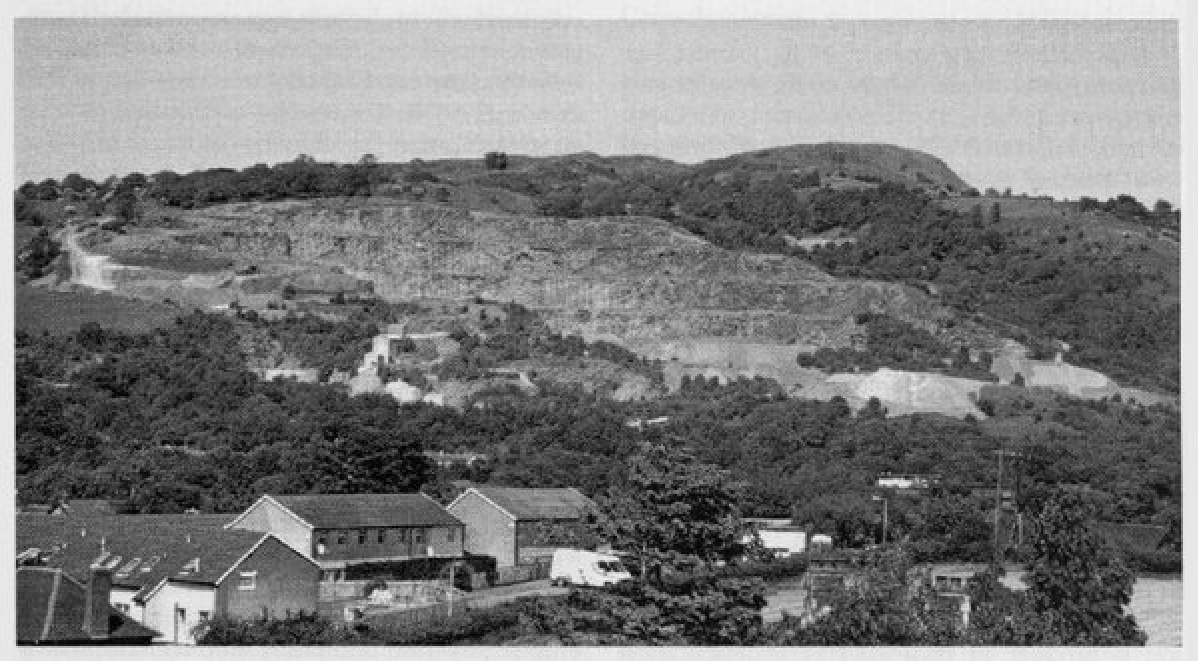

(Figure 6.29) Llanelwedd quarries, Builth Wells, viewed from the south. Westerly-dipping basic lavas, belonging to the Builth Volcanic Group, comprise much of the quarry area. Other volcanic units form the prominent features in the hills behind the quarry, the slack ground being eroded into softer shales. (Photo: R.E. Bevins.)