CADAIR IDRIS

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Introduction

The Cadair Idris GCR site comprises a well- exposed succession of acid and basic volcanic rocks of Llanvirn to basal Caradoc age, belonging to the Aran Volcanic Group (Figure6.23). The latter comprises up to 2 km of volcanic and sedimentary rocks of Arenig to Caradoc age, that crop out around the southern and eastern parts of the Harlech Dome. At the Cadair Idris GCR site, subaqueously emplaced silicic ash-flow tuffs in the lower and upper parts of the succession, are separated by a thick series of submarine basalt lavas with interbedded tuffs and mudstones. A number of dolerite sills, and a thick microgranite sheet, are also well exposed. The whole succession dips to the south or south-east.

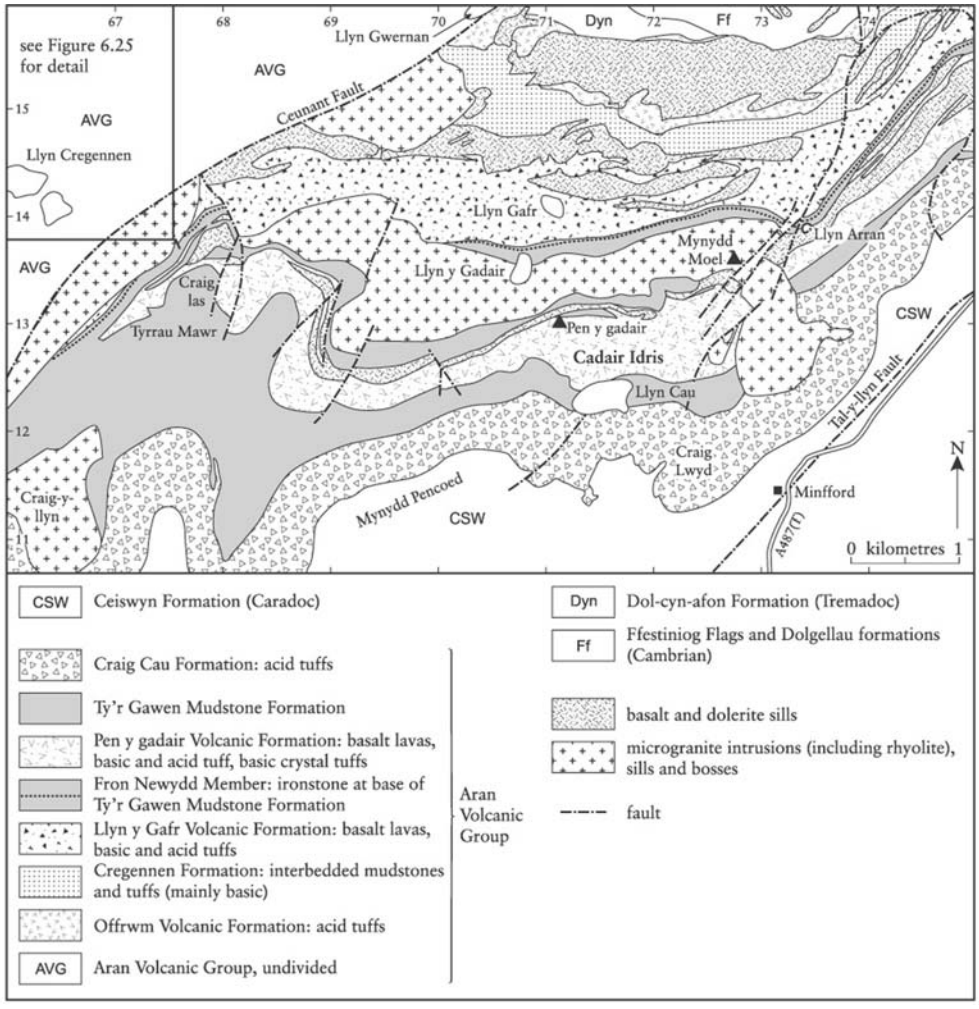

Figure 6.23: Map of the Cadair Idris area.

The first detailed descriptions of the igneous rocks of Cadair Idris were given byCox (1925) and Cox and Wells (1927) in their accounts of the stratigraphy, tectonics and intrusive igneous rocks of the Dolgellau area. Some of the intrusions within the site have been the subject of detailed structural, petrographical and geochemical studies.Lake and Reynolds (1912) described the structure of the Mynydd y Gader dolerite, which lies in the northern part of the site area, while Davies (1955, 1956, 1959) described the petrology, geochemistry and contact metamorphism associated with the Cadair Idris granophyre (now classed as a microgranite) and the Pen-y-gader dolerite, both of which crop out extensively. The site area was included in

a recent resurvey of the Cadair Idris district by the British Geological Survey (Pratt *et al.*, 1995), which involved a geochemical study of the igneous rocks by Kemp and Merriman (1994).

Exposures of the Aran Volcanic Group in the Cadair Idris GCR site area represent products of the most voluminous early Ordovician igneous episode in southern Snowdonia.

Description

The stratigraphical succession established most recently by the British Geological Survey (Pratt *et al.*, 1995) is presented below (Table 6.1), along with the earlier terminology of Cox (1925) and Cox and Wells (1927).

Silicic ash-flow tuffs of the Offrwm Volcanic Formation crop out on Mynydd y Gader to the north of the site area, where they are intruded by the Mynydd y Gader dolerite sill (Lake and Reynolds, 1912). In contrast to the Pared y Cefn-hir GCR site, at Cadair Idris there are no interbedded mudstones, although the tuffs are petrographically similar and display microscopic evidence of welding. Bedded tuffs up to 3 m thick occur locally at the top of the formation.

The overlying Cregennen Formation consists of interbedded tuffs and mudstones, which crop out along the south side of Mynydd y Gader. In the west of the area, relationships are complex as a result of slumping and later intrusions, and therefore correlation with the Pared y Cefn-hir GCR site has proved difficult (Pratt *et al.*, 1995). The upper part of the formation, in the vicinity of the Penrhyn-gwyn slate quarries, includes a silicic ash-flow tuff up to 25 m thick, which is possibly equivalent to a similar tuff seen on Pared y Cefn-hir itself. This tuff is composed of microscopic pumice fragments and glass shards that occur in a fine-grained quartzose recrystallized matrix (probably formerly vitric dust). Farther east, the formation is relatively undisturbed and consists of a coarse-grained basic tuff, 60 m thick and overlain by up to 100 m of mudstones within which there are impersistent basic turbiditic tuffs. The coarse-grained basic tuffs are massive and poorly sorted and are made up mainly of clasts up to 15 cm across of basic and acidic volcanic rocks. At the base there are clasts, up to 0.5 m across, of contorted laminated siltstone and the uppermost 10–15 m are bedded and finer grained. These basic tuffs are interpreted as debris flow deposits.

The Llyn y Gafr Volcanic Formation crops out in the relatively low ground between Mynydd y Gader and Cadair Idris. At Llyn y Gafr, the type section of the formation, massive basalt lavas in the lower part of the formation are up to 60–70 m thick and have pillowed tops up to 10 m thick. There are a few intercalations, up to 40 m thick, of basic tuffs and mudstones, along with coarse-grained debris flows of basic tuffs which resemble those in the underlying Cregennen Formation. The upper part of the formation consists of massive, vesicular and pillowed basalt lava, 70 m thick, which is overlain by coarse-grained breccia up to 75 m thick. The breccia, probably of pyroclastic origin but redeposited by a debris flow, is composed of clast-supported angular blocks of highly vesicular basalt. These blocks are mainly up to 20 cm across, although at the base massive basalt and pillow fragments are up to 1 m across. West of Llyn y Gafr the lavas of the lower part of the formation are poorly exposed, but the basaltic breccia described above increases in thickness to nearly 150 m. East of Llyn y Gafr the proportion of basalt lava, particularly that which is massive, decreases in relation to basic tuff and mudstone, and the breccia in the upper part of the formation wedges out.

The overlying Penygadair Volcanic and Ty'r Gawen Mudstone formations are intercalated. At the base of the lowest mudstone, which crops out adjacent to Llyn y Gadair and Llyn Arran, is a 25 m-thick unit of black pyritous mudstone with numerous phosphatic nodules and with lenticular oolitic and pisolitic ironstone up to 2 m thick. The mudstone has yielded fossils indicative of either the *Nemagraptus gracilis* Biozone (Llandeilo) or the lowest part of the *Diplograptus multidens* Biozone (basal Caradoc) (Pratt *et al.*, 1995). The ironstone has been worked as a source of low grade ore, with small excavations marking its outcrop.

The lowest part of the Penygadair Volcanic Formation consists of 10 m of basic feldspar crystal-rich tuffs, emplaced as debris flow deposits and turbidites, which crop out east of Llyn y Gadair. An intercalation of the Ty'r Gawen Mudstone Formation and a large microgranite intrusion separate these tuffs from a 200 m-thick succession dominated by basalt lavas. Pillow lavas

dominate exposures at the summit of Cadair Idris (Penygadair) and eastwards as far as Gau Graig (Figure 6.24). At Penygadair, the type area of the formation, individual flows up to 15 m thick are locally apparent where they are separated by thin intervening tuffs and/or mudstones. The thicker flows are massive at the base, with some incipient columnar jointing, but are pillowed at the top. The pillows are closely packed with little or no interpillow sediment and tend to decrease in size upwards within a flow from about 2 m across to about 0.2 m. They display radial and concentric fractures and most have quartz-filled amygdales. There are rare lava tubes up to 10 m across infilled with flow-banded basalt, and locally hyaloclastite occupies depressions on flow surfaces. At Penygadair there are two interbedded silicic ash-flow tuffs each about 15 m thick and composed of quartz, recrystallized pumice fragments, and glass shards along with feldspar crystals. There is microscopic evidence for welding. The lower of the two silicic ash-flow tuffs is the most persistent, extending from Tyrrau Mawr in the west to Gau Graig in the east. Between Penygadair and Tyrrau Mawr the basalt lavas wedge out and the formation consists of silicic ash-flow tuffs with interbedded tuffaceous sandstones and mudstones, altogether 65 m thick, overlain by a lenticular basaltic (?)pyroclastic breccia, 3 m thick. The breccia is composed of angular blocks of vesicular basalt up to 0.2 m across in a matrix of finer grained scoriaceous basalt fragments, which grade into glass shards.

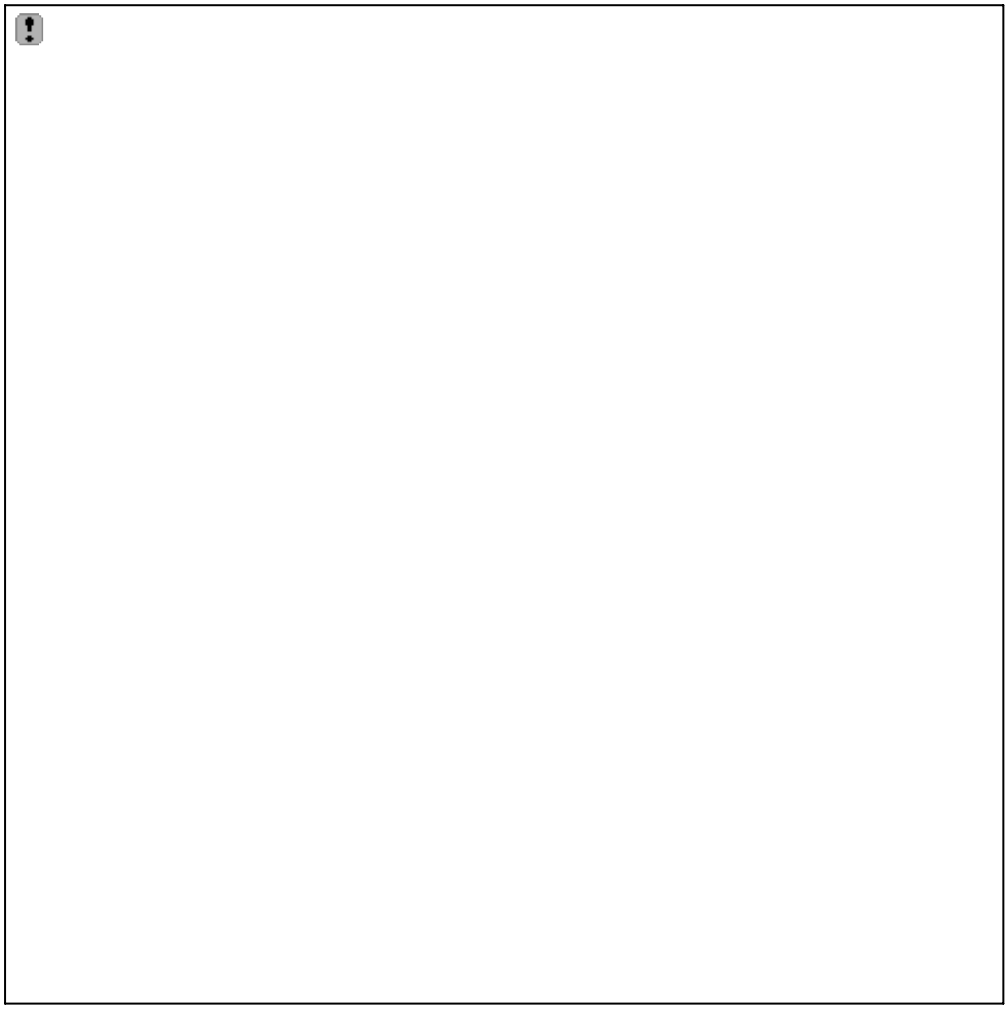

Figure 6.24: Pillowed basalts from the Penygadair Volcanic Formation, SW of Penygadair summit. (Photo: D.G. Woodhall.)

The highest intercalation of the Ty'r Gawen Mudstone Formation crops out south of Penygadair, where part of the outcrop is concealed by Llyn Cau. In the steep slopes between Llyn Cau and Craig Cau the mudstones incorporate an olistostrome, 200 m long and 20 m thick, made up of blocks of pillowed basalt up to 4 m across in a matrix of tuffaceous mudstone with a variable amount of volcanic rock fragments and feldspar crystals. It also contains irregular contorted clasts of green tuff, up to 0.3 m across, which were probably incorporated and deformed while

unlithified.

The lower part of the Craig Cau Formation, in exposures at Craig Cau and Craig Cwm Amarch, consists of a basal blocky tuff, 20–40 m thick, overlain by a disrupted sequence of tuffs and tuffaceous mudstones with lenticular mudstones and basalt lavas, altogether 200 m thick. The basal tuff is possibly an ash flow but it has incorporated many blocks of vesicular basalt (some resembling pillow fragments), dolerite, basic tuff and more rarely rhyolite, along with feldspar crystals, in a dark-green muddy matrix. The blocks decrease in size and frequency upwards and the top is relatively block-free and more silicic in appearance. The upper part of the formation consists of an ash-flow tuff, 180 m thick, with up to 10 m of bedded tuffs at the top. The ash-flow tuff is non-welded and feldspar crystal-rich in the basal 2–3 m, although above the tuff is strongly welded with a contorted welding fabric indicative of rheomorphic folding. This becomes less evident upwards as the attitude of the welding fabric becomes approximately bedding parallel. The overlying bedded tuffs are fine grained and include laminated tuffs and thin intercalations of mudstone.

Most of the igneous intrusions within the site area are dolerite sills, up to 200 m thick, of which the Mynydd y Gader dolerite (Lake and Reynolds, 1912) and the Penygadair dolerite (Davies, 1956) are the most extensive. The Cadair Idris microgranite, previously referred to as ‘granophyre' (Davies, 1959), is for much of its outcrop a sill up to 600 m thick. It forms a prominent escarpment immediately north of Cyfrwy, Penygadair and Mynydd Moel, with columnar jointing evident in the escarpment cliffs. At Mynydd Moel the sill becomes a highly discordant boss, within which the microgranite becomes fine grained and grades into rhyolite. Whereas the sill is emplaced into the lowest part of the Ty'r Gawen Mudstone Formation, the boss has intruded overlying formations as high as the upper part of the Craig Cau Formation. Here it loses its identity as a result of the lithological similarity between recrystallized ash-flow tuff and rhyolite (Davies, 1959; Pratt *et al.*, 1995).

Interpretation

The tuffs of the Offrwm Volcanic and Cregennen formations are interpreted as the subaqueous products of contemporaneous acid and basic explosive volcanism at both the Cadair Idris and the Pared y Cefn-hir GCR sites. However, the absence of interbedded mudstone in the Offrwm Volcanic Formation on Mynydd y Gader suggests that the formation is represented here by a single thick ash-flow tuff, which was possibly emplaced into shallower water than the tuffs of this formation at the Pared y Cefn-hir GCR site. The scarcity of mudstone at the base of the Cregennen Formation along the central part of Mynydd y Gader indicates that shallow-water conditions persisted during the emplacement of the lowest basic tuffs by one or more debris flows. However, the mudstone-dominated succession above indicates the establishment of deeper water conditions in which relatively fine-grained turbiditic tuffs were deposited.

The basalt lavas of the Llyn y Gafr and Penygadair volcanic formations are the products of effusive volcanism from an unknown source area. The basalt breccias possibly represent coarse pyroclastic material that accumulated close to a vent, but it is possible that the breccias represent accumulations of pyroclastic material redeposited by debris flows at greater distances from the source vents. The mudstone intercalation that separates the two formations indicates a hiatus in volcanism. The pyritous mudstones and ironstones are interpreted as the result of low sedimentation rates during this hiatus (Pratt*et al.*, 1995).

The presence of the few silicic ash-flow tuffs in the Cregennen and Penygadair Volcanic formations indicates that explosive silicic volcanism was only intermittent. However, during the emplacement of the Craig Cau Formation the situation was very different. The basaltic material incorporated in the ash-flow tuffs and other deposits in the lower part of the formation is consistent with sporadic basaltic volcanism. The lack of such material higher up in the formation suggests that basic volcanism had died out before the subaqueous emplacement of the thick silicic ash-flow tuffs that dominate the upper part of the formation. It has been suggested that the boss of the Cadair Idris microgranite lies close to the source of the silicic tuffs of the Craig Cau Formation (Cox and Wells, 1927; Davies, 1956, 1959; Pratt *et al.*, 1995).

Geochemical analyses (Kemp and Merriman, 1994) confirm the existence of bimodal basaltic and rhyolitic lavas and tuffs, and suggest that the associated dolerite and microgranite

intrusions are probably cogenetic. The rocks evolved largely by crystal fractionation of transitional tholeiitic/calc-alkaline magmas emplaced into thinned continental lithosphere, probably in an extensional marginal basin. The magmas are believed to have been generated in the mantle by the melting of subduction-modified N-type (normal) Mid-Ocean-Ridge Basalt (MORB).

Conclusions

The Cadair Idris GCR site represents the most important episode of Ordovician volcanism in southern Snowdonia. The well-exposed volcanic and associated intrusive rocks of the site area include examples of a subaqueously emplaced volcanic succession dominated by basaltic pillow lavas and silicic ash-flow tuffs.

Evidence for welding in the silicic tuffs at the base and top of the volcanic succession indicates that they were emplaced as hot ash-flow tuffs contemporaneous with explosive volcanism. However, the mode of emplacement of the basic tuffs and their association with contemporaneous volcanism is less clear. The existence of well-exposed pillow lavas provides clear evidence that effusive basaltic volcanism took place and it is likely that there was associated explosive volcanism. Many of the basic tuffs display evidence of mass-flow emplacement, suggesting that the products of this explosive volcanism were dispersed in debris flows and turbidity currents.

Some of the numerous dolerite sills display evidence of intrusion contemporaneous with the basaltic volcanism and it also seems likely that the silicic magma that produced the Cadair Idris microgranite was closely related to that which generated the silicic ash-flow tuffs of the Craig Cau Formation.

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