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# Mynydd Penarfynydd

(SH 214 259–[SH 236 273])

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## Introduction

The Mynydd Penarfynydd GCR site encompasses one of the best examples of a layered basic intrusion in the southern part of the British Caledonides. The site area centres on the prominent headland of Mynydd Penarfynydd, on the southern coast of Llan, which provides excellent coastal exposures through the intrusion (Figure 6.66) and (Figure 6.67). Much of the outcrop of the intrusion occurs within the GCR site boundary, but it continues inland to the north-east along the eastern side of Mynydd Rhiw for several kilometres, where it is only poorly exposed. The intrusion has great significance for the role it has played in influencing ideas on magma evolution during Ordovician igneous activity on Llan.

The Mynydd Penarfynydd Layered Intrusion was emplaced into Ordovician (Llanvirn) sedimentary rocks, close to the north-western margin of a sedimentary basin aligned along the Menai Straits Fault-zone. Most accounts have suggested that the intrusion is of Llanvirn age, pre-dating the major late Ordovician phase of igneous activity on Llan. Young *et al* (in press), however, have proposed that the intrusion is associated with younger (Caradoc) Ordovician activity; being contemporary with the extrusive basaltic volcanism seen in the Nod Glas Formation.

Originally the Mynydd Penarfynydd intrusion was described as a greenstone (Sharpe, 1846; Ramsay, 1866; Tawney, 1880; Bonney, 1881; Teall, 1888). The earliest detailed description of the intrusion was provided by Harker (1888, 1889) and the area was subsequently mapped by Marley (1932). The intrusion was the subject of two major studies in the 1960s and 1970s giving rise to several publications on the geology and mineralogy by Hawkins (1965, 1970), and on the geochemistry by Cattermole (1976). More recent re-examination of the intrusion, including new geochemical data, has been undertaken during mapping of both the Aberdaron and Pwllheli 1:50 000 Geological Survey sheets (Gibbons and McCarroll, 1993; Young *et al*, in press).

## Description

The Mynydd Penarfynydd Layered Intrusion is an easterly-dipping transgressive picritic and gabbroic sill within Llanvirn sedimentary rocks (Hawkins, 1970) of the Nant Ffrancon Subgroup. At Mynydd Penarfynydd, it is intruded into the undifferentiated mudstones of the subgroup, at least 200 m above the top of the Trygarn Formation, but it lies entirely within the Trygarn Formation to the north. On Mynydd y Craig the sill is over 150 m thick, and the intrusion thins gradually over a distance of 3 km to the north, before terminating abruptly NW of Tyddyn Corn.

The intrusion best demonstrates its layered nature on Mynydd Penarfynydd, within the GCR site area. The exposed section has been fully described by Hawkins (1970) and by Gibbons and McCarroll (1993). The lower 100 m of the sill is dominated by picrite (Figure 6.67). The base of the picrites shows a complex chilled zone about 10 m thick comprising a basaltic margin up to 2 m thick (Zone A of Hawkins, 1970) and about 8 m of fine-grained hornblende gabbros (Zone B of Hawkins). The thick picrites (Zone C of Hawkins) show a variable degree of layering. The picrites are overlain by banded leucogabbros, 9 m thick (Zone D of Hawkins). Hornblende olivine-gabbros, 13 m thick, (Zone E of Hawkins) appear to lie erosively on the leucogabbros, and are rich in augitic clinopyroxene and magnetite. Above this lies a unit of banded melagabbros (Figure 6.68). Higher in the intrusion, the rocks become progressively more differentiated, through a zone of secondarily-altered feldspathic ilmenitic gabbroic and dioritic lithologies, to the granophyric rocks which form the highest part of the exposed intrusion (Zones F, G, H and I of Hawkins). One small outcrop of the roof of the intrusion occurs in a small unnamed cove (at [SH 2226 2620]).

On Mynydd y Graig the gabbro typically contains brown intercumulus hornblende, commonly enclosing augitic clinopyroxene, altered plagioclase and up to 10% opaque minerals (magnetite, ilmenite, pyrite and pyrrhotite). The

texture and mineralogy are similar to the hornblende-cumulate gabbros (Zone F of Hawkins) exposed on Mynydd Penarfynydd, although layering is much less well developed. On Mynydd Rhiw (outside the GCR site) the intrusion is less well exposed, but shows a similar range of lithologies, although the gabbro is commonly more pegmatitic. In the most northerly outcrops of the intrusion, Zone F probably constitutes the floor of the intrusion, and Hawkins (1970) suggested that the upper zones (G, H and I) are probably absent or not well developed.

## Interpretation

Hawkins (1970) investigated the geochemistry of the intrusion and argued for an alkaline, rather than tholeiitic, character on the basis of the succession of rock types and the suite of minerals present. He did accept, however, that the absence of analcime and feldspathoids and the great range of rock types are features more associated with tholeiitic layered intrusions. Cattermole (1976) suggested that the intrusion was derived through fractional crystallization of a hydrated alkali olivine basaltic magma, with the marked geochemical variations produced by the intrusion of separate influxes of magma. Young *et al.* (in press) presented new geochemical data suggesting that the Mynydd Penarfynydd Layered Intrusion is subalkaline and tholeiitic in character, rather than alkaline.

Young *et al.* (in press) described the Mynydd Penarfynydd gabbros as characterized generally by very low concentrations of incompatible elements (Zr, Nb, Y) and high total Fe, MgO, Ni, Cr and V, features that are especially marked in the picritic cumulates, reflecting olivine and/or pyroxene accumulation. Two samples of melagabbro have relatively low Ni and Cr and markedly higher concentrations of TiO<sub>2</sub> and V, indicative of high modal proportions of an Fe–Ti oxide. On the Zr/TiO<sub>2</sub> vs Nb/Y diagram Mynydd Penarfynydd samples plot in the subalkaline basalt and andesite/basalt fields. Accordingly, Young *et al.* (in press) interpreted the intrusion as a suite of tholeiitic picrites and gabbros. The geochemical characteristics of the intrusion are in marked contrast to the transitionally alkaline Upper Lodge and Llanbedrog volcanic groups (see, for example, the Foel Gron and Trwyn-y-Gorlech to Yr Eifl quarries GCR site reports).

The Mynydd Penarfynydd intrusion has commonly been interpreted as being of Llanvirn age. However, the style of intrusion contrasts markedly with the nearby dolerite and basalt sills. Although the latter are locally transgressive, they only attain a highest stratigraphical level of intrusion close to the top of the Trygarn Formation (Lower Llanvirn) and commonly exhibit features (fine-grained apophyses, peperitic textures and pillows) suggestive of high-level intrusion into wet, unconsolidated, sediments. It is intruded, at the south-western limit of exposure, at a level 200 m above the top of the Trygarn Formation, but shows no indication of a shallow level of intrusion. The Mynydd Penarfynydd intrusion has therefore been reinterpreted as being of significantly younger, Caradoc age (Gibbons and McCarron, 1993; Young *et al.*, in press).

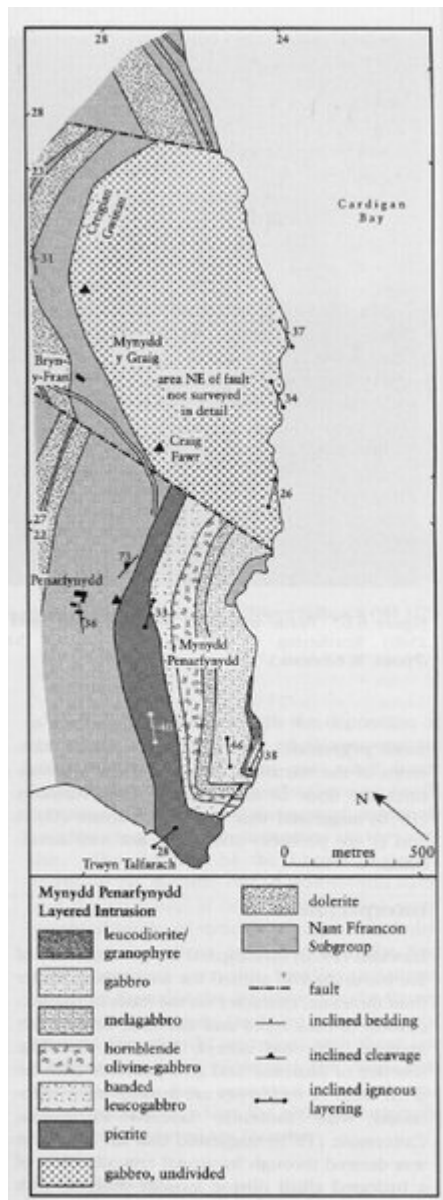
The subalkaline geochemical character distinguishes the Mynydd Penarfynydd intrusion from the major mid-Caradoc volcanic centres in western Llŷn, but it is similar to the final phase of Caradoc igneous activity in western Llŷn, which is seen to be associated with the deposition of the Nod Glas Formation, of *Dicranograptus clingani* Biozone age. The only other major basic intrusion in the area is the Carreg yr Imbill Intrusion at Pwllheli, and the general geochemical characters of the two intrusions are very similar. The position of the Carreg yr Imbill Intrusion on the line of the Efailnewydd Fault and the existence, at only slightly higher stratigraphical levels, of strongly transgressive tholeiitic minor intrusions associated with the Nod Glas Formation extrusive basaltic volcanism, argues in favour of the association of the Carreg yr Imbill Intrusion (and by extension the Mynydd Penarfynydd intrusion) with these late Caradoc basalts. However, the Nod Glas Formation is not preserved close to the Penarfynydd area, where the highest stratigraphical levels preserved are Llanvirn.

## Conclusions

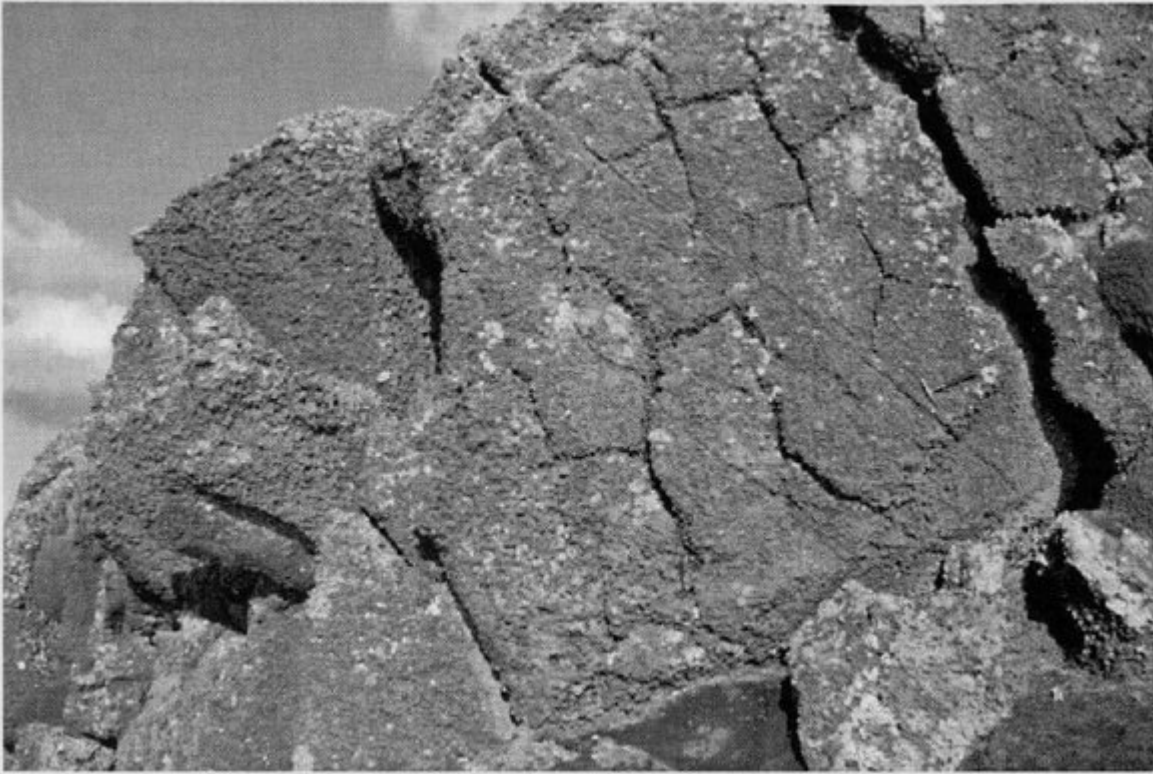
The Mynydd Penarfynydd Layered Intrusion is a classic example of a layered basic sill, one of only two Ordovician layered intrusions in Wales, with relatively easy access to the base of the sill exposed in sea cliffs. The superbly defined layering, and the range of rock types present, from picrites through gabbros to more differentiated, intermediate lithologies, makes this site one of the best exposures of intrusive igneous rock in the southern Caledonides of the British Isles. The age of the intrusion is not known with certainty, but it is now considered to be associated with the late Caradoc

basaltic volcanism seen in the Nod Glas Formation on Llŷn. This period is of great significance for it marks a major change in the style and chemistry of volcanism after cessation of activity at the major volcanic centres at Llanbedrog and Snowdon.

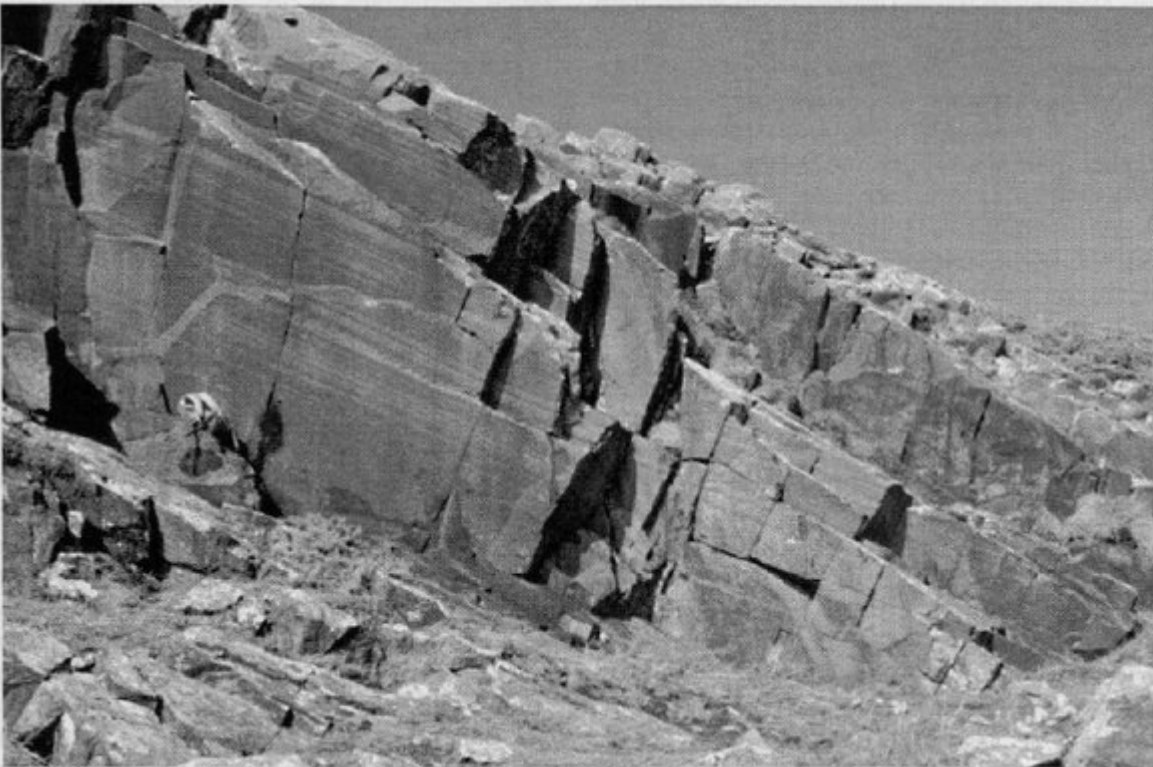
## References



(Figure 6.66) Map of the Mynydd Penarfynydd Layered Intrusion, south Llŷn.



*(Figure 6.67) Picrite within the Mynydd Penarfynydd Layered Intrusion, north of Trwyn Talarfach [SH 2152 2580] Weathering of the cumulate texture has produced the distinctive honeycomb pattern. (Photo: W. Gibbons.)*



*(Figure 6.68) Banded melagabbros from the Mynydd Penarfynydd Layered Intrusion at Trwyn Talfarach [SH 2173 2580]. (Photo: W. Gibbons.)*