Rhobell Fawr

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Introduction

Early Ordovician basic volcanic rocks and associated high-level basic, intermediate and silicic intrusions, comprising the Rhobell Volcanic Complex, are exposed in a remote tract of country on the eastern side of the Harlech Dome, in southern Snowdonia, ccntrcd around Rhobell Fawr (Figure 6.7). The site is of importance as a representative of the only substantial remnant of the early arc igneous episode in Wales, linked to subduction of Iapetus oceanic lithosphere beneath the Welsh Basin. Rare cumulate blocks in the basaltic lavas provide critical evidence for petrogenesis of the various igneous rocks, related to processes occurring in a thermally and compositionally stratified magma chamber. This is the only record of such cumulate blocks in the Caledonides of the British Isles.

The first detailed description of the volcanic sequences exposed around Rhobell Fawr was provided by Wells (1925). In the mid to late 1970s there was a resurgence of interest in the various Ordovician volcanic sequences across Wales, following the work of Fitton and Hughes (1970) who linked their origin to subduction of oceanic crust beneath the Welsh Basin. The area of Rhobell Fawr was studied in detail by Kokelaar (1977), including a detailed investigation of the petrology, geochemistry and petrogenesis (see Kokelaar, 1986).

The Rhobell Volcanic Group lies with marked unconformity on folded sedimentary rocks of Cambrian and earliest Tremadoc age. A maximum vertical thickness of 260 m of lavas, chiefly plagioclase-clinopyroxene-phyric basalts, is exposed around Rhobell Fawr, although Kokelaar (1986) estimated, from structural considerations, that originally up to 2 km of basalts were erupted. K-Ar age determinations on pargasites from basalt lavas of the complex give an age of 508 -± 11 Ma (Kokelaar *et al.,* 1982).

A N–S fault zone, termed the Rhobell Fracture, appears to have strongly influenced development of the volcanic pile, as well as defining the eastern margin of an upfaulted horst of Cambrian rocks, known as the Harlech Dome. Indeed, further movements along the Rhobell Fracture in late Tremadoc times led to folding, faulting and erosion of igneous rocks of the Rhobell Volcanic Complex, such that today they are overlain by lowest Arenig strata with marked unconformity.

Description

Kokelaar (1977) divided the Rhobell Volcanic Group into four formations:

1. Ffridd Graig-wen Formation (youngest)
2. Eglwys Rhobell Formation
3. Rhobell Ganol Formation
4. Blaen-y-Glyn Formation (oldest)

These formations successively overlap to the east. The four formations are composed almost entirely (99%) of plagioclase-clinopyroxene-phyric lavas. Rare pargasite-bearing lavas are found chiefly in the Blaen-y-Glyn Formation (Figure 6.8), while porphyritic basalts are present mostly in the Eglwys Rhobell Formation. Variations that are present in the succession are considered by Kokelaar (1986) to reflect changes in effusion rates. Breccias occurring in intimate association with the lavas are thought to be auto-elastic in origin, while minor volcaniclastic units are possibly water-reworked deposits.

The plagioclase-clinopyroxene-phyric basalts are extensively altered, with a range of secondary minerals characteristic of the prehnite-pumpellyite and lower greenschist facies. Euhedral plagioclase phenocrysts, almost always albitized, form

up to 40% of the mode, and commonly show evidence of normal or oscillatory zoning, or contain concentric zones of inclusions towards their margins. Clinopyroxenes are more commonly fresh, and have augitic compositions. These also show normal and oscillatory zoning, and inclusion-rich zones occur towards the crystal margins. Groundmass in the basalts is invariably altered.

Pargasite-bearing basalts form a minor component of the Rhobell lavas. Typically pargasite phenocrysts form 1–5% of the mode, and reach up to 4 cm in length. Both oscillatory zoning and zones at crystal margins rich in inclusions are present, sometimes both being sharply truncated by later crystal growth. Clinopyroxenes range up to 4% of the mode, and reach up to 7 mm in diameter. Both normal and oscillatory zoning are present, and margins to crystals are inclusion-rich. Clinopyroxenes are augitic in composition. Plagioclase phenocrysts, up to 2 mm in length, form up to 20% of the mode; typically they are altered. The groundmass is fine grained and altered.

Locally the lavas are cumulophyric, with cumulus ferromagnesian phenocrysts forming up to 50% of the mode. In the cumulophyric basalts pargasite forms up to 47% of the mode, while clinopyroxenes form up to 10%, and are diopsidic in composition. Plagioclase is typically absent from the cumulophyric basalts.

Rarely cumulophyric lavas of the Eglwys Rhobell Formation contain cognate cumulate blocks which reach up to 10 cm in diameter (Figure 6.9). Kokelaar (1986) reported the presence of two classes of cumulate blocks, namely pargasite mesocumulates and adcumulates, and pargasite–salite (augite) mesocumulates and adcumulates. The former class of block, which is the most common type found, contains pargasite, up to 1.5 cm in diameter, as the only cumulus phase, with variable amounts of post-cumulus material, possibly showing fine-scale grain size and textural lamination. Small inclusions are present in many of the pargasite crystals. The pargasite-augite cumulate blocks are similar to the pargasite cumulate blocks but contain up to 20% modal augite. Some of the augites contain minor chlorite inclusions, possibly after glass.

Intrusions associated with the Rhobell Volcanic Group comprise basic, intermediate and silicic varieties. Although sheet-like with respect to the Cambrian strata within which they are contained, they are dyke-like with respect to the base of the volcanic pile. Basic varieties are doleritic, typically dominated by clinopyroxene and plagioclase; leucodoleritic varieties contain only sparse clinopyroxene. Intrusions of intermediate composition (not exposed in the GCR site area) are represented by porphyritic micro-diorites, which contain plagioclase and hornblende phenocrysts (up to 40% and 3% of the mode respectively), the former showing normal and oscillatory zoning. In the more silicic (microtonalitic) intrusions, the modal proportion of hornblende decreases (to *c.* 1% of the mode) while that of quartz, present both as phenocrysts and in the groundmass, increases. The phenocrysts reach up to 0.4 mm in diameter, and form up to 5% of the mode.

Interpretation

Basaltic rocks of the Rhobell Volcanic Complex are thought to reflect a subaerial sequence of lavas which produced a volcanic pile up to 2 km thick around a fissure zone, now represented by an intense swarm of dykes. In the central zone of the swarm, intervening screens of sedimentary rocks are absent, and up to 1 km of E–W dilation across the Rhobell Fracture Zone has been estimated (Kokelaar, 1986). Activity was focused along this zone for up to 24 km in a N–S orientation, most probably with other volcanic piles developing locally. The abundant clasts of porphyritic igneous rock and the feldspar-rich nature of many sandstones in the Arenig of this part of the Welsh Basin support such a contention.

Textures in the cumulate blocks, in particular the inclusion-free and inclusion-rich zones, have been interpreted by Kokelaar (1986) as reflecting varying conditions of crystal growth, especially variations in temperature within a magma chamber, coupled possibly with variations in composition. Crystals that grew and accumulated in this magma chamber were periodically disturbed, as is shown by the presence of oscillatory zoning and by the sharp terminations to growth patterns in crystals. Disrupted crystals or blocks were incorporated into erupted magmas.

Kokelaar (1986) provided extensive whole-rock and mineral geochemistry for samples from the Rhobell Volcanic Complex and combined these data to present a petrogenetic model to explain the diverse rock types present. Geochemical and mineralogical constraints suggest that the variety of igneous rocks present in the Rhobell Volcanic Complex was derived by fractional crystallization from a basic parent. The fractionation process was heavily influenced

by pargasite in the early stages, along with clinopyroxene. Geochemically, the rocks show calc-alkaline affinities, characteristic of destructive plate margins, which supports the suggestion that these rocks were generated as a result of the subduction of Iapetus oceanic lithosphere beneath the Welsh Basin in early Ordovician times (Bevins *et al.,* 1984; Kokelaar *et al.,* 1984b).

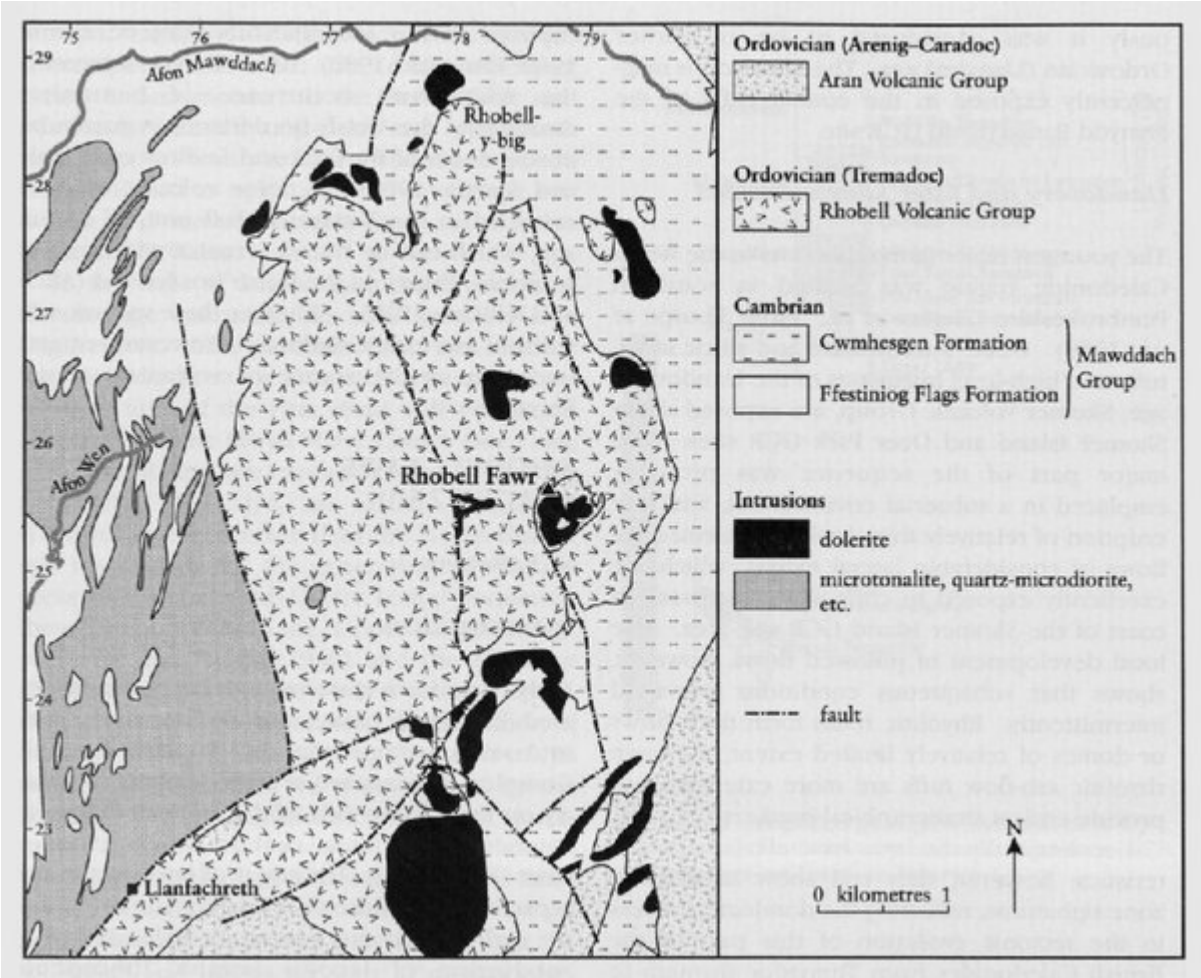
Conclusions

Basic, intermediate and silicic rocks of the Rhobell Volcanic Complex represent the extrusive and high-level intrusive products of a calc-alkaline volcanic episode which developed over a major fracture, the Rhobell Fracture, in early Ordovician times. Dyke rocks were emplaced as a swarm along the central zone of the fracture, reflecting up to 1 km of crustal extension in an E–W direction.

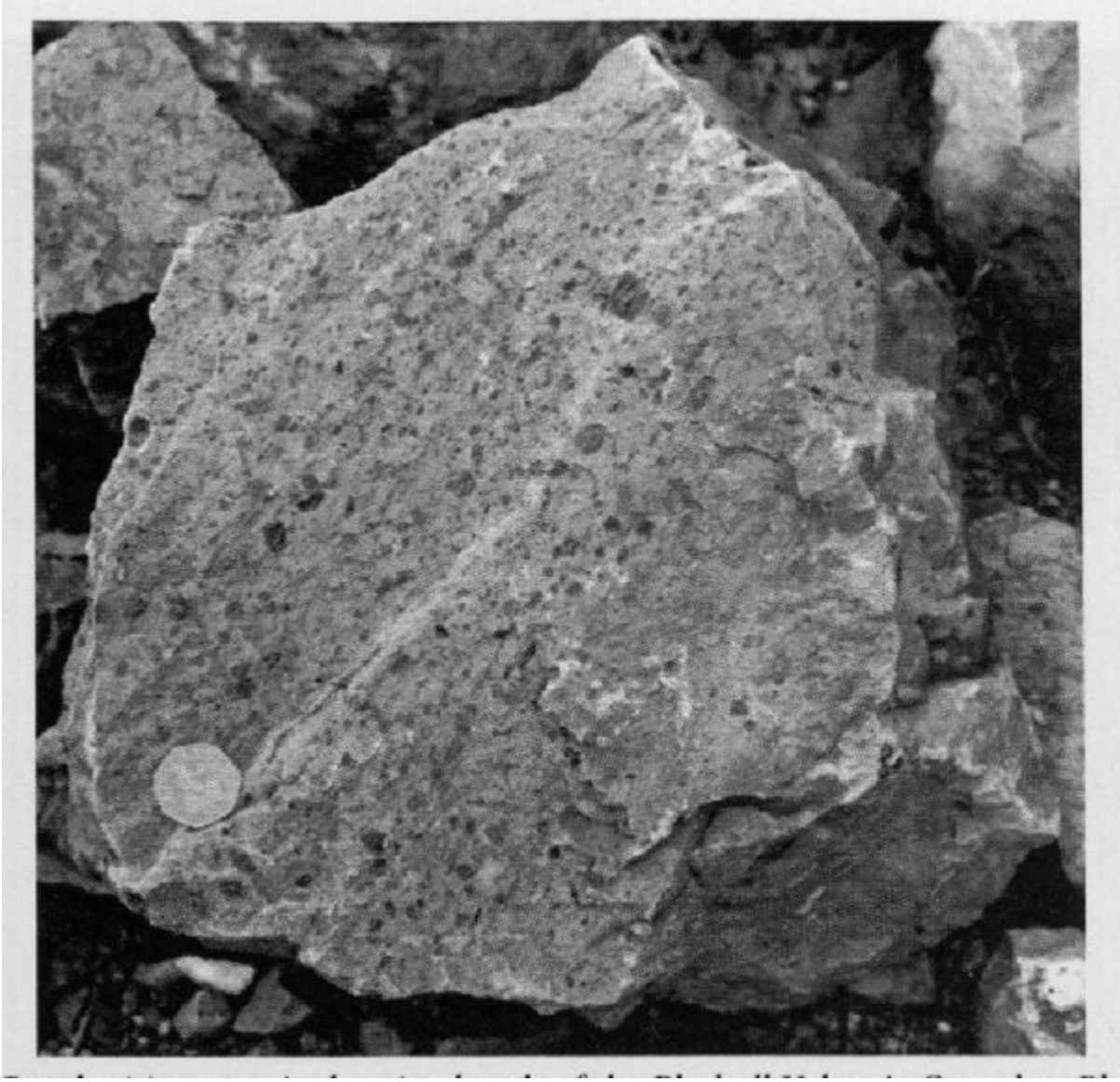
The majority of the lavas are basaltic, rarely containing amphibole phenocrysts and blocks of amphibole-pyroxene-rich rock that are unique in the British Caledonides and which provide important constraints on the origin and evolution of the magmas. Textures in the blocks imply crystal accumulation, under varying temperature conditions, in a compositionally varied magma chamber. Periodically this chamber was disturbed, releasing crystals and blocks into the erupting magmas. The various igneous rocks were generated from a basic parental magma, by crystal fractionation, dominated by the removal of the amphibole crystals from the magma.

The rocks show calc-alkaline affinities, in keeping with suggestions that these Ordovician volcanic rocks were derived as a result of the subduction of Iapetus oceanic lithosphere beneath Wales. Indeed, they represent the only substantial remnant of an early volcanic-arc episode in Wales. Following eruption of the Rhobell lavas, the character of magmatism changed, with the later eruption of magmas more typical of a back-arc basin environment (see, for example, the Pen Caer GCR site report).

References



(Figure 6.7) Map of the Rhobell Fawr GCR site, adapted from Kokelaar (1977).



(Figure 6.8) Porphyritic pargasite-bearing basalt of the Rhobell Volcanic Complex, Rhobell Fawr. (Photo: BGS no. L 1274.)

(Figure 6.9) Cognate cumulate block in basalt lava of the Rhobell Volcanic Complex, Rhobell Fawr. (Photo: R.E. Bevins.)