6 Balnacraig, Dinnet

[NJ 4755 0045]–[NJ 4855 0160]

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6.1 Introduction

The Balnacraig GCR site in northern Deeside provides a spectacular illustration of the effects of intrusion of basic magma into metasedimentary rocks that were already undergoing amphibolite-facies regional metamorphism. Here, xenolithic gneisses containing large, prismatic crystals of sillimanite have yielded valuable information on the variation of pressure and temperature with time during metamorphism. Adjacent exposures of amphibolite display polyphase folding and are intruded by veins of leucotonalite.

Pelitic, semipelitic and psammitic metasedimentary rocks, belonging to the Queen's Hill Formation of the Crinan Subgroup, were intruded shortly after deposition by sills of tholeiitic dolerite, which are now amphibolite sheets. During the Grampian Event (*c.* 470 Ma), amphibolite-facies metamorphism and migmatization occurred, and at the time of peak metamorphism, norites of the Tarland Intrusion were emplaced, resulting in partial melting of the adjacent metasedimentary rocks.

The first geological description of the area followed primary mapping by the Geological Survey (Grant Wilson and Hinxman, 1890). Work by Read (1927) highlighted the evidence for migmatization and 'injection' phenomena, as well as the presence of xenoliths of more-refractory lithologies in the gneissose pelites. Read's detailed petrography still forms the main descriptive work on the rocks, although the interpretation has changed. Read described the rocks between the outcrop of the Deeside Limestone Formation to the south and the gabbroic and granitic intrusions to the north as a 'injection complex', which he considered to be caused by the intimate admixture of silicic igneous materials with sedimentary and igneous materials of earlier date. Depending on the proportion of igneous material, the result ranged from largely metasedimentary 'oligoclase-porphyroblast-schist' through 'oligoclase-biotite-gneiss' to 'orthoclase-oligoclase-biotite-gneiss', which Read classed as largely igneous in origin. However, even the latter contains fine-grained wisps of quartz, feldspar and biotite, and isolated xenoliths, representing an original metasedimentary host.

Subsequently, Baker (1985) undertook a detailed petrological study, including geothermometry and geobarometry, on these and other selected rocks within the Dalradian of the North-east Grampian Highlands to try to unravel the timing and localization of metamorphic peaks. Then, following a resurvey of the area, Gould (1997) re-interpreted the textural features described by Read as being caused by anatexis. He also recognized the Tarland Intrusion as a syn-D3 pluton of the North-east Grampian Basic Suite, and identified the heat of the basic magma as the cause of the intense local metamorphism and partial melting of the country rocks.

6.2 Description

This GCR site is located on the northern side of the valley of the River Dee in Aberdeenshire, about 2 km north of Dinnet, and is centred upon the cottage at Balnacraig. It lies within a belt of coarse-grained, gneissose metasedimentary rock, 0.3 – 1.3 km wide (Figure 6.11), which includes the rocky hills of Creag Ferrar, Mullloch, Craigie and Scar Hill (300 m), and extends as far west as the contact with the Tarland Intrusion at [NJ 475 015]. In places the rocks are recognizably psammitic, semipelitic or pelitic, but in most places the protolith is not recognizable. From south of Craigie to Mulloch, the rocks have suffered shearing and retrogressive metamorphism. However, a traverse from the eastern side of Craigie at [NJ 477 008] to the summit of Scar Hill [NJ 482 013] enables the full range of partial melting phenomena to be examined and forms the nucleus of the site.

On the eastern slopes of Craigie there is a transition from coarse-grained pelite with scattered porphyroblasts of oligoclase up to 20 mm across, to gneisses in which pelitic material is cut by irregular veins of granitic material carrying large garnet and biotite crystals. In thin section, the pelites consist of plagioclase (An_{23}), biotite, garnet, sillimanite, and magnetite. Minor cordierite and orthoclase are also present. The sillimanite is coarsely crystalline, forming stumpy prisms aligned within the main foliation. Later retrogressive metamorphism has formed sericitic aggregates and, in places, andalusite replaces sillimanite and plagioclase.

The gneisses display a single, coarsely developed foliation, striking north-east and dipping steeply to the north-west. As the traverse is continued from Craigie to Scar Hill, the proportion of granitic material increases and the leucosome of the gneiss includes orthoclase as well as plagioclase feldspar. The feldspar porphyroblasts are mostly well crystallized, and contain few inclusions. The proportion of pelitic material decreases until all that is left is a number of large xenoliths, in which the foliation is no longer parallel to that in the host, and a few streaks of biotite and fibrolitic sillimanite.

The most noteworthy feature of the rocks is the presence of sporadic xenoliths within the porphyroblastic gneisses of more-refractory lithologies (quartzite, calcsilicate rock, silica-poor pelitic hornfels) (Read, 1927). These xenoliths vary in shape from elongated to almost spherical (Figure 6.12).

The siliceous xenoliths are banded feldspathic quartzites with sutured quartz grains. They contain small grains of basic plagioclase and flakes of colourless to red-brown biotite. The pelitic xenoliths contain fractured crystals of garnet and prismatic sillimanite and streaks of biotite lying within aggregates of sericite. Biotite and garnet are in many cases altered to chlorite. One pelitic xenolith contains staurolite, forming large prisms concentrated within certain layers and streaked out into films of pale mica with fibrolite needles. The intervening layers consist largely of large flakes of muscovite and biotite.

Xenoliths of calcsilicate rock show a poikiloblastic granular texture and consist of diopside, amphibole, labradorite plagioclase and quartz. Amphibole-rich xenoliths are abundant; compared with the orthoamphibolites in the intrusive sheets of Craig Dhu and Balnacraig Cottage (see below), they contain a higher proportion of amphibole, and the plagioclase is more calcic, reaching anorthite in some cases. Quartz occurs only as small pellets or tubules in the plagioclase and amphibole. Some specimens contain large sieve-like porphyroblasts of garnet.

A sheet of amphibolite, about 100 m thick, is well exposed at Balnacraig Cottage [NJ 479 006]. The rocks of the sheet have a grain size of 0.5–1 mm, with a well-developed planar fabric and consist of prismatic hornblende and granoblastic labradorite, with minor clinopyroxene in places. The sheet is traversed by veins of leucocratic material, both parallel to and cutting across the foliation of the amphibolite. The veins consist of plagioclase (generally oligoclase, in contrast to the labradorite of the amphibolite), with minor quartz and hornblende. In places the veins expand into large, diffuse patches within the amphibolite (Figure 6.13).

6.3 Interpretation

Modern interpretations of the xenolithic gneisses at this GCR site, and of other examples nearby within Crinan Subgroup semipelitic rocks, suggest that the least-refractory metasedimentary rocks have been partially melted during the peak of regional metamorphism (syn-D3). This was contemporaneous with the intrusion of magmas, now represented by mafic and ultramafic rocks of the Tarland, Coyles of Muick and other plutons, which produced a large heat flux. A granitic melt was formed first in semipelitic rocks, then in pelites and feldspathic psammites. As the proportion of partial melt of the pelitic rocks increased, to include some ferromagnesian material, the resulting melt crystallized as quartz, orthoclase and andesine, with minor garnet and biotite. The residue after this more-intense partial melting was highly aluminous, and recrystallized as knots of biotite, sillimanite, cordierite, magnetite and, locally, spinel. Later metamorphism, producing andalusite and sericitic aggregates, was post D3, but pre-dated the local contact metamorphism associated with the Mount Battock and Cromar granite plutons. Where partial melting of the amphibolite occurred, the first melt to form was tonalitic, crystallizing as quartz, oligoclase, and minor hornblende, reflecting its undersaturation in alumina.

Migmatites resembling those in the Balnacraig GCR site also occur within the Queen’s Hill Formation to the south-west of the Ballater Pluton, where they have been described as the Pannanich Hill Complex (Goodman, 1994; see the *Cairn*

Leuchan to Pannanich Hill GCR site report). There, garnetiferous oligoclase-biotite gneisses contain refractory inclusions showing peak regional metamorphic assemblages. The gneissose matrix is considered to have formed by reconstitution of semipelitic lithologies, aided by the presence of abundant aqueous fluids and high temperatures. Peak metamorphic conditions were estimated at 820°C and 8 kbar (Baker and Droop, 1983). Partial melting was considered to be likely under those conditions. More conclusive evidence of partial melting of similar metasedimentary rocks was obtained by Goodman and Lappin (1996) from the aureole of the Lochnagar Pluton, where intrusion of dioritic magma followed by granite magma into high-grade regional metamorphic rocks produced temperatures of up to 750° C at 2.5 kbar pressure in the aureole. Temperatures in the Balnacraig rocks would have been comparable to those in the Pannanich Hill Complex during the D3 metamorphic peak due to the proximity to the Tarland basic intrusion, so at least some partial melting could be expected.

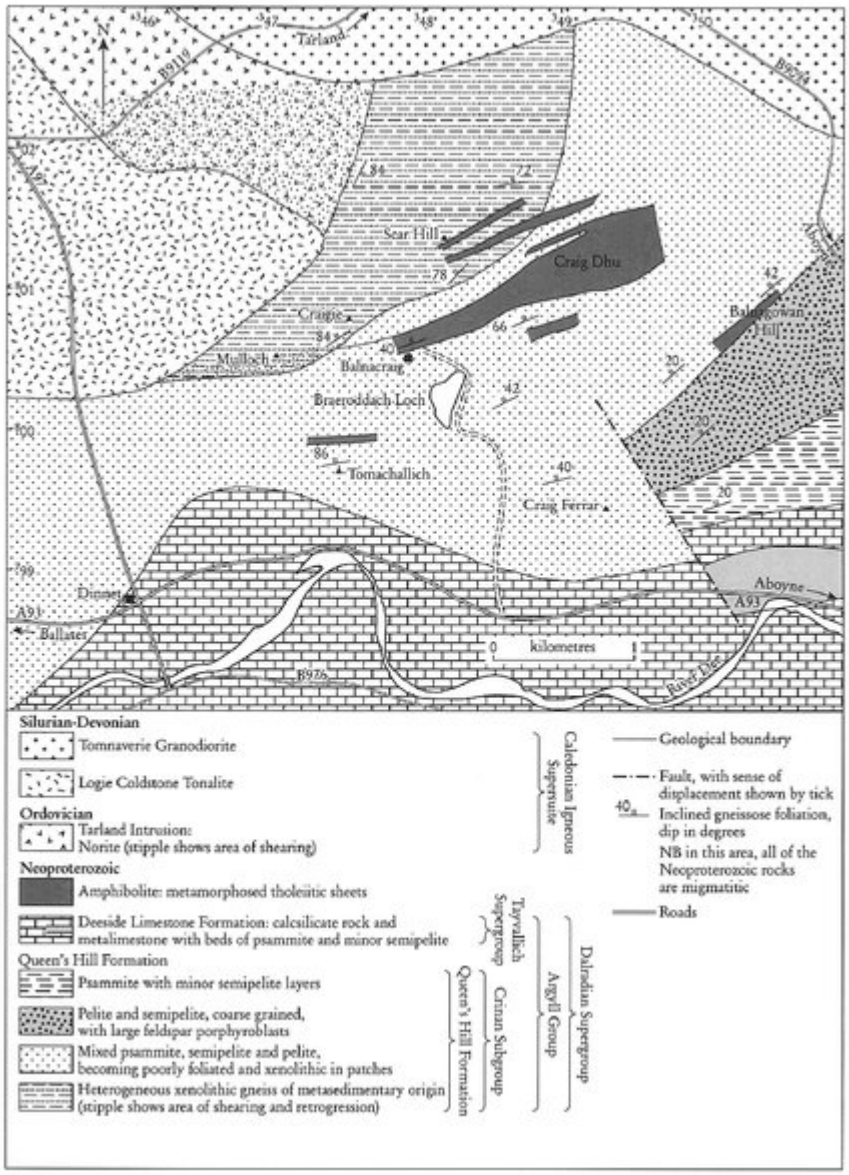
The polyphase nature of the metamorphism was demonstrated by Baker (1985), who found that andalusite, where present, always post-dated sillimanite, indicating that pressures were significantly lower during the later metamorphic episodes. Two specimens of gneissose pelite from Balnacraig gave results of 762°C at 7.6 kbar, and 799°C at 9.2 kbar for the main metamorphic event, similar to those at Pannanich Hill.

6.4 Conclusions

The Balnacraig GCR site is of national and possibly international importance as an exceptional example of the enhancement of the effects of regional metamorphism by the emplacement of basic magma shortly after the regional peak. Many classical features of migmatization of metasedimentary rocks are displayed, including veining by a granitic leucosome and the formation of xenoliths of refractory compositions within irregularly layered gneisses. The migmatization was a result of partial melting of the rocks during the local D3 phase of deformation, which occurred shortly after the regional metamorphism had reached its peak in the upper amphibolite facies. This deformation was contemporaneous with the intrusion of basic magma (the Tarland Intrusion), which might have increased the heat flux sufficiently to cause a local increase in the proportion of partial melt.

A striking feature of the gneisses is the presence of large prismatic crystals of sillimanite that formed during the peak of metamorphism. Later retrograde metamorphism at lower pressure resulted in the growth of andalusite, and the well-preserved mineral assemblages from this GCR site have contributed significantly to a study of variations in temperature and pressure during metamorphism in this part of the Grampian Highlands. Possible further research could include an investigation of variations in mineral compositions between the xenoliths and their host rocks, and a comparison with similar metasedimentary rocks near the eastern contact of the Morven–Cabrach Pluton.

References



(Figure 6.11) Map of the area around Balnacraig, Dinnet. Modified after Gould (2001, figure 11)

(Figure 6.12) Xenolithic gneiss with folded remnants of psammite dispersed in poorly foliated feldspar-porphyroblast gneiss. Craigie, 1.5 km north-east of Dinnet [NJ 476 007]. Coin is 26 mm in diameter. (Photo: BGS No. P220491, reproduced with the permission of the Director, British Geological Survey, © NERC.)

(Figure 6.13) Amphibolite, with irregular patches of feldspathic material, Balnacraig Cottage, north-east of Dinnet [NJ 4787 0056]. Coin is 25 mm in diameter. (Photo: BGS No. P 220371, reproduced with the permission of the Director, British Geological Survey, © NERC.)