2 An Suidhe, Kincraig

[NH 810 050]–[NH 827 063]

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2.1 Introduction

The lithological, metamorphic and structural correlation of the lowest Dalradian rocks of the Northern Grampian Highlands with the Moine Supergroup of the Northern Highlands has long been the subject of considerable debate (see reviews by Harris *et al*., 1994; Stephenson and Gould, 1995). Of particular importance is the evidence for a major orogenic break at or near the base of the Grampian Group (Piasecki and van Breeman, 1979b, 1983). Recent radiometric studies have confirmed the existence of Neoproterozoic (800–750 Ma) tectonothermal events within both the Moine and the oldest rocks of the Northern Grampian Highlands (Noble *et al*., 1996; Highton *et al.,* 1999), yet in the higher Grampian, Appin and Argyll group rocks of the Dalradian succession, only Palaeozoic (470–450 Ma) Caledonian events are known (e.g. Rogers and Pankhurst, 1993, Smith *et al.*, 1999). Comparable dating studies now recognize discrete tectonothermal events and it remains one of the key issues of Highland geology to define the limits of these events.

The GCR site at An Suidhe, north-west of Kincraig on Speyside (Figure 5.5), forms part of the original evidence cited by Piasecki (1980) for the existence of an orogenic unconformity, largely obscured by a zone of ductile shearing termed the Grampian Shear-zone or Slide. He recognized an apparent structural and metamorphic contrast between an older crystalline basement (his ‘Central Highland Division’) and a cover sequence (his ‘Grampian Division’). The Central Highland Division was believed to be of possible Grenvillian age (*c.* 1000 Ma) and to have experienced amphibolite-facies migmatization, gneissification and deformation prior to the deposition of the ‘Grampian Division’. Rb-Sr whole-rock and mineral (muscovite) ages from pegmatitic granites within the intervening shear-zone also provided key evidence for deformation and metamorphism of both the basement rocks and the lower parts of the cover sequence, initially by Knoydartian events (*c.* 800–750 Ma) and then by Grampian events (*c.* 470–450 Ma).

Importantly, the site is also the type area for a distinctive heterogeneous succession of metasedimentary and meta-igneous rocks including semipelite, psammite, quartzite, metalimestone and amphibolite. This succession, termed the Kincraig Formation, forms the local base to the Grampian Group and separates grey micaceous psammite from variably gneissose and sheared psammite, semipelite and quartzite typical of the sub-Grampian Group basement. The Grampian Shear-zone and dated pegmatites lie beneath this sucession, wholly within the sub-Grampian Group basement. These strata and their contacts, which are well exposed on the SE-facing glaciated crags, small quarries and stream sections south of An Suidhe summit, lie in the core and north-eastern limb of a major refolded fold termed the Leault Antiform (Figure 5.5). They preserve a variety of tectonic fabrics and metamorphic textures. Despite this complex deformation, sedimentary structures are recognizable within the basal Grampian Group rocks.

The area was mapped and described briefly during the primary geological survey of the Highlands (Hinxman and Anderson, 1915), but the first detailed description of the area was provided by Piasecki (1980). A useful map and brief descriptions of the outcrops are also included in an excursion guide (Piasecki and Temperley, 1988b). Recent mapping at the 1:10 000 scale by the present author is included in the BGS 1:50 000 Sheet 74W (Tomatin, 2004).

2.2 Description

2.2.1 Lithostratigraphy

The three main lithostratigraphical units distinguished in the An Suidhe area are, in upward succession, the Glen Banchor Subgroup of the Badenoch Group, the Kincraig Formation and the Loch Laggan Psammite Formation (Smith *et al.*, 1999) (Figure 5.6). The Kincraig Formation was previously assigned to the Ord Ban Subgroup by Winchester and Glover (1988), but this and the Loch Laggan Formation now represent the oldest strata assigned to the Corrieyairack Subgroup of the Grampian Group in the Speyside district.

The Glen Banchor Subgroup, equivalent to the basement rocks of Piasecki (1980), forms a series of low exposures south-west of Kincraig House and in the birch woods around the Leault Burn (Figure 5.5). It comprises variably gneissose to locally migmatitic and schistose semipelite, psammite with subordinate siliceous psammite, quartzite (the Blargie Quartzite Member of the Craig Liath Psammite Formation) and pelite with lenses of pale-brown to cream coloured calcsilicate rock.

The structurally lowest unit, lying within the core of the Leault Antiform (Figure 5.5), is a segregated dark schistose semipelite to pelite with thin ribs of quartzite and calcsilicate rock grading outwards into striped garnet-muscovite-kyanite-fibrolite-bearing semipelite and psammite. Where these rocks are strongly sheared, lenticular ribbons of silvery muscovite, quartz-feldspar augen and plates and veins of quartz are common, particularly towards the contact with the overlying siliceous psammite and quartzite. This overlying Blargie Quartzite Member, is a distinctive white to pale-brown well-jointed feldspathic and migmatitic quartzite with abundant microcline; it is interlayered with banded gneissose psammite and rare thin lenses of semipelite. Generally 15–25 m thick, it can be traced throughout the area as a series of ice-scoured ‘crag-and-tail’ exposures and it forms a low cliff along the northern bank of the Leault Burn at [NH 8194 0602]. Abundant minor folds, some intrafolial, in the quartzite are picked out by concordant bands of leucosome and provide evidence for the earliest phase of deformation in these rocks. Strongly flattened and segregated micaceous psammites within the Blargie Quartzite Member have been worked locally as walling stone (e.g. at [NH 8200 0604]). The overlying and structurally uppermost strata of the basement rocks comprise a striped sequence of medium-grained biotite- and K-feldspar-bearing psammite and semipelite interlayered in varying proportions.

Immediately north of Badden Cottage [NH 8251 0616], a thin unit of phyllonitic semipelite is developed along the contact between semipelite and psammite; it hosts a thin sheet (0.5 m) of foliated pegmatitic granite with rotated and recrystallized augen of quartz, feldspar and prophyroblasts of garnet and muscovite. These pegmatitic granites, hosted by sheared striped psammite and semipelite, are interpreted to have formed by strain-induced syn-tectonic recrystallization within the Grampian Shear-zone (Hyslop and Piasecki, 1999).

The overlying Kincraig Formation forms the lowest strata assigned to the Grampian Group in the area and comprises in upward succession, calcsilicate rock, quartzite, metalimestone and schistose calcareous semipelite (Figure 5.6). A 30–50 m-thick sill of massive to banded garnetiferous amphibolite obscures the base of the formation everywhere and intrudes the underlying rocks locally. However, evidence for the deposition of the Kincraig Formation onto gneissose psammite can be seen elsewhere in Speyside; in a fault-bounded block at Ord Ban [NH 895 085], on A’ Bhunanaich [NH 787 090] and at [NH 759 291], 2.5 km south of Glenkyllachy Lodge. Banding, 5–15 mm thick, in the amphibolite is defined by variations in the amount of amphibole, plagioclase and clinozoisite. The remainder of the formation, up to 50 m in thickness, is well exposed in the lower crags north-west of Kincraig House (e.g. between [NH 8221 0624] and [NH 8210 0641]) and a near-complete section through the upper contact is exposed above the metalimestone quarries around [NH 8209 0641]. At least two beds of coarsely crystalline brown-weathering metalimestone are present. They appear as a series of laterally discontinuous pods and megaboudins, 2–3 m thick and up to 40 m in length, wrapped by the main foliation; they have been quarried as a source of lime (Figure 5.7).

The Loch Laggan Psammite Formation is well exposed on the south-facing flanks and along the north-trending summit ridge of An Suidhe. The basal facies, approximately 20–30 m thick, comprises medium- to locally coarse-grained, schistose to weakly gneissose semipelite with thin ribs (2–7 cm thick) of micaceous and quartzose psammite in a regular alternating sequence. These striped beds (‘rhythmites’ of Piasecki, 1980) are intruded by a swarm of late- to post-tectonic veins of granite and related quartzofeldspathic pegmatite. Upslope, they pass gradationally into thicker bedded biotite-, quartz- and plagioclase-bearing psammite with thin beds and partings of semipelite bearing pods of calcsilicate rock. A repetitive bed-scale variation in grain size and mica content defines original grading cycles. Combined with evidence for lateral bed amalgamation and channelling, these data indicate that the section is right way up and consistently youngs

away from the underlying Glen Banchor Subgroup.

2.2.2 Structure and metamorphism

The An Suidhe GCR site lies within the southern part of a large structural window. The oldest rocks (the Glen Banchor Subgroup) are exposed in the core of this window and contain evidence of an early phase of deformation (D1) associated with amphibolite-facies metamorphic conditions (M1). An early gneissosity (S1), formed by solid-state recrystallization and probably mimetic on the original compositional layering, is defined in semipelite and psammite by coarse-grained mica foliae (melanosomes), which enclose lenticular quartzofeldspathic segregations (leucosomes). The original compositional banding (S0) might be represented within rare intrafolial minor folds but in general, recrystallization and deformation has destroyed the primary fabric.

The overlying Grampian Group strata display evidence for three episodes of deformation (D2, D3 and D4), which also occurred under amphibolite-facies conditions (M2). Bedding (S0), defined by variations in quartz and mica content, is overprinted by the main penetrative schistosity (S2), which in turn forms the second fabric in the Glen Banchor Subgroup rocks. S2, identified by shape-aligned biotite, quartz and plagioclase, varies from parallel to S0 to oblique (locally up to 15°) and is axial planar to a series of gently inclined SW-verging tight minor folds in the Loch Laggan Psammite Formation. On the northern limb of the Leault Anticline, S2 is parallel to or steeper than S0, whereas on the southern limb S2 is consistently shallower than S0 indicating local overturning. S3 is a steeply inclined to asymmetrical SW-verging crenulation cleavage that affects all the strata and is related to the formation of a broad NW-trending antiformal dome structure and sideways-facing minor folds, verging consistently to the south-west. The youngest deformation visible in the area (D4) is expressed as a series of weak open upright antiforms and synforms and associated crenulation fabric that trends north–south and refolds all the earlier structures.

The presence of the Grampian Shear-zone is indicated by a series of narrow zones (a few tens of metres wide) of distributed ductile shear that anastomose throughout the upper parts of the Glen Banchor Subgroup. These zones have gradational boundaries with the enclosing lithologies and are identified by a marked grain-size reduction. The S1gneissosity is reworked into a fine-grained mylonitic and phyllonitic foliation that wraps around subelliptical augen and porphyroblasts of plagioclase and muscovite. A suite of distinctive foliated pegmatitic granite veins (up to 0.5 m thick) are developed impersistently within the zones of most-intense strain.

2.3 Interpretation

Piasecki (1980) originally proposed that the Glen Banchor Subgroup rocks had experienced amphibolite-facies metamorphism and three separate episodes of deformation prior to the deposition of the Grampian Group. He argued that the unconformity subsequently became the focus for ductile shear strain whose effects appear to have decreased with increasing distance from the contact. Both the cover and basement rocks were then deformed by a further three episodes of deformation associated with medium- to low-grade amphibolite- to greenschist-facies metamorphism. This complex history has not been substantiated by subsequent dating studies and the recent survey by the British Geological Survey.

The evidence for an orogenic unconformity can be described in terms of two lines of evidence, stratigraphical omission and tectonometamorphic history. At An Suidhe, the absence of any recognizable strata of the basal Grampian Group (Glenshirra Subgroup), combined with the shallow marine environments represented by the Kincraig Formation, imply a major stratigraphical hiatus, with the development of a shallow marine shelf upon basement. The evidence for an extra phase of deformation (the S1 gneissosity) in the Glen Banchor Subgroup, which is absent from the overlying Grampian Group strata, indicates a structural/metamorphic break and is further supported by two independent radiometric studies.

Firstly, statistical analysis of major- and trace-element data effectively discriminates the An Suidhe metalimestone pods from Appin Group equivalents and establishes their distinctive nature within the Dalradian Supergroup (Thomas and Aitchison, 1998). However, $^{87}Sr/^{86}Sr$ isotopic ratios of the carbonate in these metalimestones, which are thought to largely reflect those of the coeval seawater, are consistent with those of younger Appin Group and Islay Subgroup metacarbonate rocks. $^{87}Sr/^{86}Sr$ in seawater is known to have changed with time and a comparison with published data

for limestones of Neoproterozoic age from elsewhere in the world constrains the depositional age of the An Suidhe metalimestones to be less than *c.* 800 Ma. Hence, on this evidence, the base of the Grampian Group in this area is younger than 800 Ma and possible significantly less (Thomas *et al*., 2004). Thus the Kincraig Formation was deposited after the Glen Banchor Subgroup rocks were affected by Knoydartian tectonothermal events.

Secondly, elsewhere in the Kincraig area, foliated pegmatitic granite veins and their phyllitic host rock within the Grampian Shear-zone have yielded Rb-Sr muscovite ages in the range 718 ±19 Ma to 573 ± 13 Ma (Piasecki, 1980) and U-Pb ages on monazite of 808 ± 11 Ma (Noble *et al.,* 1996). Reworking of both the earlier mylonitic and gneissose fabrics and the granitic veins by F2folds (e.g. at [NH 8175 0567]) indicates that the Glen Banchor Subgroup was affected by a ductile tectonothermal event prior to D2, which is the first phase of deformation recorded by the overlying Grampian Group. The relative age of the mylonitic fabric in the Grampian Shear-zone and hence the ages of monazite from the sheared pegmatite, and whether these formed syntectonically in the host rock to the S2 fabric of the Grampian Group, remains to be clarified. Unpublished studies (BGS, 2000) indicate that monazites in basement strata are complex, yielding both Precambrian and Palaeozoic ages, whereas those in the cover only record Palaeozoic events.

Cumulatively, these lines of evidence support the hypothesis of an orogenic unconformity with Precambrian tectonothermal events restricted to the basement.

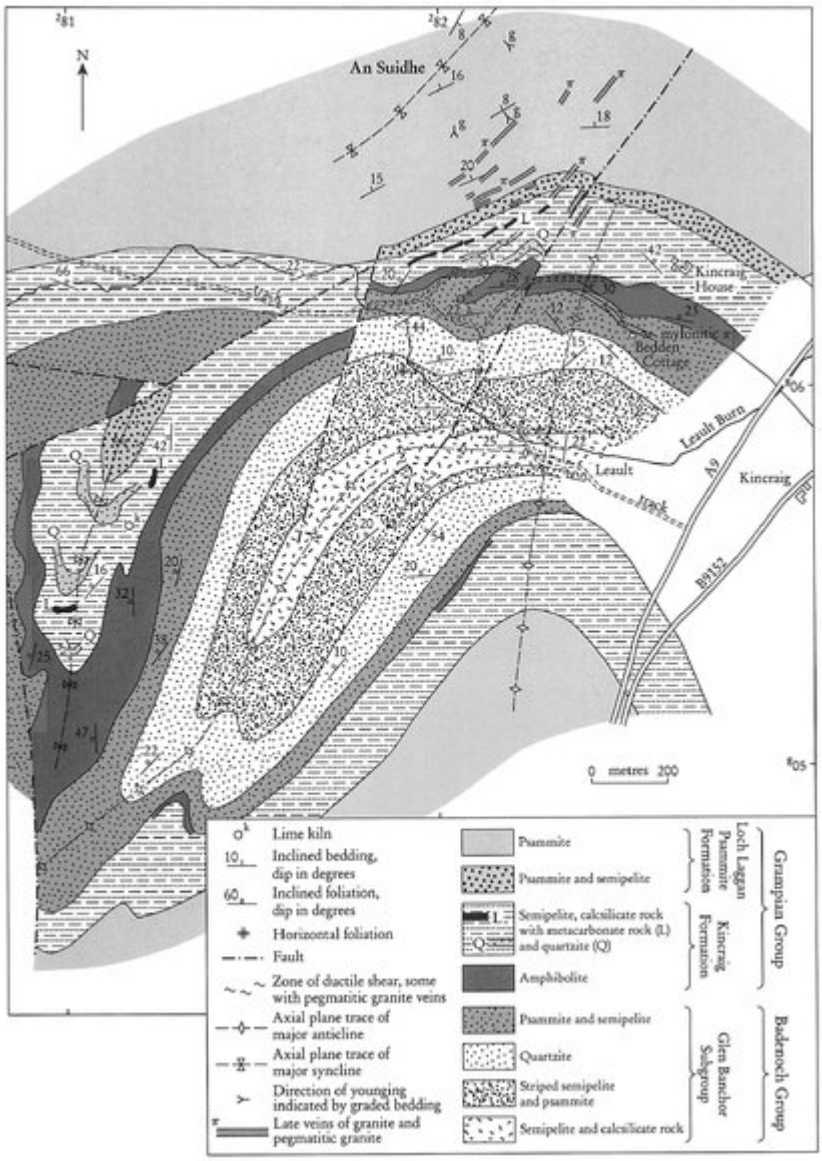
2.4 Conclusions

The An Suidhe, Kincraig GCR site is a key section in the Northern Grampian Highlands, where the relationships between pre-Dalradian basement rocks (now termed the Glen Banchor Subgroup of the Badenoch Group) and their cover (now assigned to the Corrieyairack Subgroup of the Grampian Group) were first documented. The contact between the two successions is obscured by a basic intrusion and the relationships were controversial for many years. However, recent detailed work on the lithostratigraphy, structure, metamorphism, isotope geochemistry and age dating suggests that the original cover-basement interpretation was correct and that the contact represents not just a stratigraphical and/or structural hiatus, but a major orogenic unconformity of national, if not international importance.

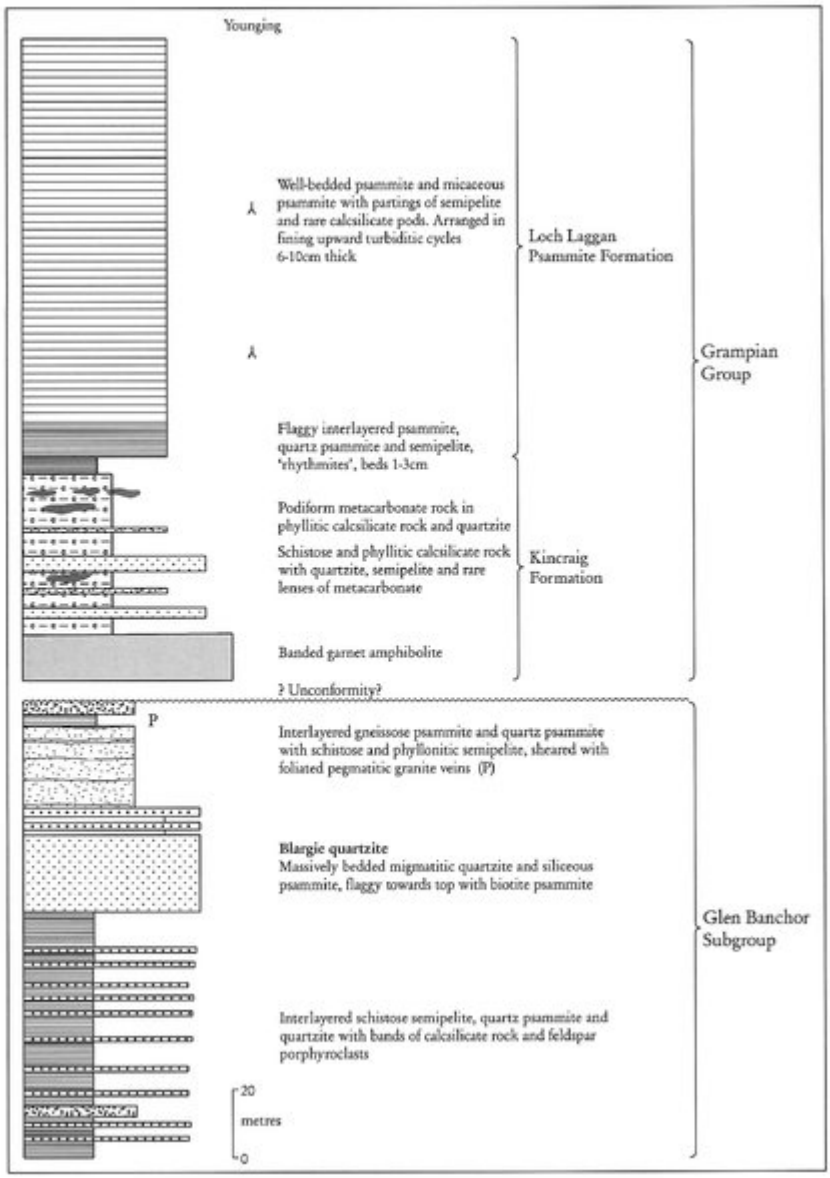
Amphibolite-grade metasedimentary rocks of the ‘basement’ Glen Banchor Subgroup are variably gneissose and locally migmatitic. They preserve at least one phase of deformation that is not seen in the cover rocks and are cut by a major shear-zone that contains syntectonic pegmatitic granites, forming part of a suite whose U-Pb radiometric ages record an 800–750 Ma Precambrian (Knoydartian) tectonothermal event.

The basal part of the Grampian Group records the encroachment over the basement of a distinctive shallow marine sequence with metalimestones, and sedimentary way-up evidence confirms that the succession youngs away from the basement. $^{87}Sr/^{86}Sr$ isotopic ratios in the metalimestones are consistent with post *c.* 800 Ma seawater and hence support the field evidence that deposition of the Grampian Group entirely post-dated the Knoydartian Event.

References



(Figure 5.5) Map of the area around the An Suidhe, Kincraig GCR site (after BGS 1:10 000 Sheet NH80NW, 1998)



(Figure 5.6) Generalized vertical section of strata at the An Suidhe, Kincraig GCR site.

(Figure 5.7) Interbanded metacarbonate rock and phyllitic calcareous semipelite overlain by semipelite of the Kincraig Formation, Leault Limestone Quarry [NH 8210 0638], An Suidhe, Kincraig GCR site. Hammer shaft is 35 cm long. (Photo: BGS No. P220941, reproduced with the permission of the Director, British Geological Survey, © NERC.)