NORTH GLEN SANNOX

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Introduction

The North Glen Sannox site presents an excellent section through the lava and black shale sequences of the Highland Border Complex (HBC) in north Arran. It illustrates one of the best and most varied developments of basic volcanic rocks within the complex. Downward-facing structures provide critical evidence for the study of the structural setting of the complex and its relationship to the Dalradian succession. The geology of the site is summarized in Figure 2.22.

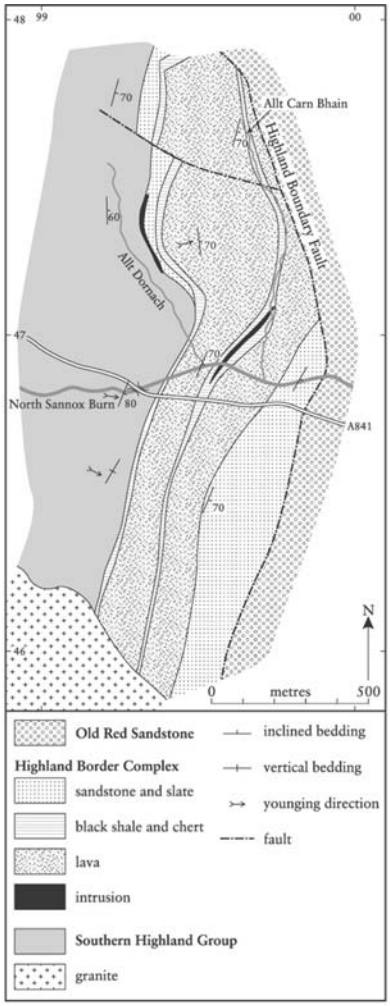

Figure 2.22: Map of the North Glen Sannox GCR site, in part after Johnson and Harris (1967) and Anderson and Pringle (1944).

Within this site the HBC outcrop forms a N–S strip that is about 2.5 km long, varies in width from 200 to 400 m and is broadly parallel to the regional strike. It is bound to the west by the turbiditic sandstones of the Dalradian Southern Highland Group and to the east by the Highland Boundary Fault and the Lower Old Red Sandstone succession (Figure 2.22). The strip is cut off to the south by the Palaeogene Northern Granite and to the north by the Highland Boundary Fault, which gradually transgresses northwards across the strike. The complex is composed predominantly of lavas with subordinate black schists, cherts and sandstones. Biostratigraphical control is poor but indicates an Arenig age.

The complex was first mapped by the Geological Survey around the beginning of the 20th

century and was reported on in resultant memoirs by Gunn *et al*. (1903) and Tyrrell (1928). The area has been the subject of considerable subsequent study, notably by Anderson and Pringle (1944), Johnson and Harris (1967) and Henderson and Robertson (1982), most of whom were largely concerned with the structural setting of the HBC rocks and their relationship to the Dalradian succession.

Description

Excellent sections are provided through the Highland Border Complex outcrop by the North Sannox Burn (Figure 2.23) and by scattered exposures on the adjacent hillsides. In the burn, turbidites of the Southern Highland Group are exposed above the road-bridge and for about 130 m downstream to their contact with the HBC rocks. In the upstream part of this section massive pebbly sandstones predominate with quartz and feldspar clasts, but flaggy sandstones, siltstones and slates become more common downstream (towards the east). The bedding strikes *c.* NNE and is generally vertical or steeply dipping towards the east. Good evidence from graded beds indicates a consistent sense of younging, also to the east, in which direction the Dalradian strata are succeeded by the HBC assemblage. This may be divided into five units that comprise, from west to east:

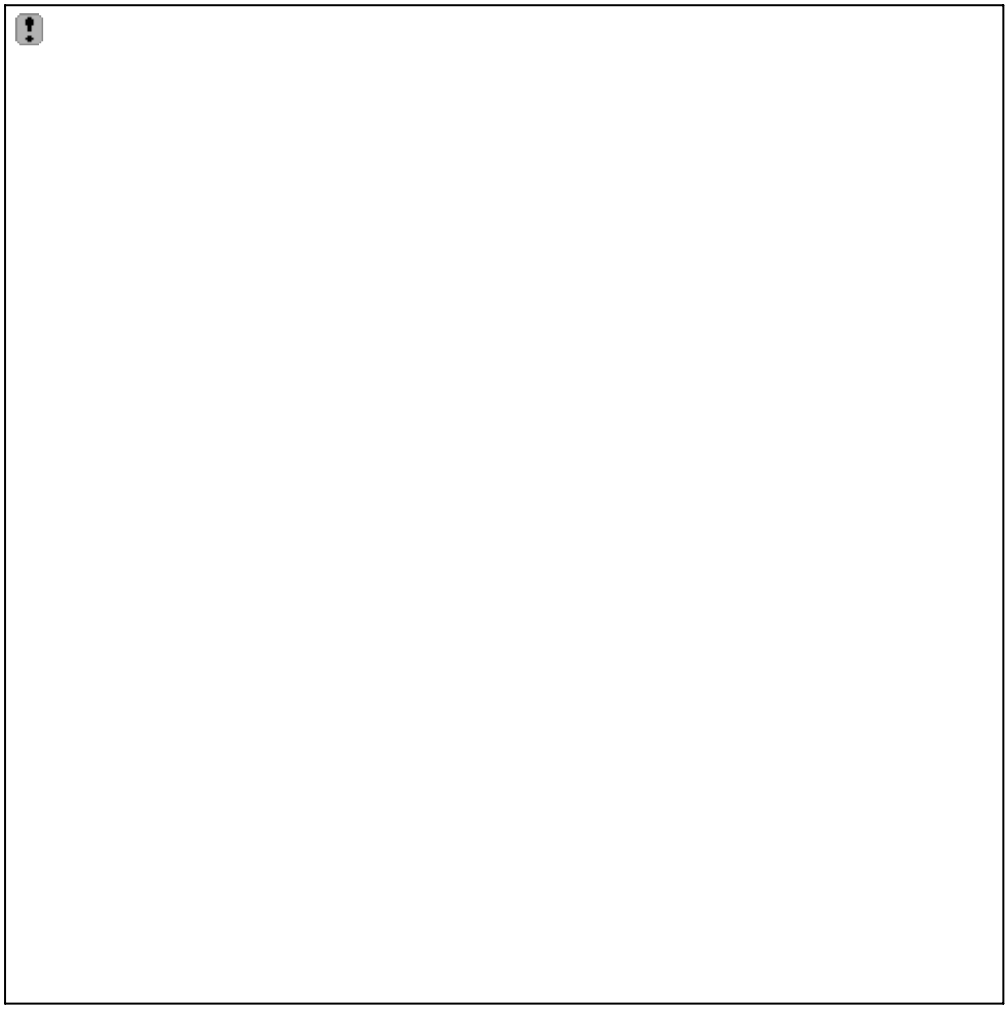

Figure 2.23: North Sannox Burn below the road bridge, a section through the lower part of the Highland Border Complex. (Photo: Nature Conservancy Council.)

1. black shales and cherts,

2. lower lava sequence,

3. black shales and cherts,

4. upper lava sequence,

5. green slates and sandstones.

Gunn *et al*. (1903) originally ascribed an Arenig age to these rocks on the basis of their similarity to the rocks at Ballantrae. Subsequently Anderson and Pringle (1944) reported a find of some poorly preserved brachipods from the central black shale unit. The shells were referred to *Acrotreta* and compared with *A. nicholsoni* described from Aberfoyle by Jehu and Campbell (1917). Curry *et al*. (1984), although unable to trace the original specimens, accepted the age albeit with some caution.

The contact between the Dalradian and HBC rocks is exposed on the south bank of the burn but is only readily examined when water levels are low. Anderson and Pringle (1944) placed the contact at the junction between fine-grained sandstones and black shales. They reported that there is no evidence of interbedding and, although the shales are disrupted, there is no sign of significant faulting; the disruption being ascribed to ‘slight movement' at the contact during the regional folding. Eastwards of the contact the black shales continue for a few metres followed by a heavily brecciated and carbonated lava which may represent an altered autobrecciated flow. This is succeeded by a further 2–3 m of black shale with chert bands.

Above the black shales lies the lower lava unit, which is here over 100 m thick and forms the first major development of volcanic rocks in the section. The lavas are greenish-grey, spilitic, commonly pillowed and locally contain zones of autobrecciation; the latter were described by Henderson and Robertson (1982) as ‘clast-supported lava rudites, composed of angular to subrounded clasts 0.05 to 0.25 m in diameter'. The pillows have chilled margins and concentric amygdaloidal zones. Johnson and Harris (1967) described almost undeformed pillows from Torr na Lair Brice with flat bottomed bun-shapes, pear-shapes and wedge-shapes all indicating younging to the east. Henderson and Robertson (1982) drew attention to the absence of intercalated sedimentary units in contrast to the basic volcanic rocks in the HBC in the North Esk and at Stonehaven.

The succeeding black shale unit is about 40 m thick and contains numerous chert beds and some beds of coarse-grained sandstone which may in part be volcaniclastic. It was from this unit, where it crops out in the Allt Carn Bhain (Figure 2.22), that Anderson and Pringle (1944) recovered the brachiopods.

The upper lava unit is up to 170 m thick and broadly similar to the lower unit although pillow structures are less well developed. Locally the rock is strongly cleaved and particularly towards its top the unit becomes so ‘schistose' that Gunn *et al*. (1903) compared its appearance to that of the Green Beds in the Southern Highland Group of the SW Highlands.

Above the lavas and forming the easternmost unit of the complex is a sandstone and slate unit broadly similar to the Southern Highland Group turbidites. In the west the unit is dominated by green slates and phyllites and the sequence becomes more sandstone rich towards the Highland Boundary Fault. Graded beds indicate an easterly sense of younging. Although Gunn *et al*. (1903) described apparent interbedding between slates and lavas at the westerly contact of the unit, this interpretation was strongly challenged by Anderson and Pringle (1944) who argued against a transitional contact in favour of a high-angle fault.

Gunn *et al*. (1903) reported intrusive basic rocks at two localities. The first lies at the base of the HBC succession *c.* 450 m north of the burn, the second crops out in the Allt Carn Bhain. Anderson and Pringle (1944) subsequently identified a third occurrence of a 2.5 m band within the central black shale unit, exposed on the south bank of the burn. They suggested that this outcrop may be an along-strike correlative of Gunn *et al*.'s (1903) second locality. The intrusive rocks appear to be altered hornblende gabbros which, although still retaining ophitic textures, now exhibit carbonated assemblages of uralitized amphibole and albitized plagioclase.

The petrology of the lavas and the associated intrusions has been studied by Ikin (1983) and Robertson and Henderson (1984). The lavas still display igneous textures although the mineralogy has been almost wholly altered with the original olivine-pyroxene-calcic plagioclase associations now represented by albite-actinolite-chlorite-epidote assemblages. The chemistry

of the rocks has been significantly affected by spilitization with strong Na-enrichment, Ca-depletion and substantial movement of many mobile elements. A study of the immobile elements, however, allowed Ikin (1983) to classify the lavas. He recognized two groups: the first covers the greater part of the lower lava sequence and has affinites to alkali basalts characteristic of within plate settings; the second, which covers the uppermost part of the lower lava unit, the whole of the upper sequence and includes the intrusions, has tholeiitic affinities and mid-ocean-ridge basalt (MORB) characteristics. Robertson and Henderson (1984) noted that the MORB chemistry is characteristic of the basic volcanic rocks developed within the HBC along the Highland edge, whereas lavas with alkali basalt chemistry are only known from Arran and Aberfoyle.

The bedding in the Dalradian and HBC rocks is congruent and dips steeply to the east with a constant sense of easterly younging. In the Dalradian succession a penetrative cleavage (S1) strikes broadly parallel to bedding and dips to the east at moderate angles to give a downward sense of facing. Johnson and Harris (1967) reported that D1 folds are rare. They recorded D2 structures evidenced by the presence of fine crenulations in the slate bands; the crenulations plunging at moderately steep angles to the SSW. Within the HBCJohnson and Harris (1967) recorded a similar structural sequence to that in the Dalradian rocks with a penetrative downward-facing S1, tight or sub-isoclinal D1 minor folds and rare D2 crenulations.

Ikin (1983) noted the presence of two high-strain zones of ‘mylonitized' lavas and associated breccias, approximately at the base of the two lava units. Henderson and Robertson (1982) also described the presence of high strain zones marked, in part, by mylonitized spilites; they noted that the high-strain fabrics post-date asymmetric folds at a locality to the north of the current site, but that the fabrics themselves are corrugated by minor folds.

Interpretation

Gunn *et al*. (1903) regarded the Highland Border Complex as an integral part of the ‘metamorphic series of the Highlands', remarkable only for its unusual lithologies. This view was largely supported and expanded by Anderson and Pringle (1944) and Anderson (1947) who argued that the Dalradian and HBC rocks had been subjected to the same history of deformation and low-grade metamorphism. They regarded the junction between the Dalradian and HBC rocks as a modified ‘disconformity or slight unconformity' and the eastern sandstone unit as a down-faulted block of Dalradian rock. They concluded that the Dalradian succession is of pre-Arenig age and that the folding and metamorphism was post-Arenig. They further argued that the lavas had been extruded on to a subsiding surface of Dalradian rocks and are broadly comparable with the ophiolitic sequences of the Alps and elsewhere.

Johnson and Harris (1967), influenced by the strong structural congruity between the Dalradian and HBC successions, concluded that ‘such would appear to be conclusive proof that the ?Arenig has been involved in the same sequence of movements as the adjacent Dalradian'. However, Ikin (1983) and Henderson and Robertson (1982), impressed by the presence of high-strain zones within the HBC succession, argued for tectonic emplacement of the complex. The latter authors further argued for ‘the HBC outcrop in Arran as a thrust-stack with zones of recrystallized Dalradian and schistose rock at the sole of each thrust sheet'. They stated that, ‘because cleavages cannot be traced continuously from the HBC into the Dalradian, we cannot correlate the cleavages in the two units'. They noted the presence of downward-facing structures in the HBC rocks and argued that the thrusting occurred before the Dalradian D3 event, probably during D2. Robertson and Henderson (1984) were less categorical about the type of emplacement suggesting a general strike-slip regime. They regarded the eastern arenite-dominated sequence as part of the HBC succession rather than as a faulted block of Dalradian rocks (Robertson and Henderson, 1984, table 1). A current view of the regional development of the Highland Border Complex (for example, Robertson and Henderson, 1984; Curry *et al*., 1984) envisages the formation of the HBC in an oceanic basin marginal to a continental mass and subsequent tectonic juxtaposition with the Dalradian. Tanner (1995) however, in a discussion of the status of the HBC, emphasized the congruity of the younging evidence and minor structures between the Dalradian and HBC successions and concluded that the greater part of the HBC (at least including the Arenig rocks) was deposited in sequence with the Dalradian rocks.

On a regional scale the available biostratigraphical and radiometric age evidence for the formation of the HBC and the tectonism in the Dalradian rocks implies that the juxtaposition of the two successions could only have taken place after the initial Dalradian deformation events. It is these factors that are in conflict with the apparent congruity of the structural sequences in the Arran section. This dilemma has driven much of the recent research in the area and gives an added regional significance to the site.

Conclusions

The North Glen Sannox GCR site contains an excellent section through one of the major developments of basic volcanic rocks in the Highland Border Complex. It is of great importance in assessing the role of this enigmatic assemblage in terms of Caledonian orogenesis and terrane assembly. The lavas exhibit good pillow structures indicating eruption under water. Associated black shale and chert sequences have yielded fossils which suggest an Arenig age. These assemblages are characteristic of rocks generated on the ocean floor. Although early workers did not recognize a significant unconformity between the HBC and the adjacent Dalradian rocks, the subsequent recognition of highly sheared (mylonitic) zones within and at (or near the base of) the HBC, suggests that it was tectonically juxtaposed with the Dalradian early in the deformational history of the two assemblages. This may, however, be difficult to reconcile with regional evidence on the relative ages of the Dalradian and HBC deposition and deformation.

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