5 Bealach nam Bo

[NN 479 065]–[NN 485 079]

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5.1 Introduction

Bealach nam Bo (Gaelic: ‘Pass of the cattle’) is a narrow pass formed by a glacial overflow channel on the northern flanks of Ben Venue, immediately west of the southern end of Loch Katrine in the Trossachs (Figure 4.14). It lies at the centre of this GCR site, which comprises about 4 km^2 of ground underlain by volcaniclastic metasandstones, ubiquitously referred to as ‘green beds’, and quartz-rich, gritty and commonly pebbly metasandstones, assigned to lithostratigraphical units within the lower part of the Southern Highland Group. The green beds are distinctive and have been treated as lithostratigraphical markers. The numerous exposures around Bealach nam Bo illustrate the wide range in styles, varying according to lithology, of the commonly spectacular structures associated with the second phase of deformation and the nature of the interaction between the first and second phases.

The area around Bealach nam Bo was mapped in the latter part of the nineteenth century by officers of the Geological Survey, but the manuscript for the accompanying memoir was never published and has only recently been made available (Cunningham Craig, 2000). Subsequently, the ground immediately south of the pass was included in R.M. Shackleton’s work on the structure of the Dalradian rocks adjacent to the Highland Border (Shackleton, 1958). He showed that the metasedimentary rocks are inverted, young towards the south and dip steeply northwards. He also noted a conspicuous ‘later fracture-cleavage or slip-cleavage’, now known to result from the main phase deformation, described below. The area was resurveyed by the British Geological Survey between 1996 and 1998 as part of the general mapping programme and lies within the BGS 1:50 000 Sheet 38E (Aberfoyle, 2004).

5.2 Description

The metasedimentary rocks within the GCR site area include green beds and associated metasandstones in the north, structurally overlying commonly gritty or pebbly, quartz-rich metasandstones in the south. Finer grained metamudstones and metasiltstones are generally rare. Although bedding generally ranges up to 1 m in thickness, some massive and coarse-grained beds are in excess of 2 m thick. Graded bedding is commonly developed and shows that the steep northerly dipping succession is generally inverted. Determination of way-up of the succession in this and adjacent areas has been critical in understanding the structural history of the rocks within the site, and in the region in general.

Following the BGS resurvey, the green beds and associated rocks have been assigned to the Loch Katrine Volcaniclastic Formation (Figure 4.14). The green beds are chlorite- and epidote-rich metasandstones, locally with abundant magnetite. The background sediment with which the abundant mafic minerals were mixed is fine to coarse grained, quartz rich and commonly gritty. The chlorite and epidote impart an olive to dark bottle-green colour to fresh surfaces, but the green beds weather to a characteristic sandy brown colour, often with a sandpaper-like surface texture where finer grained. The weathered rind extends up to a centimetre or so into the surface. Careous weathering is also a feature in places, yielding a surface honeycombed by rounded pits up to about 15 cm across and 3 cm deep. Although the green beds display little visible lithological variation in individual exposures, small lenses of quartz-rich, gritty metasandstone are quite commonly developed, often serving to highlight bedding.

The metasandstones associated with the green beds are chiefly coarse-grained, gritty quartz- and feldspar-rich metasandstones with only small amounts of chlorite and epidote. Although there is, in effect, a continuum in composition between these and the green beds, individual green beds are commonly sharply enough defined to be mapped out as

separate units within the Loch Katrine Volcaniclastic Formation.

Typical green-bed lithologies are very well exposed in cliffs at Bealach nam Bo and on ground to the south-west and north-east. In these outcrops, they are massive, thickly to very thickly bedded units of coarse metasandstone, as detailed in the sedimentary log in (Figure 4.15). A notable feature of some beds is the presence of ellipsoidal, nodular structures concentrated in bedding-parallel trains. They are up to about 10 cm long in the longest dimension and usually have weathered-out cores.

The metasandstones that lie lithostratigraphically above, but structurally underneath, the Loch Katrine Volcaniclastic Formation are assigned to the Creag Innich Sandstone Formation (see also the *Duke's Pass* GCR site report). These are predominantly clean, quartz-rich, coarse metasandstones with minor intercalations of metasiltstone and more-micaceous metasandstone. In places, spectacular pebbly lithologies form microconglomeratic units that can exceed 2 m in thickness; good examples of such rocks are to be found on the higher ground *c*. 600 m south-west of Bealach nam Bo (around [NN 478 069]). The pebbly rocks are notable for their well-rounded pebbles, their compositional maturity (chiefly quartz-vein material) and their high degree of sorting.

The structures developed in the metasandstones within and around the GCR site are complex, but allow the relationships between the regional first (D1) and second (D2) phases of deformation to be discerned. Although the D2 phase affected the whole region, it is the lithologies and the architecture of the structures formed during D1 that control the ways in which D2 structures are manifest at both local and outcrop scale.

The very thick and massive green-bed lithologies, such as those exposed in the cliffs at Bealach nam Bo [NN 480 070], commonly appear to be only weakly deformed and cleavages are poorly developed. In the exposures of metasandstones to the west and north of the pass, metre- to decimetre-scale, south-verging folds are common. In general, the hinge-zones of these folds host only a single, moderate, penetrative, axial planar cleavage, good examples of which are seen in exposures around [NN 478 075] (Figure 4.16). Even though this cleavage might have been modified by subsequent D2 deformation, it is considered to result principally from D1 deformation. This style of cleavage is very different to the coarsely spaced, anastomosing S1 cleavage characteristic of metasandstones that crop out to the south of the GCR site, towards the Highland Boundary Fault.

Bedding dips consistently and steeply to the north-north-west on either side of the F1 axial traces, showing that these early folds are tight to isoclinal. The F1 folds plunge consistently to the north-east at moderate angles. Abundant younging evidence, combined with bedding/cleavage relationships, shows that the F1 folds face steeply downwards to the north-north-west throughout the area.

The second phase of deformation, D2, is characterized by a coarse crenulation of the first cleavage; S2 is approximately parallel to bedding on the long limbs of F1 folds. The D2 crenulation is particularly well developed in the ground *c*. 400 m south-west of Bealach nam Bo (around [NN 477 071]). In general, the first cleavage is folded by D2 folds on a small scale (Figure 4.17), but bedding is not affected. The small-scale F2 folds plunge to the north-east and south-west and commonly have strongly curvilinear hinges. The style of folding varies from a chevron type with planar limbs and very sharp angular hinges, to a type that has the sinusoidal form of a classical crenulation. Domains bounded by the S2 cleavage planes ('microlithons') can be planar but are more typically lenticular in shape. Discrete S2 cleavages only form locally within the hinges of chevron-style folds and are rarely intensely developed. In lenticular, crenulated domains, the cleavage that defines the lenticle margins is a composite S1–S2 fabric. This cleavage is discontinuous along its length and is variably and widely spaced.

5.3 Interpretation

The lithologies that occur within the Bealach nam Bo GCR site are typical of Southern Highland Group metasedimentary rocks in general. The green beds are interpreted as metasandstones with a mafic volcaniclastic component, the latter derived either from contemporaneous or near-contemporaneous volcanic rocks, such as those in the Tayvallich peninsula of the South-west Grampian Highlands, or from the reworking of older volcanic terrains. How the nodular structures formed is unclear at present; Cunningham Craig (2000) suggested that they might have originated as

clay-galls, although it is possible that they could have had a volcanic origin.

The cleaner metasandstones associated with the green beds and within the Creag Innich Sandstone Formation are evidence that the background sedimentation was dominated by generally coarse sand deposited by turbidity currents and mass debris flows. The pebbly component is likely to have been derived from a mature, well-sorted beach deposit within the source area and admixed during redeposition with the finer grained sediment that forms the matrix.

Although the D2 phase of deformation affected the whole area, the various styles and characteristics of the D2 folding indicate that D2 strain was variable, generally not very high and locally partitioned. The finely spaced cleavage observed in the F1 fold hinges in green beds is considered to be primarily the result of D1 deformation, even though the cleavage might have been enhanced by coplanar D2 deformation. In addition, the variations in style and distribution of D2 structures indicate that S1 cleavages in the cleaner metasandstones were already closely spaced to penetrative on the grain scale *before* the D2 small-scale folding. This closer spacing contrasts with the wide, anastomosing S1 cleavage observed in coarse metasandstones to the south-east at the *Duke's Pass* GCR site. This suggests that D1 deformation was generally more intense at this structural level within the Tay Nappe than at higher structural levels to the south-east. Alternatively, the closer spacing of the S1 cleavage could be due to *early* D2 deformation modifying the spacing by flattening, prior to simple-shear folding of the S1 cleavages (see the *Craig a'Barns* and *Rotmell* GCR site reports). As discussed elsewhere in this special issue,there are strongly contrasting views on the significance of D2 deformation in the Highland Border region (Harris *et al.*, 1976; Harris and Bradbury, 1977; Roberts, 1977a; Mendum and Fettes, 1985; Krabbendam and Leslie, 1996; Krabbendam *et al.*, 1997; Mendum and Thomas, 1997). The arguments are not rehearsed again here, but it is considered that the evidence within the Bealach nam Bo site is consistent with north-westerly directed simple shear during at least the latter part of the D2 phase.

The steep north-north-west dips of bedding and the downward-facing character of the F1 folds result from overturning of the folded succession by a much later phase of deformation. This deformation is generally considered to have occurred prior to the main D4 compressive phase (see Stephenson et al., 2013a) and is responsible for the steep dips developed in this and other areas along the south-eastern margin of the Grampian Highlands (e.g. Harte *et al.*, 1985).

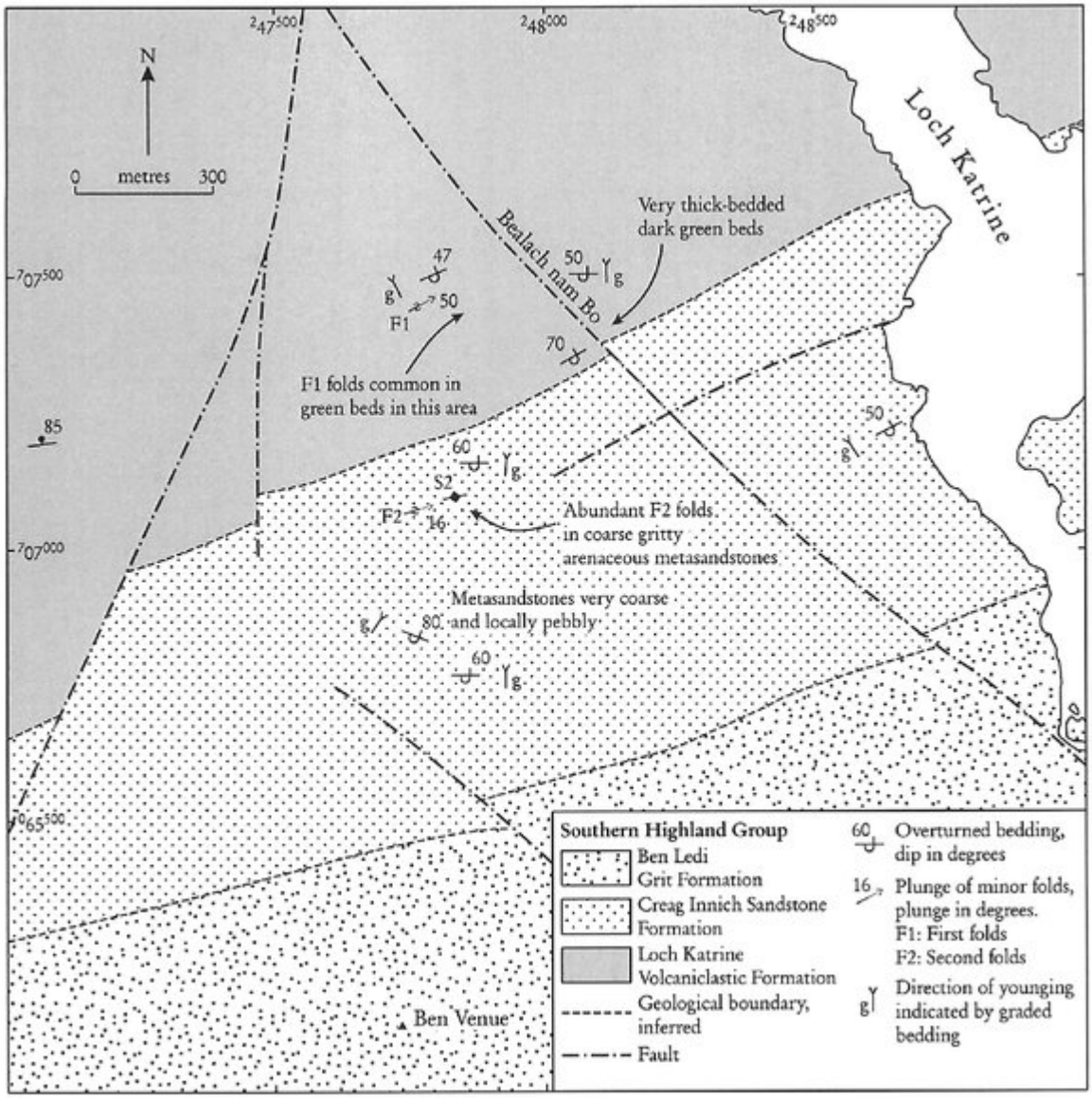
5.4 Conclusions

The Bealach nam Bo GCR site provides numerous outstanding and readily accessible exposures that reveal clearly the contrasting nature of two formations in the Southern Highland Group, both in terms of rock type and the response of these units to regional deformation events.

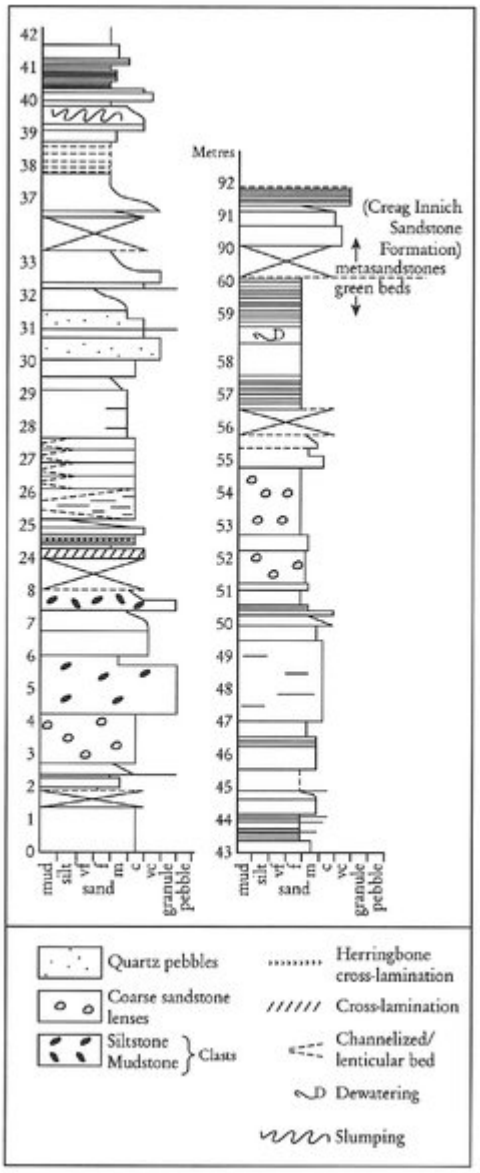
Metasandstones in the Loch Katrine Volcaniclastic Formation commonly contain volcaniclastic detritus, now manifest as chlorite, epidote and locally abundant magnetite. This detritus is sufficiently abundant in many beds within the formation to impart a strong, dark-green colour from which the 'green beds' derive their name. This detritus might have been derived from contemporary volcanic activity, although this is, as yet, unproven. The rocks within the overlying Creag Innich Sandstone Formation are dominated by clean, coarse metasandstones and locally spectacular, pebbly metaconglomerates, rich in well-rounded vein-quartz clasts.

The green beds appear to have undergone relatively simple deformation dominated by cleavage and folding resulting from the first regional phase (D1), although there might have been some modification during the second deformation phase (D2). Folds resulting from the first phase of deformation are very well exposed locally and there is ample sedimentological evidence of the way-up of beds; this allows the steeply downward- and NW-facing character of the folds to be readily demonstrated. The metasandstones of the Creag Innich Sandstone Formation are notable for the range and complexity of minor structures developed within them as a result of interaction between the D1 and D2 deformations. These observations provide important insights into the overall structural evolution of the Highland Border region.

References



(Figure 4.14) Map of the area around Bealach nam Bo, Loch Katrine, Trossachs. Based upon mapping by the British Geological Survey, 1996–1998.



(Figure 4.15) Sedimentological log through 'green beds' in the Loch Katrine Volcaniclastic Formation, exposed in cliffs at Bealch nam Bo. Adapted from Burt (2002).

(Figure 4.16) F1 folds with axial planar cleavage picked out by quartz veins in ‘green beds’ and cleaner metasandstone in the Loch Katrine Volcaniclastic Formation at Bealach nam Bo [NN 478 075]. Lens cap is 50 mm diameter. (Photo: C.W. Thomas, BGS No. P 726593.)

(Figure 4.17) F2 crenulation folds of the first cleavage in the Creag Innich Sandstone Formation at [NN 4777 0714], Bealach nam Bo GCR site. Lens cap is 50 mm diameter. (Photo: C.W. Thomas, BGS No. P 726594.)