# Bidean Nam Bian

[NN 150 546]

D.W. McGarvie

## Introduction

This GCR site is internationally important because it reveals a detailed section through the Glencoe volcano (see 'The Glencoe volcano — an introduction to the GCR sites', above). Spectacular erosion has fortuitously exposed the contact between the original land surface and the lower volcanic units, and has provided an easily accessible section through the volcanic pile preserved in the down-faulted inner block.

The site lies to the south of the River Coe and encloses the highest terrain in the area, including the mountains Bidean nam Bian (1150 m), Stob Coire Sgreamhach (1070 m) and Stob Coire nan Lochan (1115 m). It also includes parts of the 'three sisters' of Glen Coe–Aonach Dubh, Gearr Aonach, and Beinn Fhada.

## Description

(Figure 9.8)a shows the surface outcrop of groups 1 to 7, within the whole of the Glen Coe down-faulted block. A general view of the Bidean nam Bian GCR site, looking south, is given in (Figure 9.9), which shows the terrain from the River Coe up to Bidean nam Bian (part of the Loch Achtriochtan GCR site is seen to the right of the photograph). (Figure 9.10) illustrates the outcrop of groups 1 to 4 on this photograph (after Bailey, 1960). The lower slopes consist of the Leven Schist Formation (Clough *et al.,* 1909) which is overlain by the Basal Sill Complex (Group 1). This in turn is overlain by the rhyolites of Group 2, which here consist of three thick units. These are the Lower Etive Rhyolite, the Upper Etive Rhyolite, and the Upper Glen Coe Ignimbrite (Moore, 1995). The Group 3 collapse breccias and alluvium deposits crop out on the shoulder of Aonach Dubh and beyond Stob Coire nam Beith, and then the Group 4 andesites crop out towards Bidean nam Bian. These are the youngest rocks seen on (Figure 9.9) (Bailey, 1960). Outcrops of groups 1 and 2 on the west face of Aonach Dubh are shown in (Figure 9.11).

Exposures revealing the unconformable contact between the Leven Schist Formation and the overlying Basal Sill Complex show an irregular original land surface, with impersistent beds of conglomerate, sandstone, and shale above (Moore, 1995). Conglomerates are localized and appear to infill fluvial channels. In the stream draining Coire nam Beith, Clough *et al.,* (1909) recorded a *c.* 1 m-thick bed of purple sandy shale containing fragments of rock from the Leven Schist Formation.

Clough *et al.* (1909) and Bailey (1960) noted that the *c.* 17 sheets of igneous rock in Group 1 range from basalt through to andesite (the dominant lithology). The sheets exhibit flow-banding, and are largely non-vesicular. Brecciation of the upper and lower surfaces of sheets was noted by Clough *et al.* (1909), with sandy shale in the interstices (often retaining bedding). Recent investigations of these sheets (Moore, 1995) have shown that the entire sequence consists of sills with peperitic upper and lower surfaces (Figure 9.12); some sills pinch-out and bifurcate.

Clough *et al.,* (1909) commented on the uneven upper surface of the Group 1 rocks, and Moore (1995) has shown that this is a major erosional unconformity. Above this unconformity is a thin (less than 10 m thick) and irregular sequence of conglomerates and bedded sandstones infilling hollows and channels in the erosional surface.

Above the erosional unconformity are the Group 2 rhyolites, which are described in detail by Moore (1995). A thin phreatomagmatic tuff layer up to 2 m thick and consisting of planar and cross-stratified tuffs with accretionary lapilli is overlain by the Lower Etive Rhyolite, a *c.* 100 m-thick flow-laminated rhyolite with a low aspect ratio (*c.* 1:140). A stratified tuff layer represents the first phase of the eruption, but the bulk of the flow consists of flow-laminated rhyolite, accompanied by a persistent upper auto-breccia and a less well-developed lower auto-breccia. Overlying this is the

Upper Etive Rhyolite (20–30 m thick), a flow-laminated rhyolite with upper and lower autobreccias. This rhyolite also has a low aspect ratio (1:100). The third Group 2 rhyolite is the Upper Glen Coe Ignimbrite which is *c.* 80 m thick here. Roberts (1966a, 1974) called this ignimbrite the upper Group 2 ignimbrite horizon.

Group 3 rocks (collapse breccias and alluvium) overlie the Group 2 rhyolites. Clough *et al.,* (1909) described these as 'agglomerates', but with a perceptive caveat, 'it is possible, indeed, that the deposit is mainly detrital in nature, and not, strictly speaking, a volcanic agglomerate at all'. Later workers (Roberts, 1966a; Taubeneck, 1967) considered them to be breccias, a conclusion also reached by Moore (1995), who recorded various lithofacies distinguished by clast type; breccias dominated by either Group 1 or Group 2 clasts.

Group 4 rocks crop out around the summits of Stob Coire nan Lochan and Bidean nam Bian, and consist of a number of sheets (flows or sills?) of hornblende andesites approaching 280 m in total thickness (Clough *et al.,* 1909; Bailey, 1960). These rocks contain small phenocrysts of plagioclase and hornblende set within a matrix that is frequently flow-banded. Outcrops of the next group (Group 5 rhyolites) occur far to the SE on the shoulder of Beinn Fhada. According to Roberts (1966a), this is a rhyodacite ignimbrite sheet *c.* 80 m thick, which is notable for its abundance of plagioclase phenocrysts (Clough *et al.,* 1909). The sheet comprises a thin basal zone that contains abundant lithic clasts (rhyolite lava, hornblende andesite, quartzose schist — Clough *et al.,* 1909) succeeded by a welded ignimbrite within which the proportion of flattened pumice fragments increases markedly towards the top of the sheet, which is brecciated (Roberts, 1966a).

The group 6 and 7 rocks are restricted to outcrops on the southern shoulder of Beinn Fhada (Clough *et al.,* 1909). Surprisingly, no detailed account of these rocks has been published since this paper. The Group 6 rocks are well-bedded greenish-grey shales and sandstones that lie upon the eroded upper surface of the Group 5 rhyolites. Clough *et al.* (1909), and Bailey (1960) stated that there is much variation in thickness. The Group 7 rocks are andesites and rhyolites, and Clough *et al.* (1909) recorded rhyolites, hornblende andesites and one 'basic andesite' (basaltic andesite?), and made specific mention of their irregular accumulation. The oldest units crop out to the SE, while the youngest unit (a hornblende andesite containing large plagioclase phenocrysts) caps the southern summit of Beinn Fhada (Clough *et al.,* 1909). Taubeneck (1967) briefly mentioned the presence of an ignimbrite within Group 7, containing abundant 'inclusions of volcanic rocks and of quartzose basement rocks as much as an inch across'.

## Interpretation

The palaeosurface developed on rocks of the Leven Schist Formation was heavily eroded prior to the inception of Lower Old Red Sandstone volcanism, and the evidence from sedimentary rocks lying within hollows and channels suggests that there was an active, E–W-running fluvial system. The presence of sandstones and shales suggests that a small sedimentary basin developed, which acted as a trap for finer-grained sediments. The localized development of this basin, and its later (but close) association with the Basal Sill Complex, possibly signifies localized subsidence, which was a precursor to magmatism in the area. (It is relevant to note that similar features are preserved in the neighbouring Ben Nevis cauldron subsidence — see the Ben Nevis and Allt a'Mhuilinn GCR site report.)

The emplacement of the Group 1 basaltic to andesitic sills into wet sediments within the basin resulted in explosive magma-water interactions at sill margins, with peperite development (Moore, 1995). If these sills were fed from a dyke-like body (cf. Francis, 1982), the magma source would have been beneath the area. In addition, most of the sheets are andesitic, and the higher viscosities of andesitic magmas (relative to basalt) would reinforce the argument for a local source. Accordingly, they are probably indigenous to Glen Coe, whereas Clough *et al.* (1909), Bailey (1960), and Roberts (1974) believed them to be outlying members of the Lorn lavas.

The erosional unconformity above the sill complex indicates that there was a substantial period of quiescence after the Group 1 magmatism, and Moore (1995) concluded that an unknown thickness of rocks had been removed. The Group 2 rhyolites mark the onset of the graben-controlled caldera phase of Glencoe volcanism, and they are therefore syncaldera eruptive rocks. Taubeneck (1967) speculated that incremental caldera collapse was intimately associated with Group 2 eruptions — a conclusion confirmed by the detailed mapping of Moore. The first Group 2 volcanic rock, a phreatomagmatic rhyolitic tuff, indicates that this volatile-rich early magma was fragmented even further by interactions with ground, surface or hydrothermal water at the vent. The two rhyolite lavas (Lower and Upper Etive rhyolites) are not typical of rhyolite lava flows. Moore commented on features that suggest surprisingly low viscosities for such high-silica magmas, concluding that (Hawaiian) fountaining at the vent produced a 'lava-like' deposit from a pyroclastic eruption column with a very high effusion rate (possibly with an initial high volatile content lost during degassing at the vent). Hausback (1987) reported similar features from a rhyodacite flow in Mexico, where he concluded that high volatile contents plus high eruption temperatures produced a lava flow varying in thickness from 120 m to 20 m, and of unusually low-viscosity *c.* $10^5$ poise (note that $10^9$ to $10^{11}$ poise is normal for rhyodacite magma). Clearly, further work is needed on the eruptive mechanisms of the Etive rhyolites. The pyroclastic origin of the third prominent rhyolite unit — the Upper Glen Coe Ignimbrite — was previously noted by Roberts (1966a, 1974) and Taubeneck (1967).

Graben-controlled caldera collapse was associated with all of the Group 2 rhyolite eruptions, and the presence of sedimentary rocks in eroded upper surfaces of each eruptive unit indicates two important features: that caldera collapse cancelled out any constructional features created by the Group 2 eruptions; and that periods of quiescence between eruptive episodes allowed re-establishment of fluvial systems (Taubeneck, 1967; Moore, 1995; Moore and Kokelaar, 1997, 1998).

The Group 3 clastic deposits record a major phase of fault-scarp collapse and re-establishment of fluvial/lacustrine conditions (Taubeneck, 1967; Roberts, 1974; Moore, 1995; Moore and Kokelaar, 1997, 1998). The origins of the Group 4 andesites overlying the Group 3 rocks are unknown, but their aggregate thickness (*c.* 280 m) indicates a major phase of andesitic magmatism after the two major cycles of syncaldera rhyolitic volcanism (Group 2). These andesites are probably indigenous to Glen Coe, and consequently they record a significant change in the underlying magma system, with less evolved compositions predominating and available for eruption; they could represent the 'dominant volume' magma of Smith (1979). These Group 4 andesites suggest that there was insufficient repose time for the magma system to produce new quantities of silicic magma. The Group 5 crystal-rich rhyodacite ignimbrite marks a return to the explosive eruption of evolved magma. The crystal-rich nature of the rhyodacite is unusual, as the Group 2 rhyolites are markedly crystal-poor. The presence of dark inclusions of more basic magma suggests a role for magma mixing, possibly as a trigger for the rhyodacite eruption. A thorough geochemical study of the rhyolites and andesites from groups 2 to 5 would clarify possible genetic relationships.

Little is known of the rocks of groups 6 and 7,although Taubeneck (1967) concluded that Group 6 rocks record a period of post-subsidence sediment accumulation in a caldera lake. The rhyolites and andesites of Group 7, including an ignimbrite, mark a phase of renewed volcanism in the caldera, with evolved compositions again being available for eruption. Post-Group 7 volcanic and sedimentary rocks, including any syncaldera ignimbrites erupted during the late-stage, cataclysmic caldera-forming (cauldron subsidence) event, have all been removed by erosion.

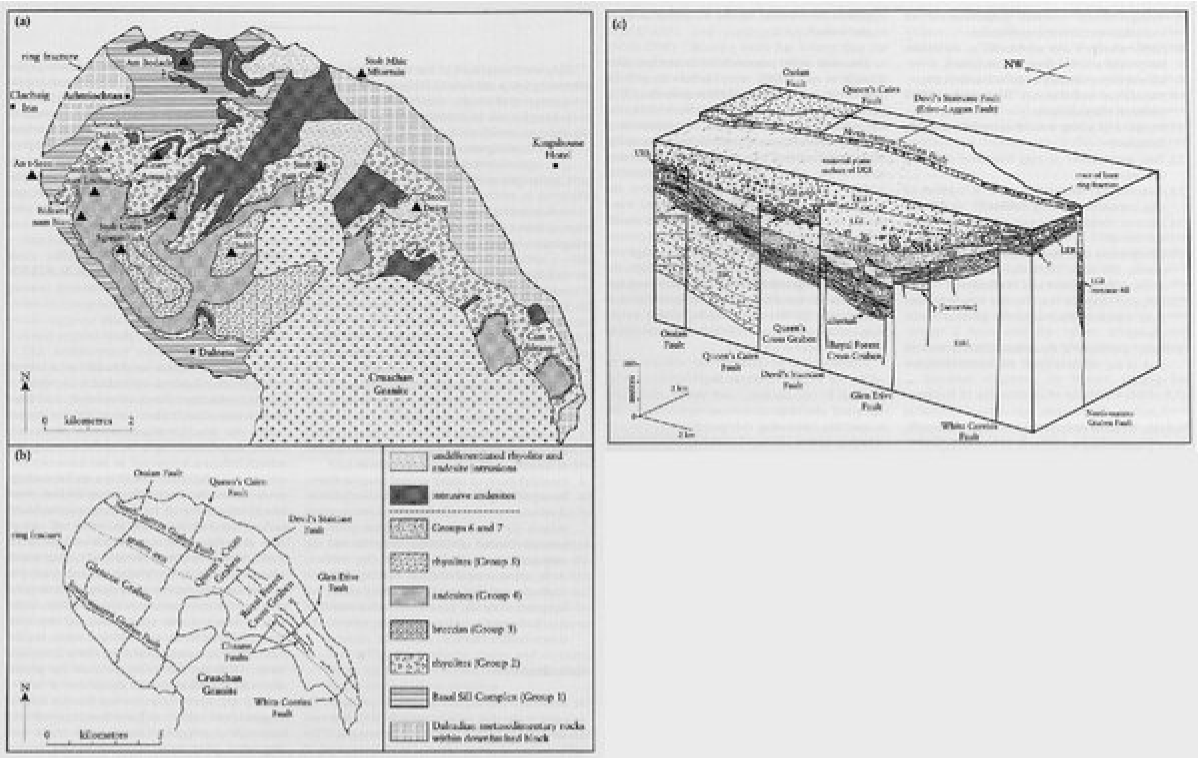
## Conclusions

This extensive GCR site provides superb three-dimensional sections through the calc-alkaline Glencoe volcano, a well-preserved example of cauldron subsidence. Rocks preserved include those forming the ancient land surface (Dalradian metasedimentary rocks), and a graben-controlled caldera fill of volcanic and sedimentary rocks. An unknown thickness of material has been removed by erosion.

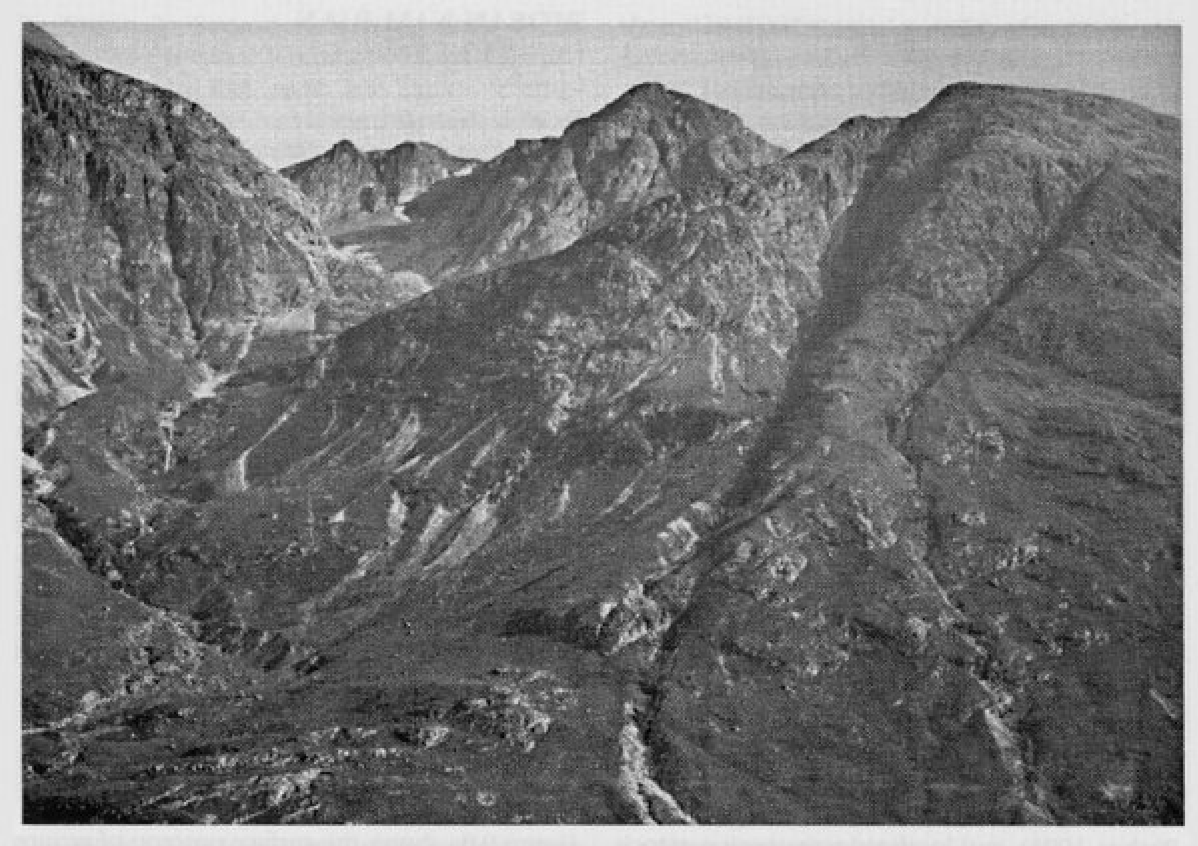
After an initial pre-caldera andesite-dominated phase (Group 1), there were two major cycles of syncaldera rhyolitic volcanism and caldera collapse (Group 2), which were followed by major fault-scarp collapse and a lengthy period of quiescence (Group 3). Renewed magmatism (Group 4) resulted in a substantial thickness of andesite sheets being emplaced, before a return to the explosive eruption of rhyodacite magma (Group 5). Sedimentary caldera-lake deposits (Group 6) indicate substantial graben-controlled caldera collapse after the volcanism of groups 4 and 5, while the rhyolites and andesites of Group 7 (the youngest rocks preserved) record further eruptions of evolved magma.

One final point is worthy of emphasis: the rocks preserved here record a consistent pattern of eruptive activity accompanied by incremental, graben-controlled caldera collapse. Subsidence kept pace with intracaldera volcanic and sedimentary fill during the early development of the Glencoe volcano. Late-stage, ring-fracture-controlled caldera collapse (cauldron subsidence) certainly took place, and this was directly responsible for preserving the rocks of groups 1 to 7, but unfortunately, the volcanic products of this late-stage, cataclysmic event have been removed by erosion.

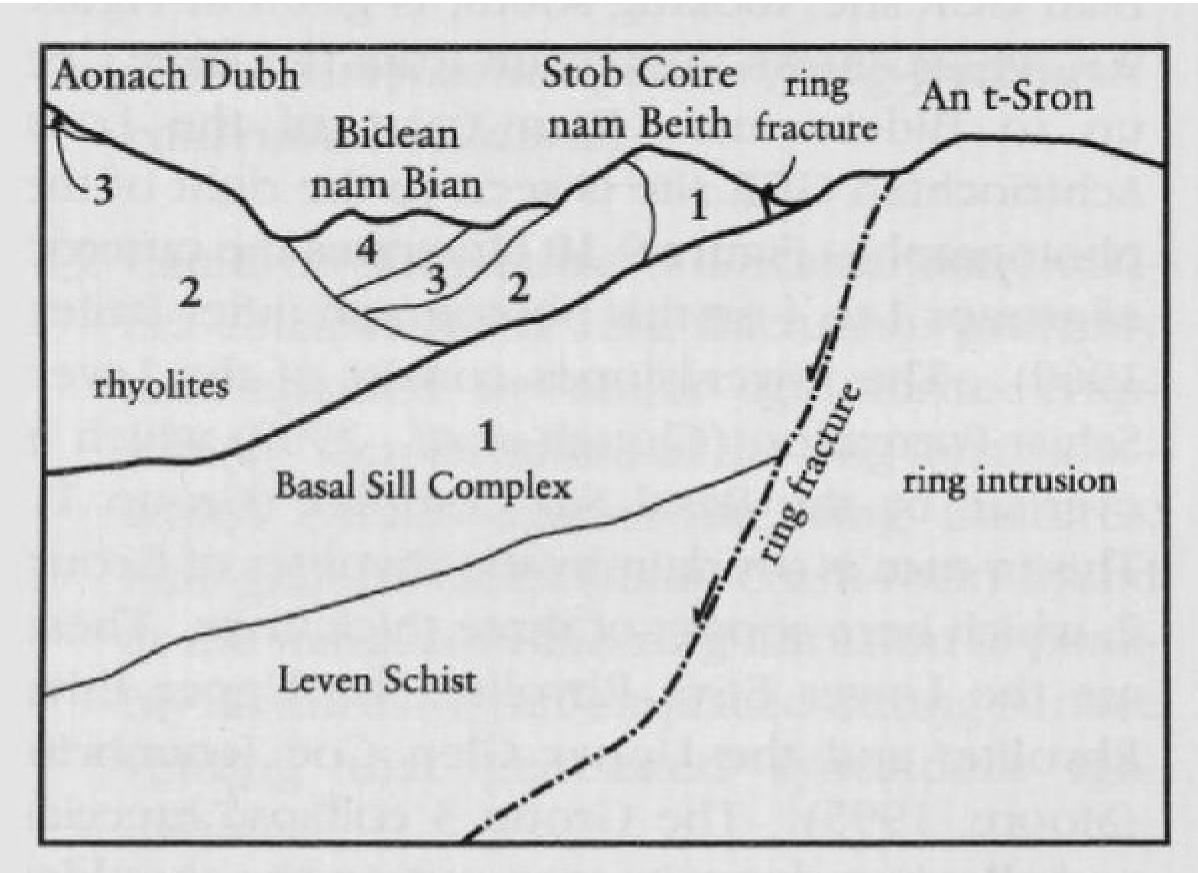
[References](#)



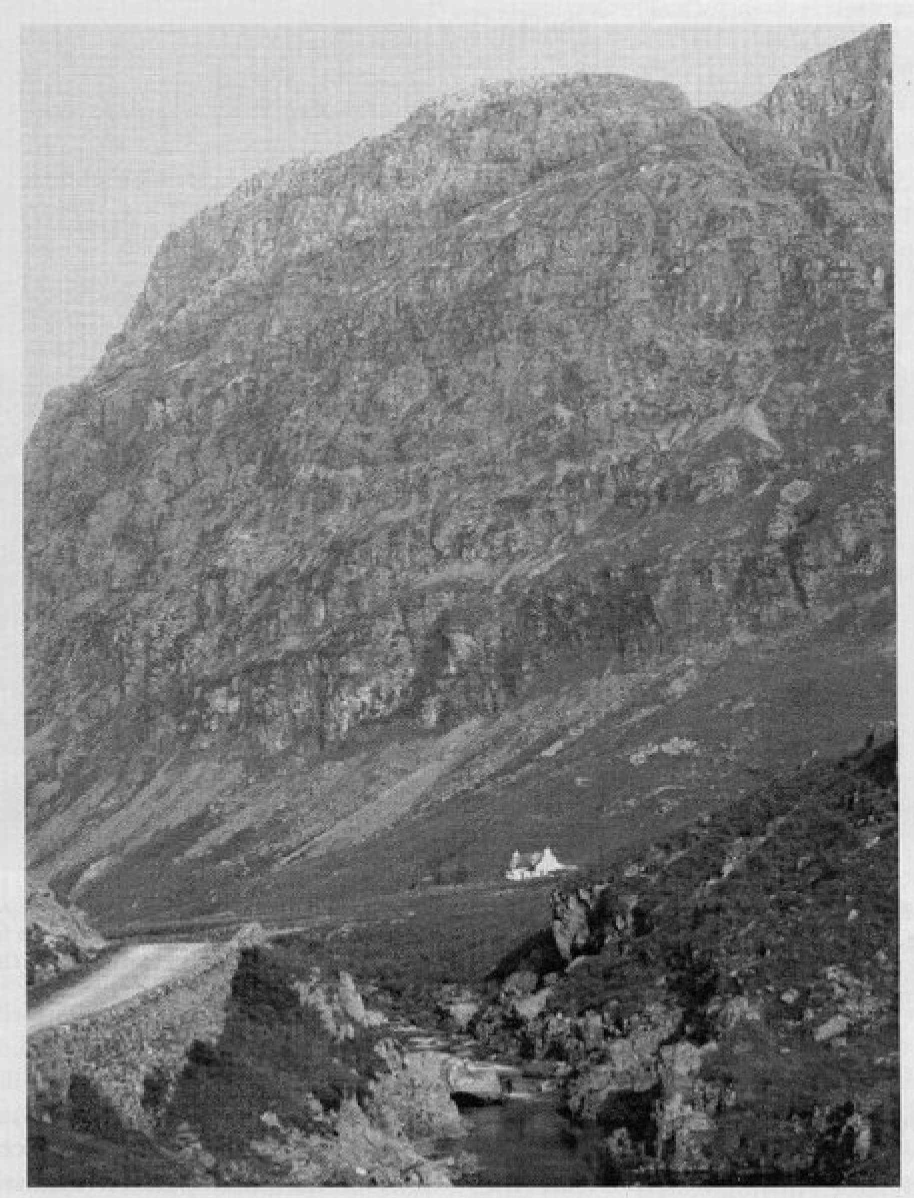

*(Figure 9.8) (a) Map of Glen Coe showing rocks enclosed by the ring fracture (i.e. within the down-faulted block); Dalradian metasedimentary 'basement'; groups 1 to 7 (with groups 6 and 7 shown together); and undifferentiated intrusive rocks (rhyolite and andesite). Group 3 rocks are sandwiched between groups 2 and 4 rocks throughout most of the area, and only substantial group 3 outcrops are shown. The Etive Dyke-Swarm, minor intrusions, and small outcrops are omitted. The ring intrusion is not shown (see the Stob Mhic Mhartuin GCR site report). Note the incursion of the younger Cruachan granite into the cauldron block from the south. Redrawn after Clough et al. (1909), Roberts (1966a), Roberts (1974), and Moore (1995). (b) Map of the Glencoe cross-graben fault system preserved within the ring fracture (after Moore and Kokelaar, 1997). Figure 9.8(c) Block diagram showing the 3D structure of the Glencoe caldera as interpreted by Moore and Kokelaar (1997). The sections have been restored to a horizontal plane surface presumed to have been formed by the eruption of the 'Upper Glencoe Ignimbrite' (top of Group 2). Thin deposits from this eruption extended north of the North-eastern Graben Fault, but are not shown. The long axis of the block diagram lies along the axis of the Glencoe Graben. DAL, Dalradian metasedimentary rocks; BSC, Basal Sill Complex; LER, MER and UER, Lower, Middle and Upper Etive rhyolites (lower Group 2); LGI and UGI, Lower and Upper Glencoe ignimbrites (upper Group 2); p, phreatomagmatic tuff.*



(Figure 9.9) View up Coire nam Beitheach towards Bidean nam Bian, Glen Coe, showing the outcrop of groups 1 to 4, plus the ring fracture and ring intrusion. See Figure 9.10 and the text for details. (Photo: BGS no. B619.)




(Figure 9.10) Interpretative sketch of Figure 9.9 showing the relationships between topography and lithologies at the Bidean nam Bian GCR site, after Clough et al. (1909). See text for details.



*(Figure 9.11) The west face of Aonach Dubh, Glen Coe. Scree-covered lower slopes are Leven Schist, which is overlain by intrusive sheets (up to 17) and sedimentary rocks of the Basal Sill Complex (Group 1). The summit region is capped by the thicker rhyolites of Group 2. (Photo: BGS no. B616.)*

*(Figure 9.12) Peperite, clearly showing the brecciation of andesitic magma with fine-grained sandstones and shales forming the matrix between the andesite blocks. Beside the 'old road' near Achtriochtan farm, Glen Coe. This particular exposure is no longer visible; it was probably destroyed during construction of the new road, or has been covered by scree. (Photo: BGS no. C1154.)*