STOB MHIC MHARTUIN

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Introduction

The Glencoe volcano is of international importance because of the cauldron subsidence, which has preserved a sequence of Old Red Sandstone volcanic rocks within a downfaulted block, encircled by a ring fracture system and an irregular ring intrusion (see The Glencoe volcano – an introduction to the GCR sites', above). The ring fracture is the subject of this GCR site, which occupies the summit and surrounding area of Stob Mhic Mhartuin (706 m). Its importance lies in the good exposures of the ring fracture, where the relationships between the down-faulted inner block and the surrounding undisturbed metasedimentary rocks are especially clear. As with elsewhere at Glen Coe, there is an intimate association between the ring fracture and the ring intrusion. An unusual feature of this site is that there are two ring fractures, of different ages.

Description

Stob Mhic Mhartuin is regarded as the type locality for the ring fracture (Bailey, 1960), although it is in fact quite atypical in some aspects (Taubeneck, 1967). Clough *et al*. (1909), Bailey (1960), and Roberts (1966b) all provided detailed descriptions of the ring fracture and some of the key relationships are illustrated in Figure 9.16 (after Roberts, 1966b). Here it appears in two branches and contact metamorphic relationships led Clough *et al*. (1909) and Roberts (1966b) to conclude that the southern branch is the younger. This description concentrates on the southern (younger) ring fracture (Figure 9.15).

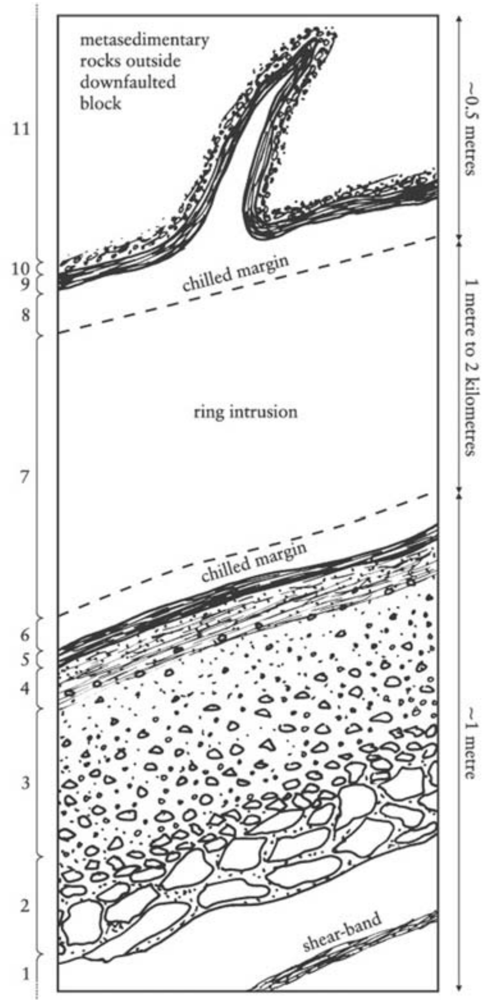

Figure 9.16: Sketch (note variable scale) showing relationships in the Stob Mhic Mhartuin area between the downfaulted block, the ring intrusion, and the undisturbed metasedimentary rocks outside. Note the broad symmetry that is present, with 7 (ring intrusion) flanked by chilled margins (6 and 8), which are in turn flanked by 'flinty crush-rock' (5 and 9) – all of which probably constitute an ancient vent system. The 'flinty crush-rock' is flanked by a complex series of microbreccias to the west (2, 3 and 4), and by a much simpler microbreccia to the east (10), and these are themselves flanked by unbrecciated Dalradian metasedimentary rocks (1 – within the downfaulted block; and 11 – outside the downfaulted block). After Roberts (1966b), and Garnham (1988). Key: 1, Bedded quartzites within downfaulted block; 2, Quartzites cut by veinlets of granulated quartzite; 3, Quartzite microbreccia; 4, Banded quartzite microbreccia with matrix of 'flinty crush-rock'; 5, 'Flinty crush-rock' (note sharp and straight contact with 6); 6, Chilled margin of ring intrusion; 7, Ring intrusion; 8, Chilled margin of ring intrusion; 9, 'Flinty crush-rock' (note sharp but irregular contact with 8); 10, Quartzite microbreccia; 11, Undisturbed Dalradian metasedimentary rocks outside the downfaulted block.

Figure 9.15: The outward-dipping Glencoe ring fracture at Stob Mhic Mhartuin (down-faulted block on the right). The prominent dark band running up to the right is the 'flinty crush-rock', and above it (to its left) is the ring intrusion, here a porphyritic microdiorite, which is chilled at the contact. Between the 'flinty crush-rock' and the low ground on the right (Dalradian quartzites within the downfaulted block) are crushed and brecciated quartzites (see Figure 9.16). The outward-dipping orientation of the contact is probably due to rotation accompanying collapse of the downfaulted block. (Photo: BGS no. D1562.)

Immediately north of the ring fracture lies the ring intrusion, here a porphyritic microdiorite, which forms a near-continuous (but irregular) ring around the down-faulted inner block (Figure 9.17). The ring intrusion typically has a smooth and chilled inner contact against the ring fracture, which contrasts strongly with its irregular and variably chilled contact against the outlying metasedimentary rocks (Roberts, 1966b). Clough *et al*. (1909) placed great emphasis on a fine-grained lithology called 'flinty crush-rock' (described later), which lies at the smooth inner contact between the ring intrusion and the ring fracture (Figures9.15 and 9.16). However, Roberts (1966b) reported that 'flinty crush-rock' also occurs at the outer, irregular contact, and argued that it is just a finer-grained facies of the ring intrusion.

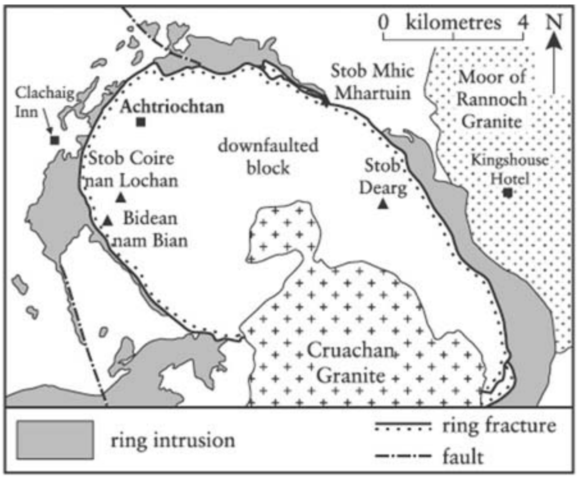

Figure 9.17: Sketch showing the ring fracture and ring intrusion system around Glen Coe. Relationships are less clear in the south where there are difficulties distinguishing the ring intrusion from neighbouring intrusions. Minor outcrops of the ring intrusion (which are numerous) have been omitted for clarity. Redrawn after Clough et al. (1909), Roberts (1974) and Garnham (1988).

The ring fracture strikes approximately NW–SE at this locality and dips outwards at 60° to the NE. The ring intrusion chills against the ring fracture, and there is a 2 cm-wide zone of dark, vitreous rock ('flinty crush-rock') between the chilled ring intrusion and the crushed metasedimentary rocks of the down-faulted inner block. The contact is surprisingly straight, sharp, and persistent. Within the 'flinty crush-rock' there are clear signs of flow, with lighter- and darker-coloured layers developed parallel to the contact (individual layers are traceable for a few metres), plus there are oval structures (long axes parallel to the contact) suggesting flow either down-dip or up-dip. There is a fairly sharp contact between the 'flinty crush-rock' and the adjacent lithology to the SW, which is a strongly flow-banded microbreccia with elongate and rounded fragments (smaller than 1 cm) set in a matrix of the 'flinty crush-rock'. At the contact with the 'flinty crush-rock' some whitish zones are present in the microbreccia, and in places the 'flinty crush-rock' appears to either cross-cut these zones or to have incorporated remnants of them within it. To the SW the flow-banded microbreccia grades (over a distance of 1 cm) into a zone of whitish rock that consists of crushed fragments of quartzite (Clough *et al.*, 1909). Within this crush zone there are two distinct lithologies: one adjacent to the flow-banded microbreccia, which is a mix of light and dark components, and one to the SW, which is characteristically white in colour. To the SW are relatively undisturbed quartzites of the down-faulted inner block with vertical bedding and NNW strike. However, within 40 m of the ring fracture there are crush zones (up to 10 cm wide) that have the same strike and dip as the ring fracture, and that are more abundant nearer to the ring fracture.

Interpretation

Roberts (1974) presented a unifying model of explosive eruptions at the ring fracture producing the ignimbrites that are now preserved within the down-faulted block. However, Moore (1995) has demonstrated that piecemeal subsidence associated with Group 2 ignimbrite eruptions took place within an early graben-controlled caldera, and not at the ring fracture, thus invalidating the model of Roberts. The cataclysmic event that led to late-stage cauldron subsidence (i.e. ring fracture-controlled caldera formation), contrasts with the earlier graben-controlled volcanism and caldera collapse. The ring intrusion probably represents a syncaldera, subvolcanic, non-erupted magma that was associated with cauldron subsidence on the encircling ring fracture(s).

While there is good evidence for major subsidence of a down-faulted inner block along encircling ring fractures at Glen Coe (summarized by Clough *et al.*, 1909 and Bailey, 1960), there is uncertainty regarding the magnitude of the subsidence. Bailey (1960), Taubeneck (1967), and Roberts (1974) all placed considerable emphasis on the presence of sedimentary rocks intercalated throughout the volcanic pile, and concluded that episodic subsidence kept pace with the eruption of syncaldera volcanic rocks. Moore (1995) agreed with this conclusion, adding that the subsidence was graben-controlled. Furthermore, Moore has shown that the Group 2 ignimbrites were erupted from vents in the central area of the volcano, whilst Garnham (1988) found no geochemical correlation between the ring intrusion and volcanic rocks of the down-faulted inner block. Thus, any syncaldera volcanic rocks that accompanied *en bloc* subsidence of the down-faulted inner block have since been removed by erosion. If a major eruption accompanied cataclysmic caldera collapse (i.e. cauldron subsidence) – and this would be wholly consistent with ring-fracture-controlled caldera formation elsewhere (see Smith and Bailey, 1968; Smith, 1979) – the ring intrusion could be the remnants of a vent which gave rise to eruptions of ignimbrite.

At the ring fracture itself, subsidence was accompanied by comminution and crushing of the country rocks of the down-faulted inner block. There is a clear progression from crushed country rock quartzite in contact with undisturbed vertically bedded quartzites of the down-faulted block, through to a bedded microbreccia incorporating progressively lesser amounts of crushed quartzite, through to the dark ‘flinty crush-rock'. The incorporation of crushed quartzite into the ‘flinty crush-rock' suggests that the ‘flinty crush-rock' is younger.Roberts (1966b) presented convincing evidence that the ‘flinty crush-rock' is simply a rapidly chilled variant of the ring intrusion, and this suggests that magmatic activity either accompanied or postdated down-faulting.

The original workers (Clough *et al*., 1909; Bailey, 1960) regarded the ‘flinty crush-rock' as a pseudotachylite (a melt produced by extreme friction). This interpretation was questioned by Reynolds (1956), Roberts (1966b), and Taubeneck (1967), who all proposed a magmatic origin. The veins and tongues of ‘flinty crush-rock' that occur away from the ring fracture (Taubeneck, 1967) further support a magmatic origin. Clough *et al*. (1909) did comment on these offshoots of the ‘flinty crush-rock', but attributed them to injection of the still-fluid pseudotachylite away from its source. It is significant thatRoberts (1966b) also found ‘flinty crush-rock' at the outer (irregular) contact, and concluded that the ‘flinty crush-rock' is simply a marginal facies of the ring intrusion. Reynolds (1956), Roberts (1966b) and Taubeneck (1967) all regarded the ‘flinty crush-rock' as an intrusive tuff. Recent work at Ben Nevis, where there is also ‘flinty crush-rock' (Bailey and Maufe, 1916), has further strengthened the case for a magmatic origin. Burt and Brown (1997) concluded that the Ben Nevis ‘flinty crush-rock' is an intrusive tuff, and that it represents the remnants of a vent which probably encircled the Ben Nevis volcano (see the Ben Nevis and Allt a'Mhuilinn GCR site report).

The presence of two separate ring fractures, of different ages, suggests two periods of subsidence, although Taubeneck (1967) has questioned this interpretation. The older ring fracture is not found encircling the entire down-faulted block, and its significance is therefore uncertain.

The ring fractures are outward-dipping at this locality, which is atypical. BothTaubeneck (1967) and Roberts (1974) demonstrated that the ring fractures are inward-dipping or vertical at the vast majority of localities, implying that the down-faulted inner block has the shape of an upward-opening cone. At calc-alkaline volcanic centres, major caldera collapse involving chamber roof collapse along concentric, inward-dipping ring fractures (cf. cauldron subsidence) invariably triggers the eruption of substantial volumes of ignimbrite (Druitt and Sparks, 1984). By analogy with caldera complexes elsewhere, it is likely that at least one such late-stage cataclysmic event took place at Glen Coe. Thus Roberts (1974) was partly correct in concluding that there had been a major ring fracture-controlled caldera event at Glen Coe. He did, however, misinterpret the role of the Group 2 ignimbrites, which were erupted during an earlier phase of small-scale, graben-controlled caldera formation, and not during late-stage cauldron subsidence (Moore, 1995).

Conclusions

Rocks exposed around the summit of Stob Mhic Mhartuin in Glen Coe preserve features developed during late-stage cauldron subsidence (cf. ring fracture-controlled caldera collapse), when a down-faulted inner block sank. Without this subsidence the volcanic rocks that form the rugged topography of Glen Coe would not have been preserved. The ring fracture, which separates the down-faulted inner block from the undisturbed rocks outside, is well exposed. By analogy with volcanic centres elsewhere, major subsidence of the down-faulted inner block along concentric, inward-dipping ring fractures, led to cataclysmic eruption of ignimbrites, much of which would have been deposited within the subsiding caldera. Subsequent erosion has removed these deposits, but the ring intrusion that partly encircles the ring fracture is probably the remnants of a concentric vent.

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