Chapter 8: timing of eruptions

It is difficult to determine the duration of the individual eruptions and the time interval between them. The recognition that the Basal Andesite Sill-complex is only a small remnant of an extensive volcanic field, most of which has been eroded away, implies that a considerable time elapsed after the andesitic magmatism and before the eruption of the Etive rhyolites; there is, however, some ambiguity about how long this gap may have been. Unroofing of the Rannoch Moor Pluton was well advanced before eruption of the Etive rhyolites (clasts of the granite are abundant in the Kingshouse Breccias), but the timing of its unroofing relative to the andesitic magmatism is unclear. Clasts in fluvial conglomerate that rests on the Dalradian metamorphic 'basement' *beneath* the andesite sheets include granite and basic plutonic rocks resembling kentallenite, indicating that plutonism and unroofing were advanced in this vicinity before the andesites were emplaced, but it is unclear whether or not this recorded history predated emplacement of the Rannoch Moor Pluton. If the latter was emplaced after the andesitic magmatism, the time gap represented by the unconformity on the top of the sill stack would have to be a couple of million years or more (the minimum time between pluton intrusion and unroofing; see Harayama, 1992). On the other hand, if the basal conglomerate does relate to the Rannoch plutonism and the andesites were emplaced long after the pluton, the duration marked by the unconformity on the sill stack could be considerably shorter. Nevertheless, the 500 m of tectonic downthrow that preserved the Basal Andesite Sill-complex west of the Queen's Cairn Fault must have occurred in the interval recorded by the unconformity; for example, if the interval was 500 000 years, the tectonic downthrow rate would have been 1 km per million years or more, which seems reasonable given the strong tectonic control evident in the subsequent piecemeal caldera development. On balance, it is simplest to infer that the basal conglomerate beneath the sills does record early unroofing of rocks of the Rannoch intrusion.

Each of the ignimbrites reflects sustained deposition from a single, albeit perhaps long-lived (hours to days), explosive eruption. The intervals between ignimbrite-forming eruptions were long enough to permit fluvial erosion, involving incision of canyons, with subsequent development of lakes and alluvial fans. The alluvial fans, however, may have formed quickly, since the contemporaneous tectonism was evidently sufficient to cause rapid switches from erosion to normal fluvial or lacustrine sedimentation, as well as switches to relatively catastrophic alluvial-fan aggradation. In at least one instance the interval was long enough to permit emplacement and then removal of a substantial thickness of andesitic lavas (the Lower Streaky Andesites; such an interval may also be recorded by the Upper Streaky Andesites, but the evidence is less clear).

It is inferred that the multiple nature of the collapse and caldera filling at Glen Coe directly relates to the strong tectonic influence. Eight major eruptive events are known to have occurred and probably more were involved; had the crust not been so disrupted there might have been fewer and larger eruptions. By analogy with the Taupo Volcanic Zone, New Zealand, which shows rapid tectonic extension (7–20 mm per year) and consequent high frequency of caldera-forming eruptions (Houghton et al., 1995; Wilson et al., 1995), the intervals between such eruptions at Glen Coe were probably in the order of several thousands to one or two hundreds of thousands of years (see also Smith and Luedke, 1984). It is tentatively estimated that the time between the emplacement of the Lower Etive Rhyolite and the last subsidence and intrusion along the peripheral fault system of the caldera volcano was no more than two or three million years; a large part of the uncertainty lies in not knowing what may have originally overlain the uppermost preserved volcanic strata (Dalness Ignimbrite Member) and what duration of activity is recorded in the diverse ring-fault intrusions. Also, there is considerable uncertainty regarding the time marked by the unconformities in the succession; conceivably, the intervals marked by the unconformities that cut the two streaky andesite units may have been underestimated. Magmatism at the site continued with emplacement of the Clach Leathad Pluton, before a southwards shift of the focus of magmatism to the Etive Pluton, but the time scale for this later activity is at present poorly known.

The incremental, tectonically influenced development of the caldera volcano, which records many pulses of magmatic activity and alternations between emplacement of andesite and rhyolite or rhyodacite, raises the questions of whether such pulsing was fundamentally similar to that involved in the incremental growth of the closely adjacent plutons and whether there ever was a large, longlived magma chamber beneath the Glencoe Caldera-volcano Complex. There are several points bearing on this. Plutonic intrusion temporally bracketed the development of the caldera volcano, with only limited spatial separation (no more than 10–20 km) of the successive foci of magma ascent, so it may be reasonable to suspect that processes and rates of magma generation at depth were similar throughout. Both the Rannoch Moor and Etive plutons show pulsed intrusion of magmas with composition apparently in the same range as in the volcanic succession, namely intermediate (diorite/andesite) to silicic (granite/rhyolite). It appears that subterranean volumes of rhyolite magma were centrally invaded by andesite magma beneath the Glencoe Graben, with consequent very shallow intrusion and eruption to form both of the (mingled) streaky andesite units. Later, large outpourings of andesite and dacite occurred without magma mingling (the volume of the Bidean nam Bian andesites is estimated at more than 12 km^3), possibly because of magma ascent to one side of any reservoir of rhyolite, via the An t-Sròn intrusion. The ignimbrites in the succession show no evidence for any substantial compositional zonation of the magma chamber, although it might have occurred but not been tapped. Thus, the weight of evidence presently available suggests that there was no relatively shallow large or long-lived magma body that evolved substantially by magmatic differentiation, but that the volcano tended to have relatively small reservoirs at shallow depth and was supplied relatively frequently by intermediate and silicic magmas that both originated from depth, like the plutons. This may be a characteristic attribute of caldera volcanoes that form on crustal discontinuities during substantial accommodating extension or transtension.

Glen Coe was the site where geologists first addressed the possible relationships between a volcano and underlying coeval intrusions, almost 100 years ago, and despite the numerous subsequent studies much still remains to be understood, not least the fundamental cause and duration of the magmatism. It seems certain that the Glencoe caldera volcano and its adjacent plutons will remain an outstanding natural laboratory for the study of magmatic and volcanic processes for many years to come, and equally likely that unexpected new insights will be derived in the future from these spectacularly exposed rocks.

References