Chapter 6 Later related magmatism

Clach Leathad and Etive plutons

At a late stage, during or after emplacement of the fault-intrusions, the Glencoe Caldera-volcano Complex was extensively invaded by silicic magma that formed a granitic pluton with a dome-shaped upper (roof) contact. This intrusion is widely exposed in the south-east and centre of the volcano complex (Figure 25) and it almost certainly underlies much of the rest of it. No base to this pluton is known and most geologists have considered it as part of the large Etive Pluton; it was interpreted as a ‘northern lobe’ of the outer, Cruachan Intrusion part of the Etive Pluton. In this chapter the relationships of the plutonic intrusions are reconsidered and, for reasons explained, the so-called northern lobe within the Glencoe volcano complex is given a new identity, as the Clach Leathad Pluton. Clach Leathad is a mountain summit, at 1099 m, in the north-east of the outcrop [NN 240 493]; the Gaelic name means ‘stone slope’ or ‘stone hillside’, presumably referring to the vast ribbed exposures of the characteristic monzogranite that occur north-east of the summit and extend some 300 m down into Coire an Easain. On a clear day, both the local form of the Clach Leathad Pluton and its scale in relation to the Etive Pluton, with the distinctive (and eponymous) peaks of Ben Cruachan 25 km away to the south-west, are strikingly and beautifully evident from the summit.

The main outcrop of the Etive Pluton extends 22 km from south-west to north-east and 17 km north-west to south-east, an area of some 300 km2. It forms the largest outcrop of the numerous, broadly coeval and genetically related intrusions that densely populate the Grampian Terrane (Figure 3). It consists of an outer part referred to as the Cruachan Intrusion, predominantly of grey quartz-diorite and quartz-monzodiorite that show a tendency to be more silicic in composition with height (Anderson, 1937), within which lies the large Starav Intrusion, composed of porphyritic and nonporphyritic varieties of monzogranite. In the extreme south there are diorites and remnants of another volcano (see Anderson, 1937; Geological Survey Sheet 45, Oban). Topographical outliers of syenogranite, which rests with flat-lying contact on the Cruachan Intrusion, appear to be remnants of one or more near-horizontal or tilted sheets, the intrusive affinities of which are unclear (Anderson, 1937; Bailey, 1960; Batchelor, 1987; Jacques, 1995).

It has long been known that the pinkish monzogranite of what was previously called the northern lobe of the Cruachan Intrusion (now the Clach Leathad Pluton), is petrographically distinct from all of the other plutonic rocks to the south (Kynaston and Hill, 1908; Clough et al., 1909; Bailey and Maufe, 1916; Anderson, 1937; Bailey 1960; Batchelor, 1987; Jacques, 1995). Barritt (1983) has shown that this northern intrusion differs geochemically from the rest, and has its own centred and concentric compositional variations, as illustrated by mapped abundances of the trace elements thorium (Th) and uranium (U). A steep, north-west-trending sheet of leucocratic monzogranite, which is generally 100 to 200 m wide and referred to as the Meall Odhar Intrusion, extends from Meall Odhar [NN 188 463] to Stob Dubh [NN 167 484] and intervenes between the northern intrusion (Clach Leathad Pluton) and the main body of the Cruachan Intrusion to the south (see British Geological Survey, 2005). This sheet appears to be a multiple intrusion that was emplaced along a fault, or fault-zone, and towards its north-east margin it contains centimetre-thick seams of microbreccia and mylonite parallel to its contacts (see Bailey, 1960); this feature along the junction of the two plutonic masses disappears under superficial deposits towards the south-east, where its projection lies along the deep valley occupied by the Allt Dochart [NN 19 45].

The Meall Odhar Intrusion was emplaced after some dykes of the Etive Dyke Swarm (see below), which are cut or altered by the intrusion (Bailey, 1960), and dykes are far more common within the Clach Leathad Pluton than in the rocks just to the south. One dyke that cuts the Glencoe volcano complex and its ring-fault yielded a radiometric Rb-Sr age of 411.7 ± 5.1 million years (Thirlwall, 1988; sample site given as 183 562), which, although perhaps not very reliable, is significantly older than the Rb-Sr dates available from the Etive Pluton: 401 ± 6 million years for the Cruachan Intrusion and 396 ± 12 million years for the central Starav Intrusion (Clayburn et al., 1983). Taken together, these relationships indicate that the Clach Leathad Pluton significantly predated the main Etive intrusions and that it cannot be interpreted simply as an offshoot from the latter. Furthermore, contrasting features of the two bodies suggest that they have been displaced vertically relative to each other; the northern intrusion and its host volcano complex appear to have been displaced downwards, or the Etive Pluton upwards, or both, so that former different levels are now juxtaposed. It is not at all clear what structures might have acted to allow this, but the phenomenon is, in effect, mirrored at the south-western end of the Etive Pluton, where the Lorn lavas are thrown down to the south-west for considerably more than 1 km on the Pass of Brander Fault (Figure 3). This problematic relationship between the plutons is explained below, and is an additional reason for separating the two.

There is no question that the outcrop of the Clach Leathad Pluton is in the roof zone of the intrusion, where magma welled up to replace foundered crustal blocks of Dalradian metasedimentary rocks and Glencoe igneous rocks. The monzogranite cuts the uppermost preserved strata of the Glencoe Volcanic Formation, as well as the ring-fault system, and, although the contacts of the intrusion define a steep dome shape (Figure 25), the host volcanic succession shows no sign of upheaval. These relationships are clearly seen in the flanks of the Lairig Gartain, around [NN 195 538] and across the ridge that links Stob a' Ghlais Choire [NN 239 516] and Clach Leathad [NN 240 493]. They show that intrusion here involved detachment and subsidence of a large part of the volcanic pile and its basement, as was originally inferred by Clough et al. (1909) and illustrated by them as a type of 'cauldron subsidence' (Figure 5)a. The intrusion is rich in drusy cavities, which are common features in uppermost parts of granitic plutons and record accumulation of volatile constituents during rystallisation, and in its overlying roof rocks there has been intense hydrothermal alteration. Patchy to pervasive silicification and recrystallisation have substantially obliterated original rock textures and compositional variations; rather uniform white-weathered surfaces occur widely instead of etched pyroclastic fabrics, while some secondary nodular developments give the false appearance of coarse fragmental deposits. In the east, amongst crags above the River Bà [NN 265 490], and along the river itself [NN 258 478], an offshoot of the pluton has an irregular or sheeted contact with tonalite within the Glencoe fault-intrusion system (see p.93). Good exposures show that the contact lacks a chilled margin (Jacques, 1995), which indicates that the pluton was intruded shortly after the latest fault-intrusion here. There is no evidence, however, that the pluton emplacement was accompanied by any magmatic eruption at the surface.

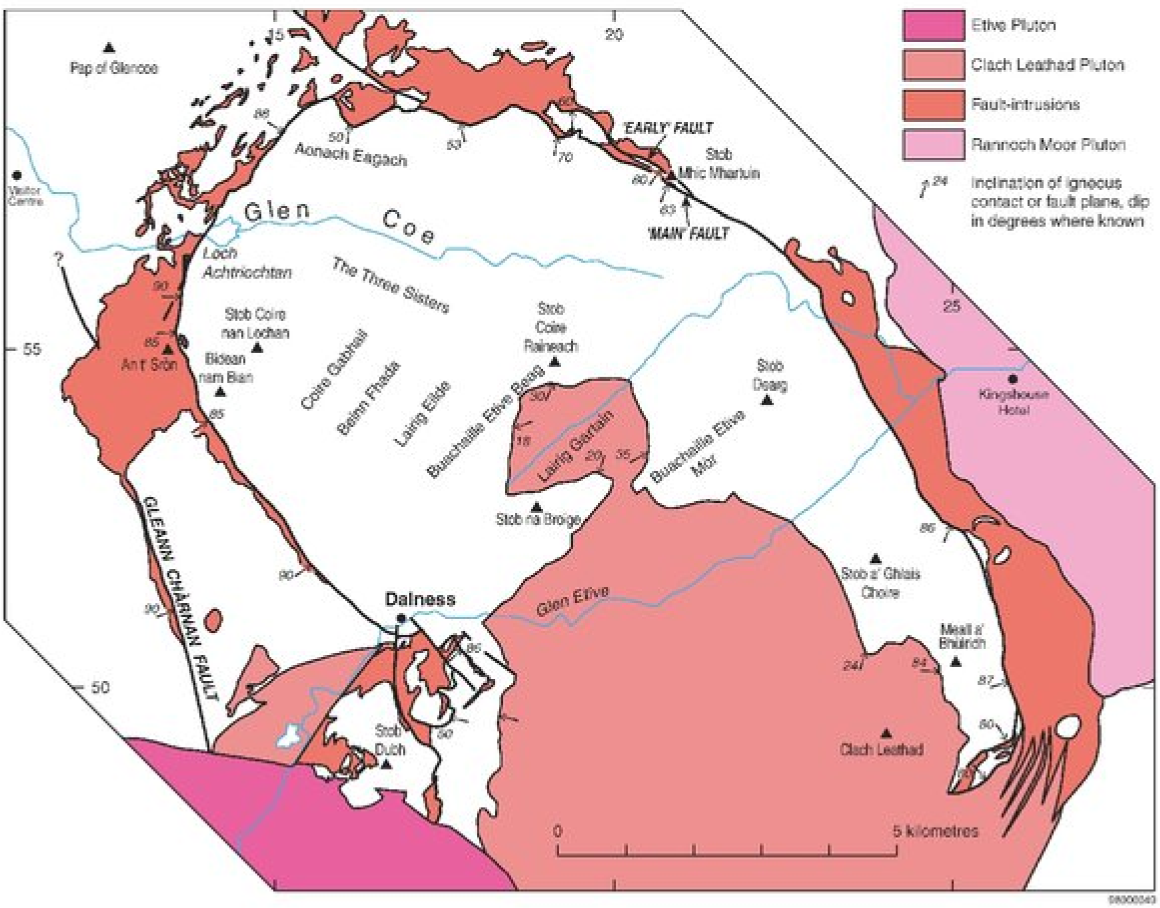
It is unlikely that much more than 1 km thickness of volcanic succession ever existed above the preserved succession, so it seems that the upper levels of the present exposure, at the top of the Clach Leathad Pluton, represent depths no more than 1 or 2 km beneath the original surface that existed at the time of intrusion. On the other hand, at the same level of exposure now, the Etive Pluton shows no evidence for proximity to any original roof contact, and has a 2 km-wide thermal metamorphic aureole, which, from hornfels near the southern contact, records formation beneath a cover between 3 and 6 km thick (Droop and Treloar, 1981). Such a thick cover cannot have simply extended northwards over the Glencoe volcano complex and Clach Leathad Pluton. Hence it is inferred that the Etive Pluton must have been displaced upwards, or the Glencoe volcano complex downwards, or both. A few of the Etive dykes are continuous between the two plutons, which suggests that any differential vertical motion must have predated these. Relative movement along the line of the Meall Odhar Intrusion, which contains cataclastic seams of microbreccia and mylonite, is indicated, but no tectonic dislocation continuing farther west has been recognised.

In the light of this reappraisal, the newly named Clach Leathad Pluton is viewed as representing a late phase of magmatism in the Glencoe area, and its now less clear association with the Etive Pluton is a major rationale for giving this northern monzogranite a separate identity. It is unclear what may have constituted all of the 3 to 6 km-thick cover of the Etive Pluton at the time of its emplacement, but the upper part is likely to have included a thick sequence of lavas, probably continuous with the Lorn pile now preserved south-west of the Pass of Brander Fault (Figure 3).

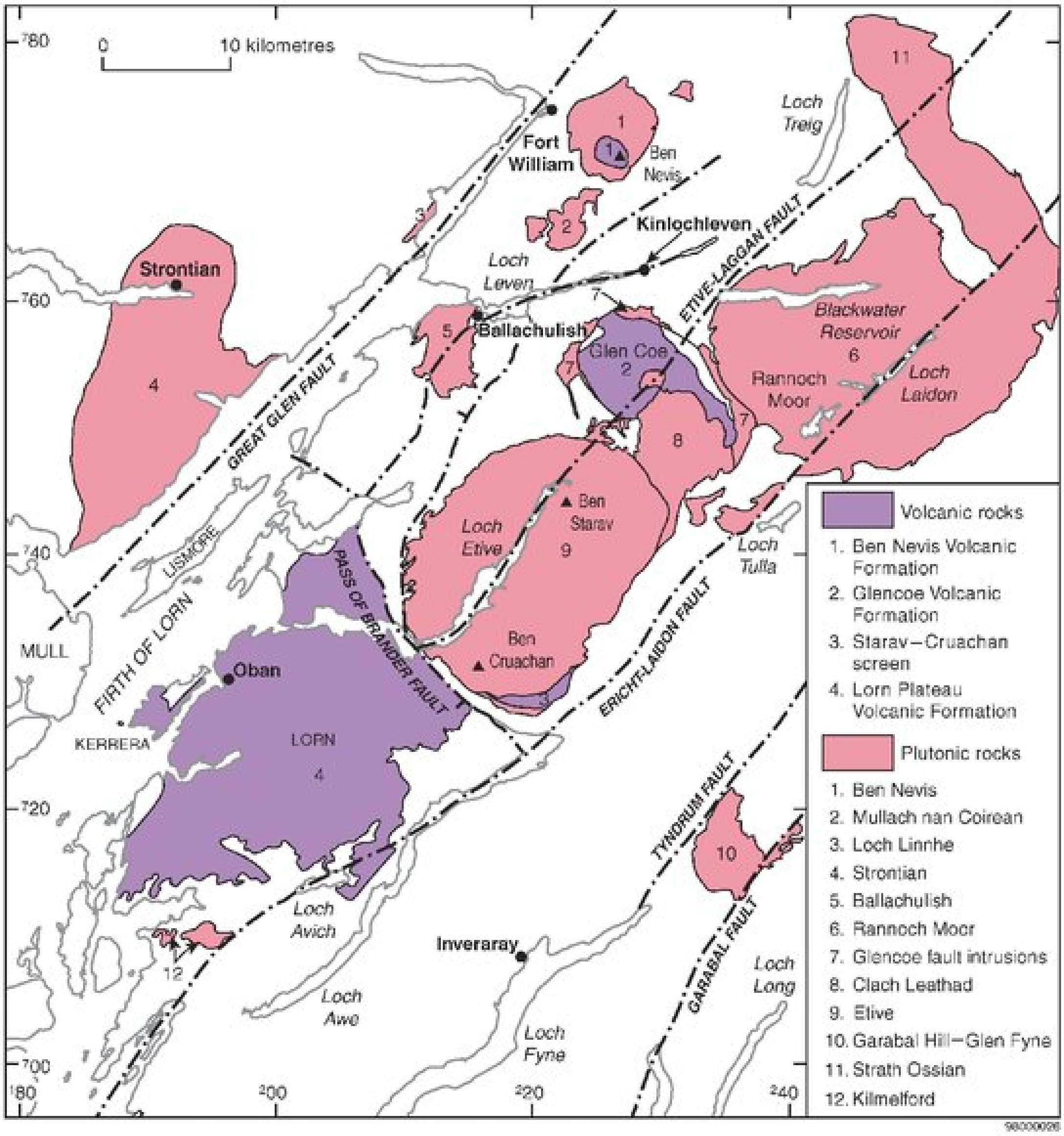
Etive Dyke Swarm

The Glencoe Caldera-volcano Complex, the Clach Leathad Pluton, and the Cruachan Intrusion of the Etive Pluton are cut by numerous north-east-trending dykes, referred to collectively as the Etive Dyke Swarm (Clough et al., 1909; Bailey and Maufe, 1916). Overall, this swarm extends north-east–south-west for some 100 km and is up to 20 km wide; it appears to be centred upon the Etive Pluton, where it cuts all but the central Starav Intrusion, but cross-cutting relationships (described above) prove that part of the swarm existed before the Etive plutonic activity. The dykes have not been remapped in the recent study, and many are not represented on the 1:25 000 scale geological map (British Geological Survey, 2005). They are composed of porphyritic microdiorite, micromonzodiorite, microgranodiorite or microgranite, commonly with phenocrysts of plagioclase, quartz or biotite in the more silicic types and hornblende in the less silicic varieties. Typically, the dykes have chilled margins and average 3 to 4 m in width; in some cases they can be traced continuously for more than 10 km. Locally, contrasting rock types occur together in multiple dykes, as for example in Gleann Fhaolain [NN 154 515] (see Bailey and Maufe, 1916, fig. 28). Clearly, emplacement of the Etive Dyke Swarm was associated with north-west to south-east crustal extension, but previously published estimates of the overall extension are too great, and the notion that their removal would restore the caldera volcano to a circular outline is erroneous (see p.29). While in places the dykes make up some 30 per cent or more of the outcrop over several hundreds of metres, a maximum of about 10 to 15 per cent of north-west to south-east extension overall seems more consistent with what can be gleaned from the well-exposed areas. Surveys of the dykes in selected areas in the vicinity of the Glencoe volcano (Morris and Hutton, 1993) have found mismatches of opposed contacts, oblique dyke offshoots and asymmetrical terminations, which all indicate emplacement involving a component of sinistral strike-slip strain (i.e. sinistral transtension), consistent with the more regional picture for the south-west Highlands up to this time. However, the early surveyors provided evidence for pure orthogonal opening of dykes, especially in matching opposed contacts (Clough et al., 1909, pp.642–643; Bailey and Maufe, 1916), and they also noted that the dykes have the same orientation as the numerous joints that break the surrounding rocks: mostly near vertical, but inclined where the joints are inclined. Emplacement of the Etive dykes seemingly started after emplacement of the Clach Leathad Pluton, and was well underway before emplacement of the Cruachan Intrusion, terminating before final emplacement of the Starav Intrusion. Evidently the dyke swarm formed over a long period, and it seems probable that there were various episodes of extension and transtension during this time, or the strain types may have been localised (partitioned). An interesting feature is that the Etive Dyke Swarm seems not to record any stress-field deflection in the immediate vicinity of the Glencoe Caldera-volcano Complex; there is no obvious influence of any north-west-trending discontinuity at the site of the former Glencoe Graben, even though this feature apparently was exploited by dykes at a later time, during the Early Permian (see British Geological Survey, 2005).

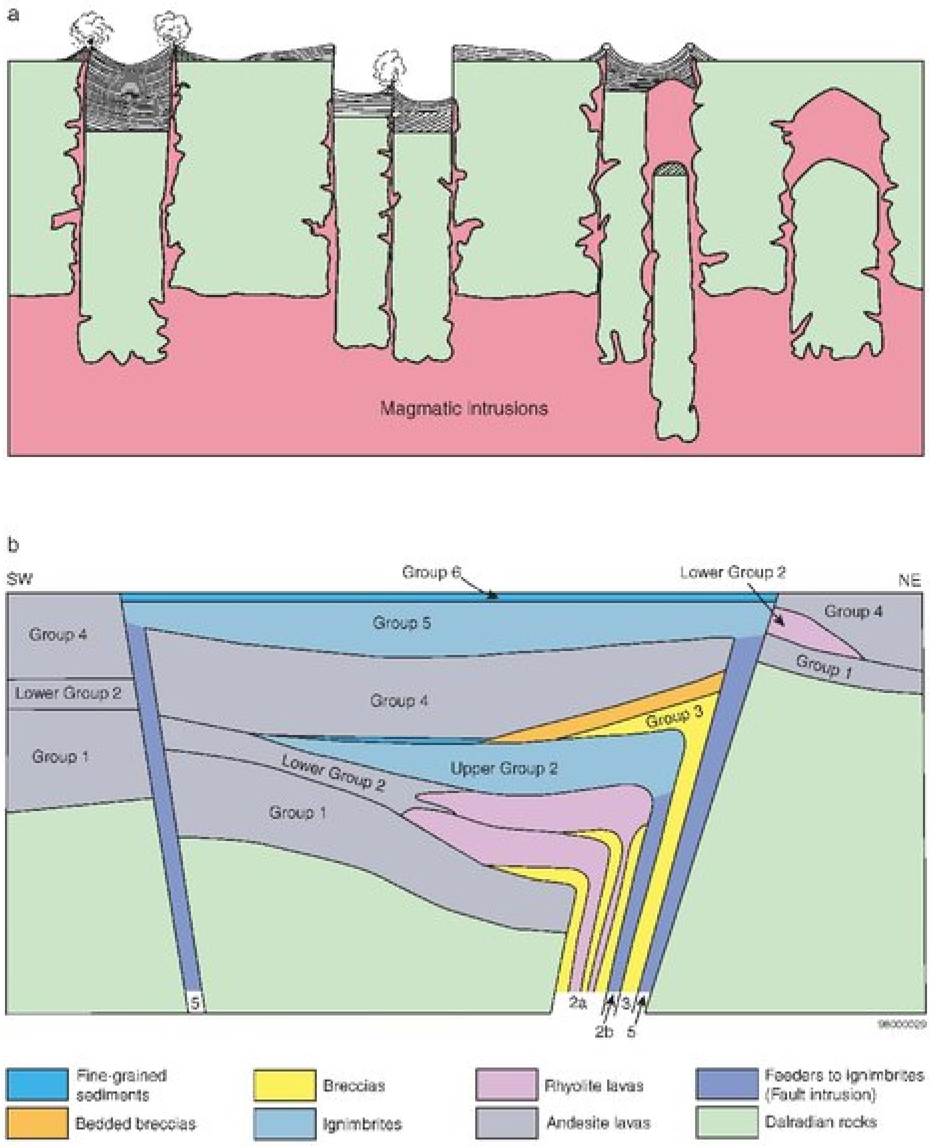
References



(Figure 25) Ring-fault system, associated fault-intrusions and the passively emplaced Clach Leathad Pluton.



(Figure 3) Distribution of Siluro-Devonian volcanic and plutonic rocks showing faults that were active during the magmatic activity.



(Figure 5) Models of cauldron subsidence. a. The original models of cauldron subsidence derived from studies at Glen Coe (modified after Clough et al., 1909). b. Model of asymmetrical subsidence of a coherent caldera-floor block (after Roberts, 1974). Note the depiction of pronounced inward dip (downward convergence) of the bounding faults. This geometry is implausible for straightforward central-block subsidence and does not occur in reality.