Langdale Pikes

[NY 271 063]–[NY 300 082]

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Introduction

The imposing Langdale Pikes have long fascinated geologists, and many crags in the area, such as Gimmer, Raven, and Whitegill are classic climbing localities (Figure 4.20). The Langdale Pikes GCR site illustrates further features of the Scafell Caldera of the Borrowdale Volcanic Group. Variations within the ignimbrites contrast markedly with correlatives in the neighbouring sites, such as the Ray Crag and Crinkle Crags, and Rosthwaite Fell GCR sites, to provide evidence that the Scafell Caldera collapsed in a chaotic, piecemeal fashion, with numerous localized graben that ponded thick tuffs. However, the Langdale Pikes GCR site has been selected principally for its continuous sections through the Scafell Caldera lake succession, arguably the best example of its kind worldwide. Dramatic thickness variations of individual units in the succession indicate continued differential subsidence of the caldera after it was flooded. There is also a unique example of a subaque-ously emplaced intracaldera pyroclastic lag breccia containing scoria. Neolithic stone-axe factories within the area exploited silicified fine-grained volcaniclastic rocks of the caldera-lake facies and represent one of Britain's oldest stone industries.

Previous work in Langdale was by Hartley (1932), Millward (1976), and Moseley and Millward (1982). Recent mapping, which involved tracing distinctive thin tuff layers as stratigraphical markers, has revealed the presence of a major reverse fault, the Langdale Fault, which runs along the northern slopes of Great Langdale (Branney and Kokelaar, 1994a) and this has led to a substantial change in the interpretation of the stratigraphy. The revised stratigraphy is simplified and thinner, because units near the valley floor are repeated up slope by the fault (Figure 4.12) and (Figure 4.21). Recent descriptions are given in Kokelaar *et al.* (1990), Branney *et al*. (1992), Kneller *et al.* (1993b), Kneller and McConnell (1993) and Branney and Kokelaar (1994a); these accounts are summarized in Millward *et al.* (in press) and the results are incorporated in the Geological Survey 1:50 000 Sheet 38 (1996).

Description

The Langdale Pikes GCR site extends from Grave Gill [NY 277 065] to Whitegill Crag [NY 298 071], and from the summits of Pike of Stickle [NY 274 073], Harrison Stickle [NY 298 073] and Pavey Ark [NY 284 078] to the lowest exposures on the north side of Great Langdale. The lowest unit present is a single exposure of the Long Top Tuffs (Airy's Bridge Formation) at Grave Gill. More generally, the lowermost exposures are of the Bad Step Tuff the basal unit of the Crinkle Tuffs (Figure 4.12), because this was thickly ponded in a small, ephemeral intracaldera graben in this part of Great Langdale. In this GCR site the Bad Step Tuff is over 400 m thick, but its base is not exposed.

The Bad Step Tuff is an ignimbrite that closely resembles a flow-folded rhyolite lava. Its pyroclastic origin is inferred on the basis of evidence elsewhere, where it is thinner (see the Ray Crag and Crinkle Crags GCR site report). Its uppermost 10 m are autobrecciated and interstices between the blocks are infilled with a fine-grained silicic tuff of possible co-ignimbrite ash-fall origin. It is overlain by the Rest Gill Tuff, a turquoise laminated silt- to fine sand-grade unit, which exceeds 3 m thick locally on the downthrow (south) side of the Langdale Fault, but is only a few centimetres thick on the upthrow side. This is overlain by massive eutaxitic ignimbrites of the Crinkle Tuffs, which locally display superb examples of small- and medium-scale rheomorphic folds. They thicken markedly towards the NW Intercalated with them, and overlying them, are layers and lenses of breccia, up to 20 m thick, with angular, framework-supported blocks (up to 2 m across) of Bad Step Tuff and eutaxitic Crinkle Tuffs ignimbrites. These pass up into subaqueously deposited sedimentary rocks. The breccias overlying the uppermost ignimbrite of the Crinkle Tuffs, and the transitional beds into the lacustrine fades, have been grouped somewhat arbitrarily together as the Lingmell Formation (Figure 4.21).

The overlying lacustrine rocks belong to the Seathwaite Fell Formation (Figure 4.21). The total thickness of the caldera lake succession is approximately 540 m, but individual units vary dramatically in thickness. The lowest unit of this formation is the Three Tarns Member, which varies laterally from 3 m of ripple cross-laminated sandstone and siltstone above Whitegill Crag, to 80 m of laminated silicic mudstone, siltstone and fine-grained sandstone at Pike of Stickle. It commonly shows parallel and wavy lamination and slump structures. The mudstone is flinty, with a conchoidal fracture, and was worked for stone axes around Harrison Stickle and Pike of Stickle in Neolithic times. Epidote- and chlorite-rich fiamme are concentrated towards the tops of some beds and are inferred to represent pumice lapilli flattened during burial as a result of their diagenetic alteration to clays (cf. Branney and Sparks, 1990).

Two prominent dark bands seen in crags just below the summits of Pike of Stickle and Harrison Stickle form the Harrison Stickle Member (Figure 4.21). These are massive breccias and are 30 m thick on Harrison Stickle. They are overlain by the Dungeon Ghyll Member, about 60 m of intensely disturbed siltstone and epidotized sandstone (Kneller and McConnell, 1993). Some beds contain fiamme.

The succeeding Pavey Ark Member, named after Pavey Ark [NY 285 078], comprises a massive, heterolithic coarse breccia, with an upwards-fining top that exhibits cross-bedding. The breccia is about 200 m thick in the east and thins westwards. South of the Langdale Fault it is about 10 m thick, and locally occurs as discontinuous pods. Its grain size varies gradationally. The breccia contains blocks of lapilli-tuff rhyolite, sandstone, and concentrations of ragged amygdaloidal andesite clasts, whose embayed and folded shapes, sometimes draped and deformed around lithic clasts, indicate they were hot and plastic (Figure 4.22). These juvenile bombs commonly contain small angular rhyolite clasts. The Pavey Ark Member is overlain on Thunacar Knott by siltstone, sandstone and tuff of the upper part of the Seathwaite Fell Formation.

Interpretation

The dramatic thickness variations in the Crinkle Tuffs ignimbrites and overlying caldera lake sedimentary rocks indicate a complex pattern of caldera subsidence, in which different areas subsided rapidly at different rates. The thickness of individual units in the caldera lake succession varies dramatically, indicating continued differential subsidence of the caldera after it was flooded. Volcanotectonic faults that bound the areas of differential subsidence are exposed in cross section. Zones of vertical and highly attenuated welding fabrics along the fault planes indicate ductile shear rather than brittle fracture and show that the faults moved when the ignimbrites were still hot (Branney and Kokelaar, 1994a).

Good examples are the Dungeon Ghyll Fault [NY 290 066] and the Grave Gill Fault [NY 277 065], where 10 m-wide shear zones with vertical fiamme are well exposed. As the caldera progressively subsided, these faults were re-activated, sometimes with dip-slip throws in the opposite direction to the previous displacements. For example, thickness variations across the Grave Gill Fault [NY 277 065] show that an early easterly downthrow, which ponded the Bad Step Tuff, was reversed during the next phase of the eruption (see Branney and Kokelaar, 1994a). The net displacement rate of these faults is much more rapid than has been recorded from tectonic faults. Contrasting successions on either side of the Langdale Fault indicate that it moved during caldera collapse and formed an unstable topographic scarp on the caldera floor that shed rock avalanches containing blocks over 2 m across. Elsewhere, strata geometries and thickness changes indicate that fault blocks rotated during caldera collapse. For example, well-exposed ignimbrites thicken gradually from 40–200 m [NY 278 070]–[NY 273 070] below Pike of Stickle, and indicate a sudden fault-block rotation of at least 20° just after the Bad Step Tuff eruption (Branney and Kokelaar, 1994a).

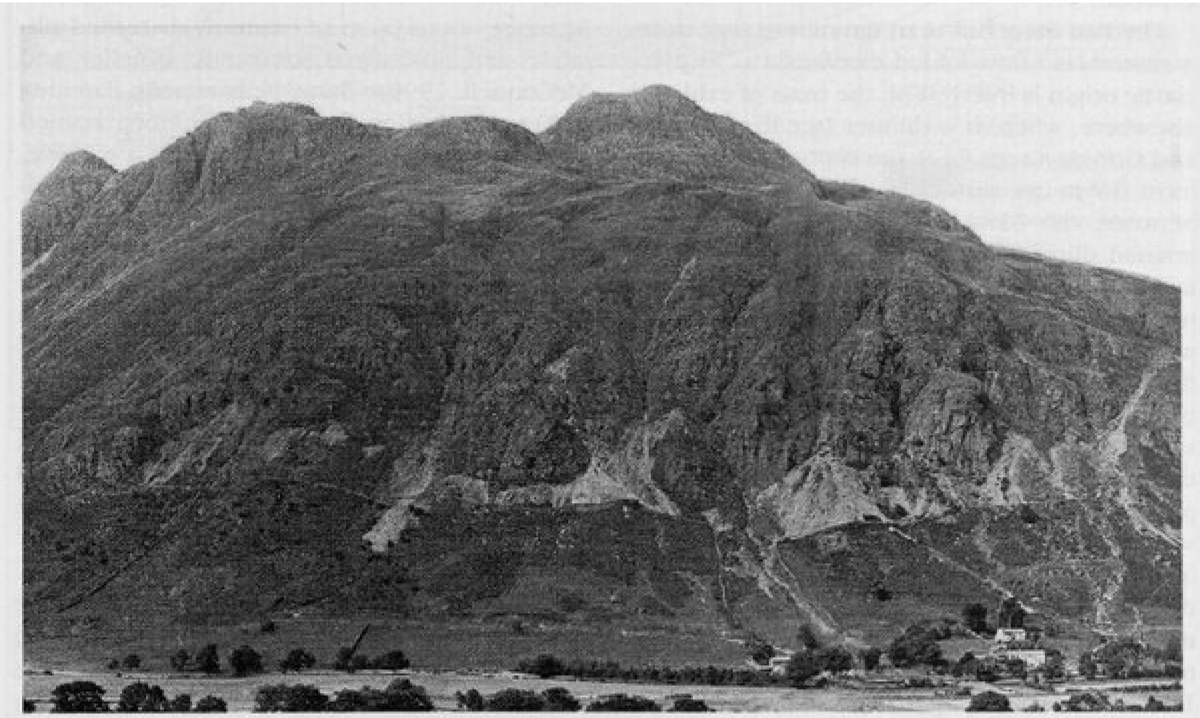
A transition from subaerial to lacustrine deposition as a result of flooding of the Scafell Caldera is recorded by the Lingmell Formation, and the upwards-fining succession may be a result of water gaining access to vent regions, causing an increase in explosivity (phreatomagmatism). The basal deposits of the Seathwaite Fell Formation are probably turbidites and ash falling directly into lake water, with wave and current reworking. The Harrison Stickle and Dungeon Ghyll members were rapidly emplaced as sediment-gravity flows, possibly derived from pyroclastic eruptions, and their soft-state disruption may record slumping, liquefaction due to sudden loading, and seismic shock. The Pavey Ark Member records another, larger volume sediment-gravity flow. Clasts within it closely resemble mafic scoria 'rags' found in association with proximal lag breccias at flooded calderas like Santorini, Greece (Mellors and Sparks, 1991). Away from the Langdale Pikes, the Pavey Ark Member fines upwards and laterally into sandstone and locally, eutaxitic tuff (Kneller and McConnell, 1993). The presence of hot magma spatter in the gravity flows suggests that the flows were generated by a pyroclastic eruption. The breccias probably represent intracaldera, lacustrine scoriaceous co-ignimbrite lag breccias from a major pyroclastic flow eruption that occurred in the flooded caldera. The fine-grained component could represent water-settled or trapped ash from the pyroclastic flows, or from the disturbed lake bed. This interpretation makes the Pavey Ark Member unique worldwide, because all other documented scoria-bearing co-ignimbrite lag breccias were subaerially deposited on caldera rims, and their intracaldera equivalents are inaccessible beneath caldera lakes.

Conclusions

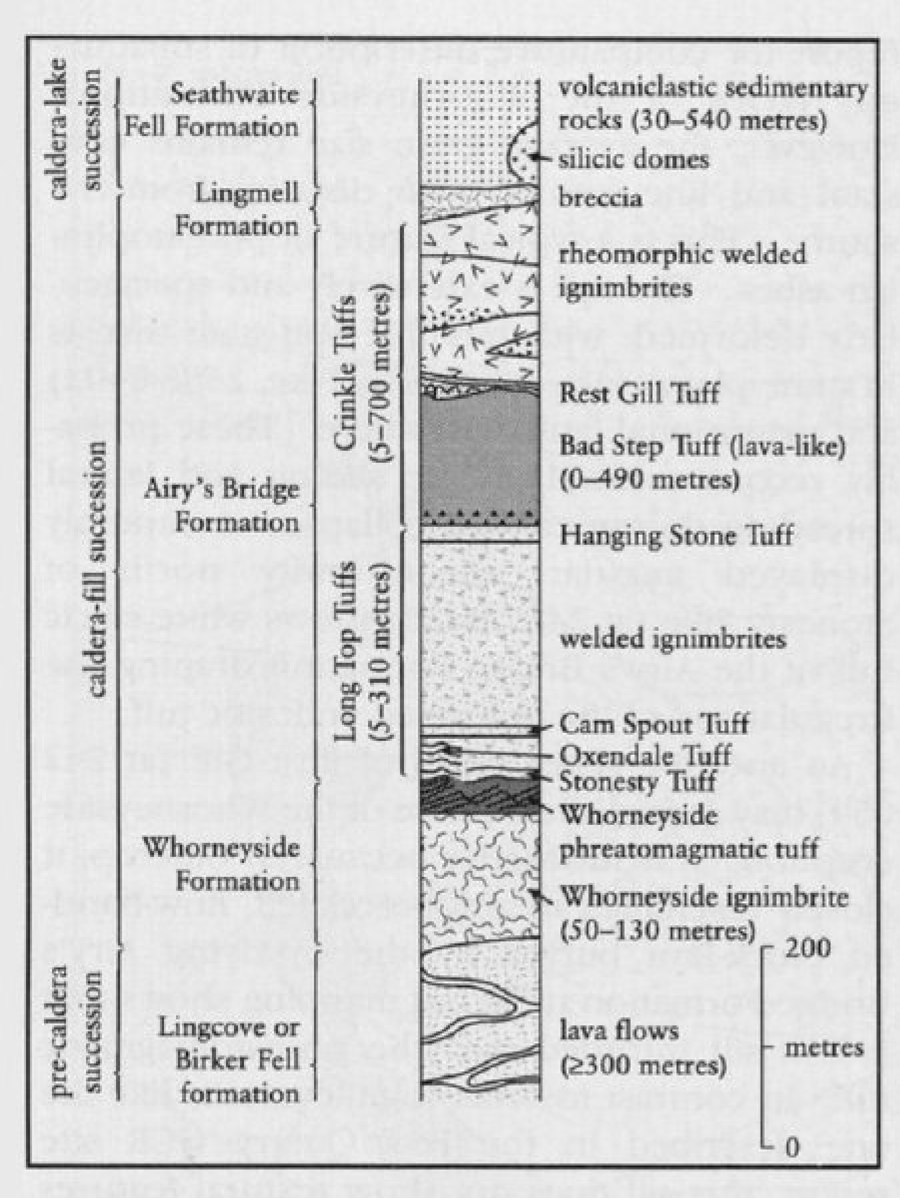
The geology of the Langdale Pikes is remarkable because it records the final stages of collapse of a large caldera, and its inundation by water. It exposes the entire caldera lake succession (Seathwaite Fell Formation) of the Scafell Caldera, arguably the best-exposed succession of its type worldwide. Sedimentary structures recording subaqueous pyroclastic and sedimentary processes, and soft-sediment deformation are beautifully picked out by recent weathering of the glaciated rock surfaces. The site includes the type localities of the Harrison Stickle and the Pavey Ark members of the Seathwaite Fell Formation. The latter is the only example recorded in the world of subaqueous spatter-bearing breccia. It has international significance because it complements interpretations of sub-aerial deposits formed in similar eruptions at the Santorini, Taal, and Rabaul calderas.

Continuous sections through the uppermost caldera ignimbrites display superb plastic folds and both abrupt and gradual thickness variations, indicating fault-block subsidence and fault-block rotations within a subsiding caldera floor. The site was a fault-controlled depositional centre for the Bad Step Tuff, the ponding of which is localized within the Langdale part of the caldera. The site exposes internationally important examples of exhumed caldera-floor faults that have complex re-activation histories, and vertical welding fabrics along them. The Langdale Fault was originally a normal fault, active during the volcanic eruptions, but it was subsequently re-activated as a thrust, repeating the Langdale stratigraphy. It formed a scarp that shed avalanches, and the resultant coarse breccias exposed on the Langdale Pikes are among Britain's finest examples of caldera-collapse breccias.

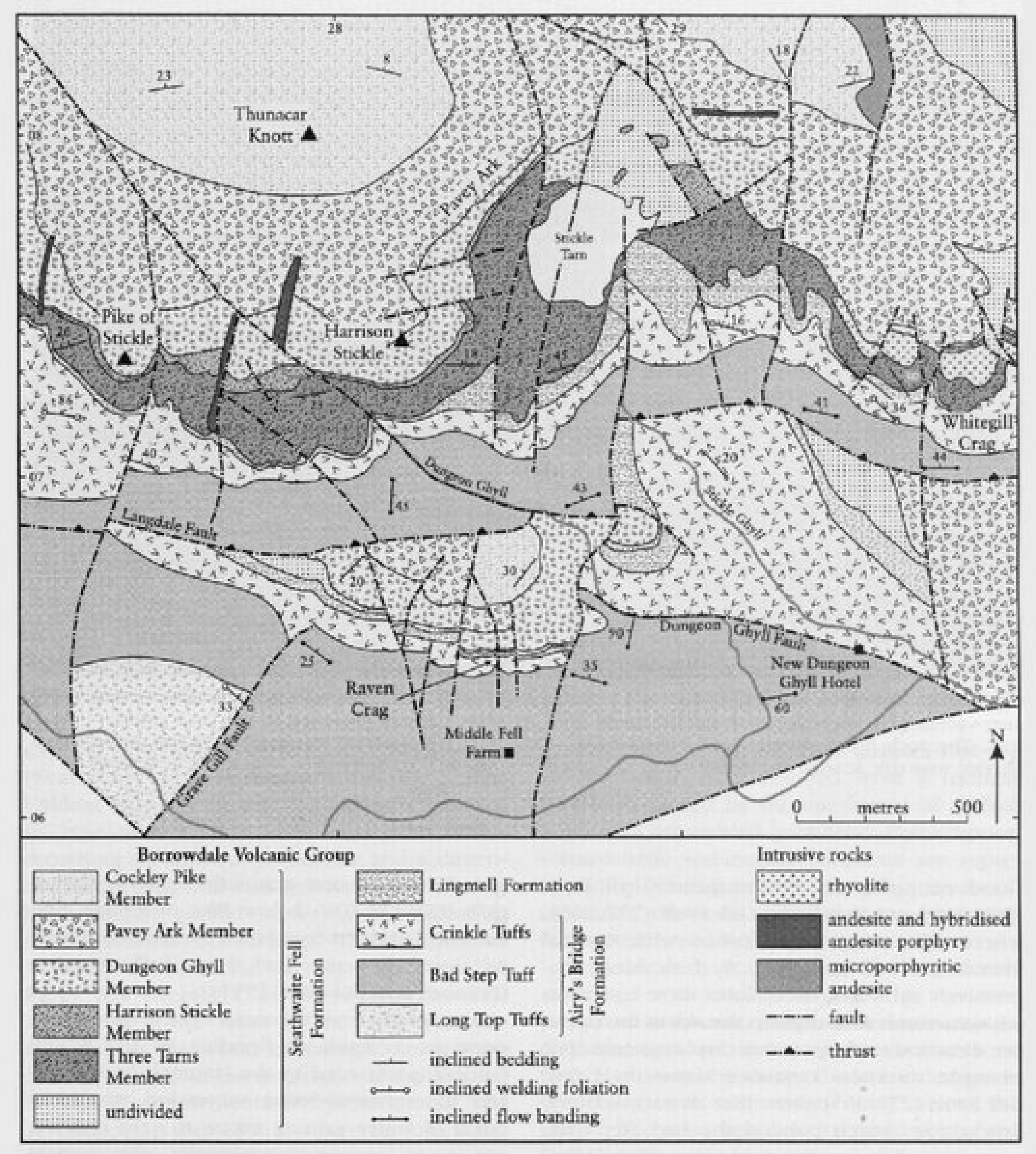
References



(Figure 4.20) The Langdale Pikes, viewed from the south. Welded ignimbrites within the Scafell Caldera form the lower crags and Gimmer Crag (top left of centre). Pyroclastic and sedimentary rocks of the caldera-lake succession are well exposed on Pike of Stickle (far left) and Harrison Stickle (right of centre). (Photo: D. Millward.)



(Figure 4.12) Generalized lithostratigraphy of the Scafell Caldera succession (after Branney and Kokelaar, 1994a).



(Figure 4.21) Map of the Langdale Pikes, Great Langdale (based on mapping by M. J. Branney, B. J. McConnell and B. C. Kneller, for British Geological Survey).

(Figure 4.22) Pavey Ark breccia from the top of Pavey Ark. Rag-shaped clasts with fluidal outlines indicate that they were hot bombs and spatter incorporated into a pyroclastic density current during a large explosive eruption. The rock is interpreted as a subaqueous scoria-rich co-ignimbrite lag breccia, similar to subaerial phreatomagmatic scoria-rich deposits around Taal caldera lake in the Philippines. (Photo: M. J. Branney.)