Complex relationships along the upper contact of an andesite sill intruded into laminated volcaniclastic sandstone, Middle Fell, Wasdale, Cumbria. The white weathered zone of siltstone between the laminated sandstone and andesite suggests that water-saturated sediment was fluidised during emplacement of the andesite. The hammer head is 17 cm long. (P005180).

Basaltic, andesitic, dacitic and rhyolitic sills, individually up to 250 m thick, contributed significantly to the development of the volcanic succession. A very large number are hosted in bedded volcaniclastic units within the Duddon, Kentmere, Ambleside and Helvellyn basin successions. Fewer sills are recognised in the Birker Fell Formation, except in the Eagle Crag Member.
Many of the sills are vesicular and have peperitic margins, the textures indicating the importance of fluidisation during emplacement at shallow levels into water-saturated sediment. In some cases, the carapace of sediment was so thin that parts of the overburden slumped off and became mixed with peperitic clasts in associated mass-flow deposits. By contrast, podiform andesite sills up to about 30 m thick, and within the Helvellyn Basin succession south of Ullswater, have thin chilled margins indicating intrusion into consolidated rock, possibly at a very late stage in the volcanism.

Whilst some of the sills were emplaced during pyroclastic eruptions, the timing of intrusion of most others is uncertain. Their occurrence at many levels in the volcanic pile implies that there were multiple episodes of injection. Moreover, localised concentrations of andesite intrusions, such as that in the eastern Lake District associated with the Kentmere Basin succession, may represent the sites of volcanoes or, perhaps, the early phase of caldera cycles.

**Petrography of the volcanic rocks**

The Borrowdale volcanic rocks contain up to 30 per cent phenocrysts, comprising mainly plagioclase feldspar. Some clinopyroxene is typically present in the mafic rocks, with pseudomorphs after olivine occurring in a few. By contrast, orthopyroxene becomes the dominant mafic mineral in the felsic rocks, with orthoclase and biotite in a few of the most silicic. Almandine garnet phenocrysts are locally abundant in some andesite and dacite, but they are most abundant in the silicic ignimbrites. The garnetiferous rocks are peraluminous and the mineral and whole-rock compositions are related. The tendency for some calc-alkaline magmas to become peraluminous may be due to the assimilation of pelitic sediment. In the Lake District the source of this could be Skiddaw Group mudstone, but this was available only at relatively shallow crustal levels.

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