Harter Fell, Dunnerdale.

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This excursion is an adaptation of Itinerary 11 by Millward in the Geologists' Association Guide (1990). It is entirely within the Birker Fell Formation which dominates the lowermost part of the Borrowdale Volcanic Group. The unit is up to 2700 m thick and about 60% is andesite lava flows (including sills) but it also contains basalt, basaltic andesite, and dacite lava flows as well as pyroclastics (ignimbrites and airfall tuff) and reworked material (fluviatile and lacustrine). This assemblage formed a low-profile plateau volcanic field mainly fed by fissure eruptions. The andesite lava flows are normally tens of metres thick but individual flows can be 200 m. Most flows can be traced for no more than five kilometres. The typical flow has blocky autobrecciated margins and on the upper flow surface the cavities between fragments became infilled with sediment either washed in as reworked pyroclastics or settled in from air-fall pyroclastic events. An overall extensional tectonic setting is the only way such a thick pile of subaerial volcanic material can accumulate and be preserved. Convergent tectonics, such as subduction at a continental margin, readily provide such opportunities as most arc systems are in tension (slab roll-back).

The focus for the field meeting is two prominent felsic marker horizons within this otherwise monotonous pile of andesites and derived materials. Locally in contact but otherwise separated by a few tens of metres of bedded volcaniclastics, the Little Stand Tuff Member (LST) and the Great Whinscale Dacite Member (GWD) can be traced laterally for 16 and 13 km respectively. The LST is a rhyodacite ignimbrite and in almost every exposure it is readily identified by the presence of lithophysae which are spherulites that have a central vug. As is the case for spherulites, lithophysae are characteristic of high-temperature devitrification of coherent silicic glass and are found in formerly glassy lavas and welded pyroclastic deposits. They begin to grow at an early stage in the cooling history, when the hot glass is still able to deform plastically and involve nucleation of spherulites on small vesicles. As spherulitic crystallization proceeds, the vesicles are expanded by the exsolving volatiles. The vugs vary from circular to star shaped and may remain open, or be lined, or filled with minerals such as agate or chalcedony. Lithophysae range up to larger diameters than spherulites, reaching a few tens of centimetres across (McPhie et al., 1993).

Locality 1 Brandy Crag SD 2256 9893 (eastern end).

The upper autobrecciated couple of metres of the andesite lava flow has cavities between clasts infilled with white-weathering airfall tuff/reworked tuff. Above and below the LST there is well-bedded probably water-lain volcaniclastics. The characteristic nodular nature (lithophysae) of the LST is not very

Locality 1 Brandy Crag – marker horizons within the Birker Fell Formation [photo taken from SD 22490 98812]



Great Whinscale Dacite – dacitic lava erupted at high temperatures.

Between the GWD and the LST is an andesitic, bedded mixture of pyroclastics and fluvial reworked pyroclastics.

Andesite lava flow – the upper couple of metres is autobrecciated, cavities between clasts infilled with airfall tuff/reworked tuff.

prominent here. Also the flattened pumice fabric is weak and not very evident. Both these features can be clearly seen near the summit of Harter Fell.

There is an andesitic ignimbrite a few metres above the LST. It is a very distinctive unit because it contains large fiammé around 10 cm long and the whole unit is a little over three metres thick.

The base of the GWD is at a colour contrast – lighter GWD above (felsic) and darker unit below (andesitic). The basal couple of metres of the GWD is autobrecciated and above that it is flow banded. The bulk of the GWD is flow jointed and the upper few metres can be amygdaloidal. Isoclinal folds of flow-banding are seen in the lower part of the GWD above the lowermost autobrecciated zone. Many of the clasts in this breccia have disrupted flow banding or flow folds.

Locality 2 Fault with slickenlines and slickenside SD 22542 99203

The exposed fault in this gully dips 58^{o} towards the SE and strikes 226-046^{o}. The slickenlines plunge 52^{o} → 098 (pitch 68^{o} from 046 on the fault surface). The sense of movement cannot be securely determined. This exposed minor fault is not along the gully and the fault that controls this topographic feature is not exposed though there is plenty of vein quartz in the scree including some moderate sized blocks.

Locality 3A Autobrecciated base of the GWD SD 21956 99823.

This locality allows more comfortable examination of the basal autobrecciated zone in the GWD than is possible at Brandy Crag. The blocks are typically 15 – 20 cm in diameter and the contact with the underlying bedded volcaniclastics is clearly visible.

If you peer over the top of this mini crag you will see, very close by, a small rectangular tarn which is a key geographical reference point. Just a few metres west of locality 3A, towards the small tarn, is a good eexample of fluviatile reworking of primary pyroclastics. Very rarely on Harter Fell is there



Figure 2 Locality 3A – basal autobrecciated zone of the GWD.

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evidence for deposition in lakes (grading and elutriation channels) but there are examples around Locality 3.

In the general area above the rectangular tarn there are good exposures of GWD. Both the GWD and the LST are distinctive in their own right. Together they make an excellent marker horizon in the Birker Fell Formation in what would otherwise be a sequence perhaps overwhelmed by correlation challenges. These two units are found approx. 1200 metres above the base of the formation. Unusually laterally extensive, the GWD can be mapped over a distance of 13 km. Such a viscous magma can only flow so readily if it was erupted at high temperatures. The bulk of the GWD is typified by the prominent flow joints (Figure 3) which are so distinctive they can be recognised in well-travelled erratics.



Figure 3 Strongly developed flow-joints in GWD

Locality 3B Little Stand Tuff SD 21880 99869.

A complete section through this unit is easily accessible here highlighting the unit's distinctive nodular appearance. Also present is the weak eutaxitic fabric (alignment of flattened pumice fragments) that prove the ignimbritic origins of the unit. The in-situ crag exposure shows the overall distribution of lithophysae (mostly 4 to 6 cm).

The in-situ exposure is north facing, damp, and has an organic coating. Better opportunities to examine lithophysae in detail are provided by joint faces on fallen blocks. On a fresh surface the 4-6 cm nodules weather positively whereas on joints, sectional views are seen.

Locality 3C Impact sag SD 21837 99857

For the bedded units between lava flows, and for the obvious pyroclastics, it can be quite a challenge to determine how they were deposited. In this fallen block it is clear that a rectangular pyroclast approx. 16 cm long has impacted stratified airfall deposits. The clast is picked out in faint green by selective epidotisation.



Figure 4 Lithophysae (~4 cm diameter) at Locality 3B in the Little Stand Tuff showing trilete central vugs.



Figure 5 Folded flow-banding in an andesite lava flow (field of view ~3 m).

Locality 4 Isoclinally folded flow-banding in andesite lava flow, Birker Fell Formation. SD 21733 99619.

The layering known as flow banding can result from just a few percent variations in the amount of tiny crystals (microlites) and/or tiny vesicles. During magma ascent, and whilst it flows over the Earth's surface, repeated episodes of fracturing, healing, and attenuation in the flow stretch out pockets of different texture to create banding. Flow banding was once thought to be created by segregation of phenocrysts and microlites during magma flow. On close inspection the bands are seen to have ragged margins. Flow banding is normally weakly defined but can be emphasised by weathering to be nearly as well developed as bedding in sedimentary rocks.

Close to Locality 4 at SD 21727 99666 a thin layer (<20 cm) of small accretionary lapilli (smooth areas) overlies autobreccia at the top of the flow-banded GWD (also amygdaloidal).

Locality 5 Harter Fell Summit SD 21850 99726

The summit consists of an autobrecciated top to an andesite lava flow with laminated sediment infilling cavities between blocks. By tracing such horizons the British Geological Survey has mapped several lava flows around the summit (see GA Guide, 1990).

As ever, careful observations are required to be sure that an effusive origin has been determined rather than an intrusive peperitic contact.

References:

G A Guide (1990) Geologists' Association Guide, Geology of the Lake District 1990.

McPhie et al. (1993). Volcanic Textures, *University of Tasmania, Centre for Ore Deposit and Exploration Studies.*