



Crinkle Crags Excursion: formation of the Scafell caldera

Cumberland Geological Society

September 7th 2016

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LOGISTICS

- **Please Note: for localities 2 & 7 you may feel more comfortable with a hard hat for close examination of the layer and grain characteristics.**
- Meet at Three Shire Stone, Wrynose Pass [NY 278027] to discuss the weather and decide whether to go up the Crinkles or to do the low level Side Pike alternative.
- If the weather is OK start walking from Three Shire Stone at **10h00** on the Red Tarn path.
- A brief pause at Red Tarn will allow inspection of the remnants of medieval iron mining – small fragments of kidney ore from spoil tips.
- Climb the fairly steady gradient towards Crinkle Crag, leave the path to skirt the western side of the first Crinkle, and from a height of 780m drop down to Locality 1 on the side of Adam-a-Cove at 710m.
- Once Locality 2 is reached we have a string of localities at around the 750m contour though the last stop is just below Long Top at 850m. The return walk to Three Shire Stone takes just over an hour.

PURPOSE

- through its infill of pyroclastic deposits, to trace the explosive history of the Scafell caldera [$>>400 \text{ km}^3$] including several super-eruptions.
- to use deposit characteristics to determine how the magma fragmented, and how the fragments were transported and deposited.
- to consider the evidence for foundering of the magma chamber roof in a highly faulted manner [piecemeal].



ASPECTS COVERED

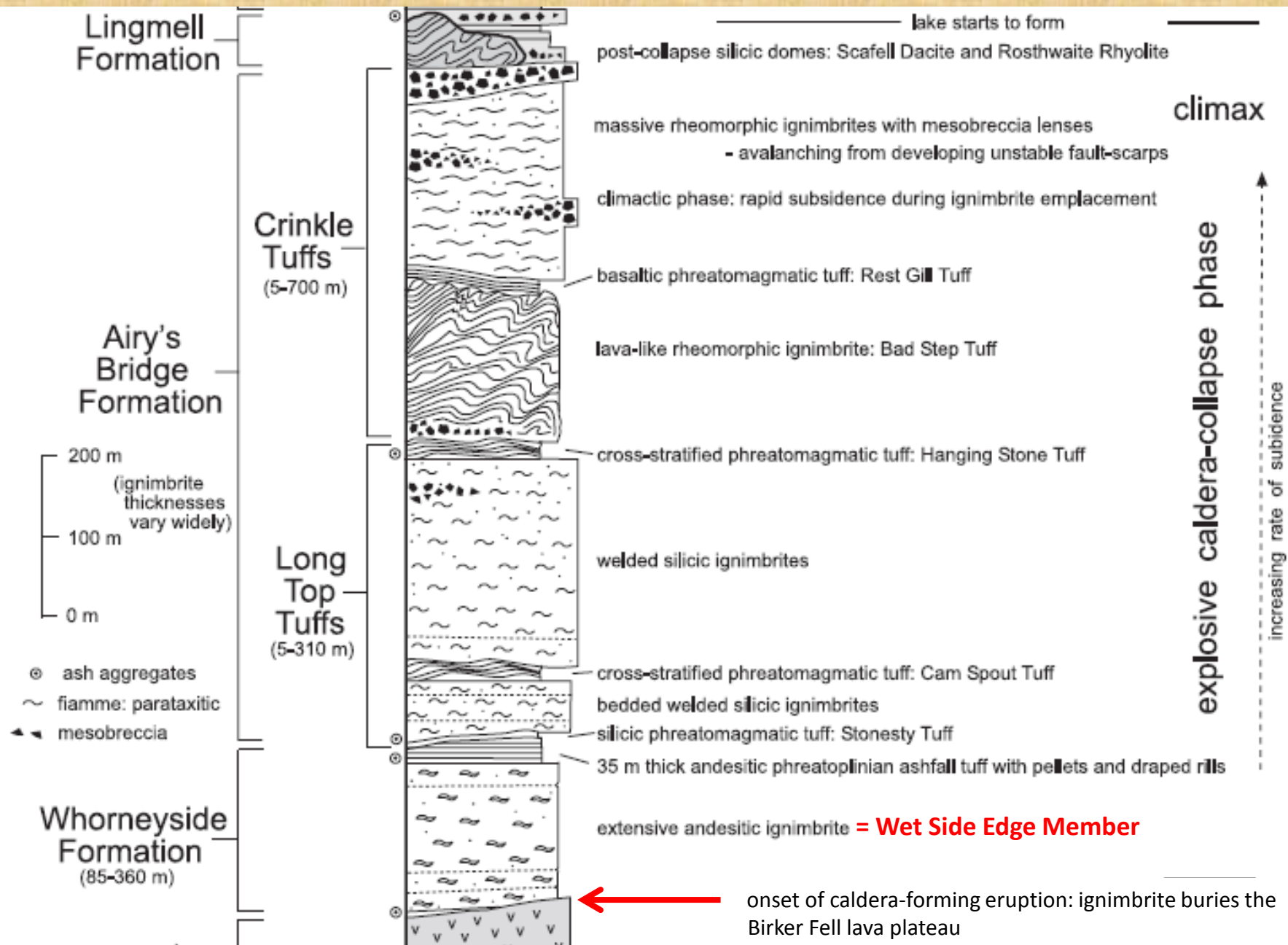
- We will start at the point where the volcanic behaviour of the Borrowdale volcanics changed dramatically from mainly lava eruptions to massive-scale violent explosive eruptions.
- It is claimed that the Scafell caldera is one of the best places in the world to study the effects of removing large volumes of magma from a magma chamber resulting in the collapse and breakup of the roof.
- This piecemeal caldera collapse episodically tipped large volumes of lake water into the magma chamber. The Scafell caldera had several events of this nature including the largest of this kind in the earth's history.

ASPECTS COVERED [cont'd]

- As the magma chamber roof broke up, bedded air-fall tuffs were tilted before significant lithification to produce an array of outstanding soft-sedimentary deformation structures.
- We will see cross-bedded ignimbrites, and welded ignimbrites, and will use the deposits to infer how the magma fragmented, the eruption style, how the pyroclasts were transported, and how they were deposited.
- We will assemble the evidence for the air-fall nature of the Whorneyside bedded tuff which is very different from air-fall deposits of purely magmatic explosivity.

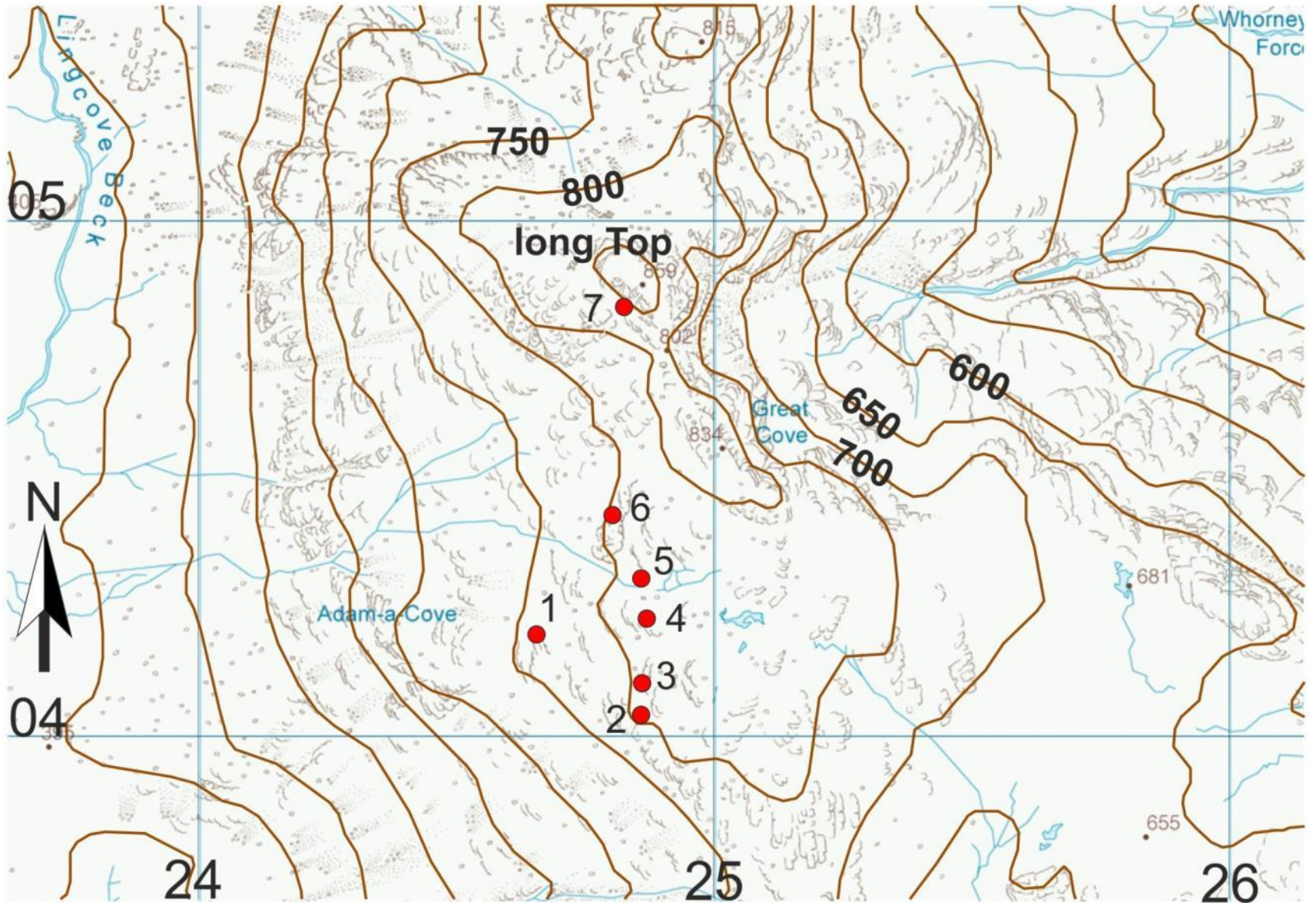


A loose block of welded ignimbrite seen on the path from Red Tarn to the First Crinkle. The pumice fragments [brown] have been considerably flattened and the ragged ends are broken vesicles.



Simplified vertical succession for the Scafell caldera in the Borrowdale Volcanic Group [from Brown et al. 2007 based on Branney & Kokelaar 1994].

Localities for the Cumberland Geological Society Field Trip September 7th 2016



Base map from Ordnance Survey OpenData. Kilometre grid.



LOCALITY 1 In the bottom few metres of the Whorneyside Formation there are interbeds of welded and unwelded ignimbrite. Both were deposited by pyroclastic currents, the unwelded examples as shown here are from the lower end of the density spectrum and they develop sedimentary structures such as the cross-bedding seen in this photo. Typically low-density pyroclastic currents are generated by magmatic explosivity enhanced by interaction with external water [phreatomagmatic]; these are cooler, damp flows, and hence do not weld.



Above Locality 2 there is over 100m of andesitic welded ignimbrite – the Wet Side Edge Member of the Whorneyside Formation. In contrast to the pale weathering rhyolitic ignimbrite higher in the sequence, the andesitic variety is a bit gloomy in its weathering aspect. What were blocks of pumice/scoria have been flattened [because the deposit was hot] to form fiamme; here recessively weathered probably because they were hydrothermally altered.



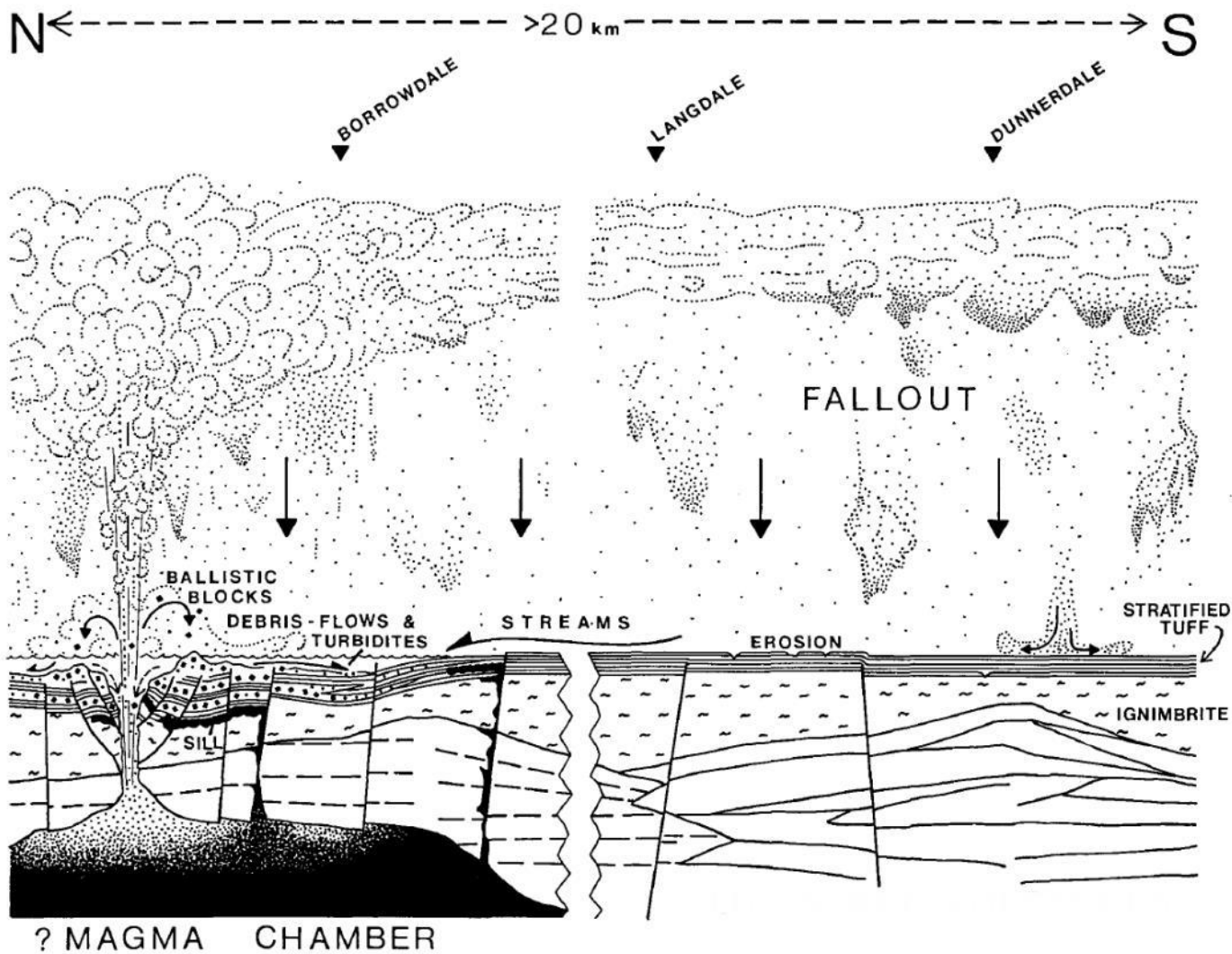
Locality 2 [NY 2487 0403] At least two significant thrusts and many minor ones in the Whorneyside bedded tuff on Stonesty Pike; the deformation took place as fault blocks, defined by caldera-forming volcano-tectonic faults, tilted. The pale bed just below the centre is formed of coated pellets [formerly accretionary lapilli].



Locality 2 Detail of a coated pellet bed – would detailed examination promote these to accretionary lapilli status? Even if this were to happen the latest classification would have them as accretionary pellets!



Erosional rills within the Whorneyside bedded tuff formed in a brief lull in the fall-out event. Layer thickness variations in the rill-filling material is key to distinguishing between deposits from pyroclastic currents and air fall processes [Stonesty Pike, Locality 2].





Branney 1991

Schematic interpretation of the phreatoplinian phase of the Whorneyside eruption. The Birker Fell andesite lava plateau has been completely buried by the Whorneyside ignimbrite and are faulted during initial stages of caldera subsidence. Water has inundated proximal areas following near-vent subsidence that allowed access of large volumes of surface water to the magma. The phreatomagmatic ash is widely deposited as dense showers of ash and accretionary lapilli generated locally within an extensive umbrella cloud. The subaerial ash-fall deposit is subjected to minor rill erosion by surface run-off water following eruption-triggered precipitation. Near the vent, “leakages” of degassed andesitic magma intrude wet deposits, forming peperitic sills (black). Subaqueous ash and peperite slump back into the phreatoplinian vent to be re-ejected. Wet accumulations of ejecta around the vent slough off, forming debris flows and turbidites. Distal ash is not shown. No vertical scale.




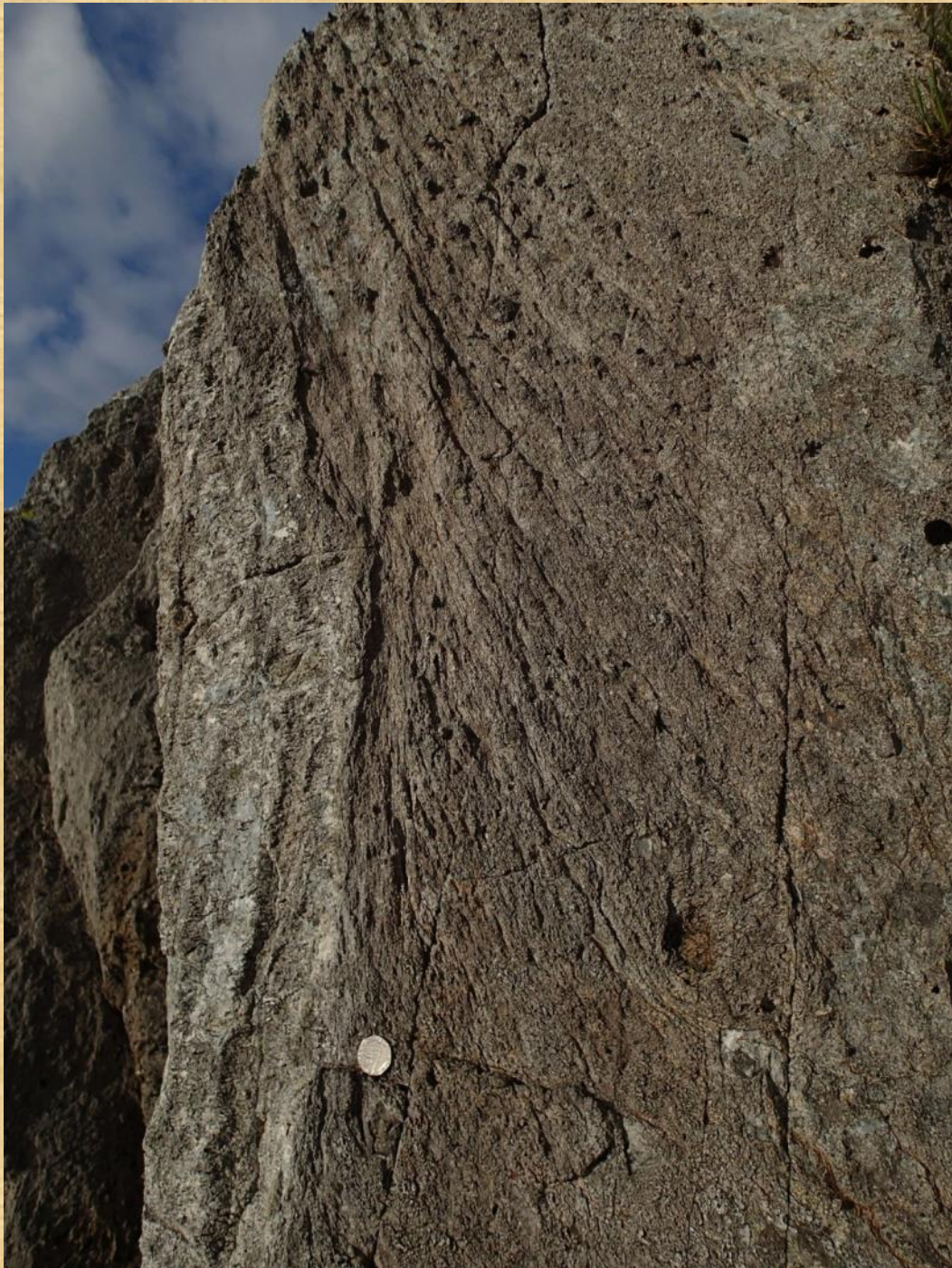
Locality 3 [NY 24867 04085] impact sags caused by lapilli-sized fragments [not quite bomb-sags]. Whorneyside bedded tuff, scale centimetres.



Locality 4 [NY 24855 04111] Angular unconformity between the andesitic Whorneyside bedded tuff  and the overlying pale-weathering rhyolitic Stonesty Tuff  , the basal component of the Airy's Bridge Formation. Siccar Point this is not as the events represented here happened on a timescale of months to years and were created by block rotation during piecemeal caldera collapse.



Locality 5 [NY 24849 04316] Isaac Gill Fault – a volcano-tectonic fault that downthrows Airy’s Bridge Formation rhyolitic ignimbrite to the north against Whorneyside bedded tuff clearly rotating the bedding in the latter. Looking back to Locality 4 shows the general dip of the bedded tuffs and at locality 5 the bedding  abruptly turns to near vertical.



Locality 6 [NY 24815 04417]

Deflection of the gently dipping welding fabric to near vertical adjacent to a volcano-tectonic fault formed during caldera collapse. The ignimbrite was still hot during the deformation of the fabric as demonstrated by the ductile nature of the deflection. The rhyolitic ignimbrite is part of the Airey's Bridge Formation.



Locality 7 [NY 2487 0481] Cross-bedded accretionary lapilli tuff. This is the Hanging Stone Tuff and, despite being only a few metres thick, can be traced to Seathwaite Slabs, near Seatoller. The abundant welded rhyolitic tuffs hereabouts are punctuated by several similar horizons; they are the result of water briefly accessing the magma resulting in a phreatomagmatic eruption which generates moist low-density pyroclastic currents characteristically creating sedimentary structures and ash aggregates. The overlying unit, the Bad Step Tuff, is now classed as a “lava-like rheomorphic tuff” which has variously been interpreted as a lava flow or an intrusion but has now been shown to be an ignimbrite.



Detail of the accretionary lapilli [accretionary pellets in a recent proposal] from **Locality 7**; the largest is 10mm in diameter. Note the rim fragments which show that the laminated coatings were brittle during transport.



Ignimbrite so intensely welded that the pumice fragments are hard to recognise, so much so that this was initially recognised as a lava flow rather than a deposit from a pyroclastic current. Bad Step Tuff, central Crinkle Crag [the grey lichen is 3cm in diameter].

Source Material

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2. Branney, M.J. 1990. Explosive volcanism and volcanotectonic subsidence at Crinkle Crag. *Geologists' Association Guide, The Lake District*.
3. Branney, M.J. 1991. Eruption and depositional facies of the Whorneyside Tuff Formation, Lake District: an exceptionally large-magnitude phreatoplinian eruption. *Geol. Soc. Am. Bull.*, 103, 886–897.
4. Branney, M.J. and Kokelaar, B.P. 1994. Volcanotectonic faulting, soft-state deformation and rheomorphism of tuffs during development of a piecemeal caldera, English Lake District. *Geol. Soc. Am. Bull.*, 109, 507–530.
5. Francis, P.W. & Oppenheimer C. 2004. *Volcanoes*. Oxford University Press.
6. Millward D. et al. 2000. *Geology of the Ambleside District*. Memoir of the British Geological Survey, Sheet 38 (England and Wales).