

Crinkle Crags Excursion:
formation of the Scafell caldera

Joint Westmorland and Cumberland Geological Societies Excursion
12 June 2024

Leader: David Haselden

Based on the CGS Field Excursion led by Clive Boulter
7th September 2016
All photos by D Haselden unless otherwise noted

LOGISTICS

- Meet at the Blea Tarn National Trust Car Park (NY 2956 0432) to consolidate car use, discuss the weather and decide whether to go up the Crinkles or to do a lower level alternative. Two alternatives will be offered depending on the weather; Wrynose Pass to Blea Tarn and Side Pike.
- **Please be prepared to leave promptly.**
- If the weather is good we will head up to the Three Shire Stone **for 10h00** and set off 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 Crags, crossing a major caldera fault at Browney Gill, to reach a large cairn just before the first Crinkle (NY 2513 0440) Here we'll leave the path and head for Locality 1 in Adam-a-Cove (NY 2462 0415) involving a descent of ~70m.
- After ascending to Locality 2 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.
- **Please Note: for localities 2 & 7 you may feel more comfortable with a hard hat for close examination of the exposures.**

PURPOSE

- Through it's infill of pyroclastic deposits, to trace the explosive history of the Scafell caldera [>>400 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).



Source - internet

ASPECTS COVERED

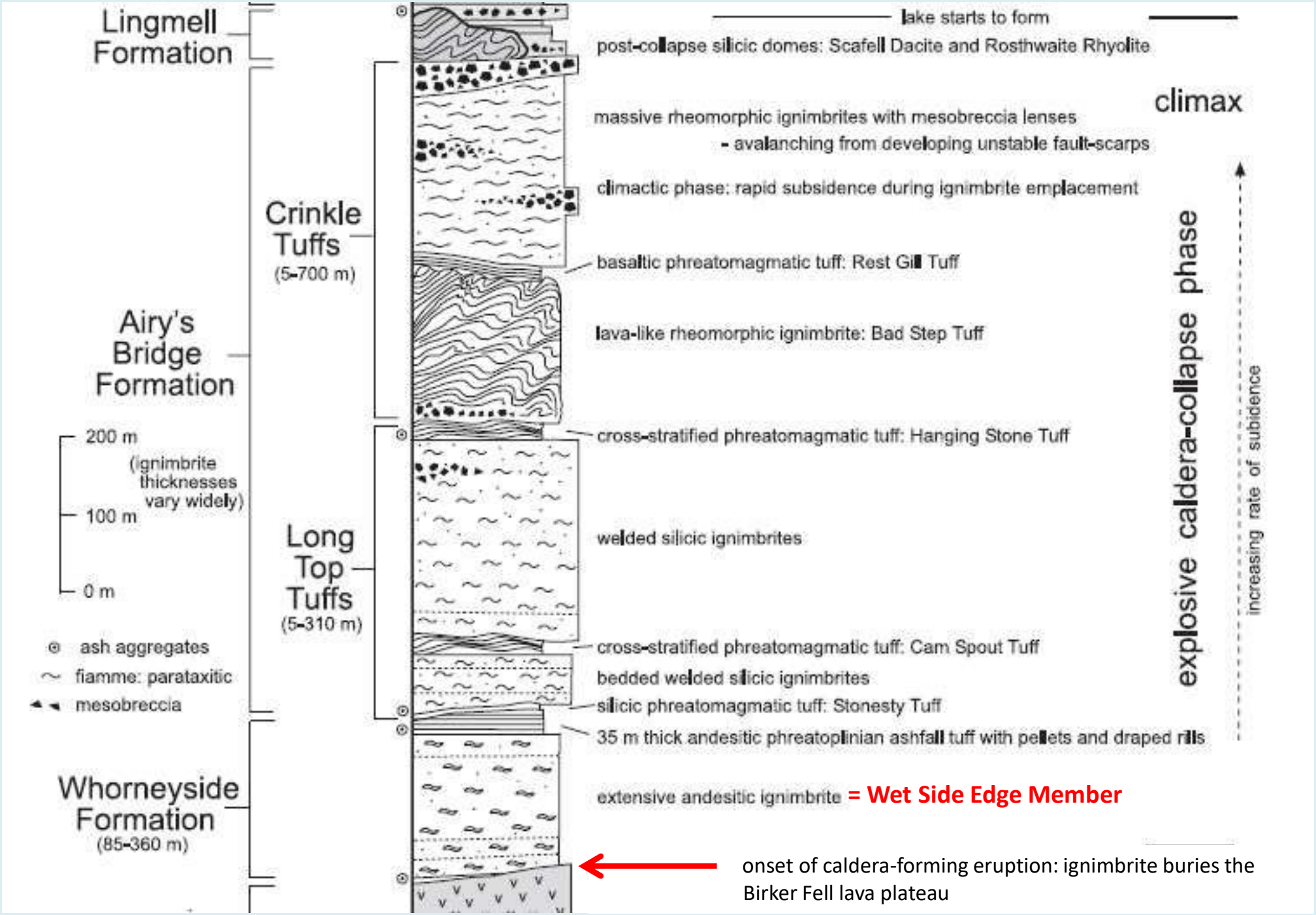
- Locality 1 is at the point where the volcanic behaviour of the Borrowdale volcanics changed dramatically from mainly effusive lava eruptions to massive-scale violent explosive eruptions.
- The Scafell caldera is one of the best places in the world to study the effects of removing large volumes of magma from a magma chamber resulting in the breakup of the roof and piecemeal caldera collapse.
- 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 (phreatoplinian) in the earth's history.

ASPECTS COVERED [cont'd]

- We will look for the evidence for the air-fall nature of the Whorneyside bedded tuff which is very different from air-fall deposits of purely magmatic explosivity (Locality 2)
- As the magma chamber roof broke up the bedded air-fall tuffs were tilted before significant lithification to produce an array of outstanding soft-sedimentary deformation structures (Locality 2)
- We will see a variety of deposits produced by a pyroclastic density currents (ignimbrites) including cross-bedded ignimbrites, and welded ignimbrites.

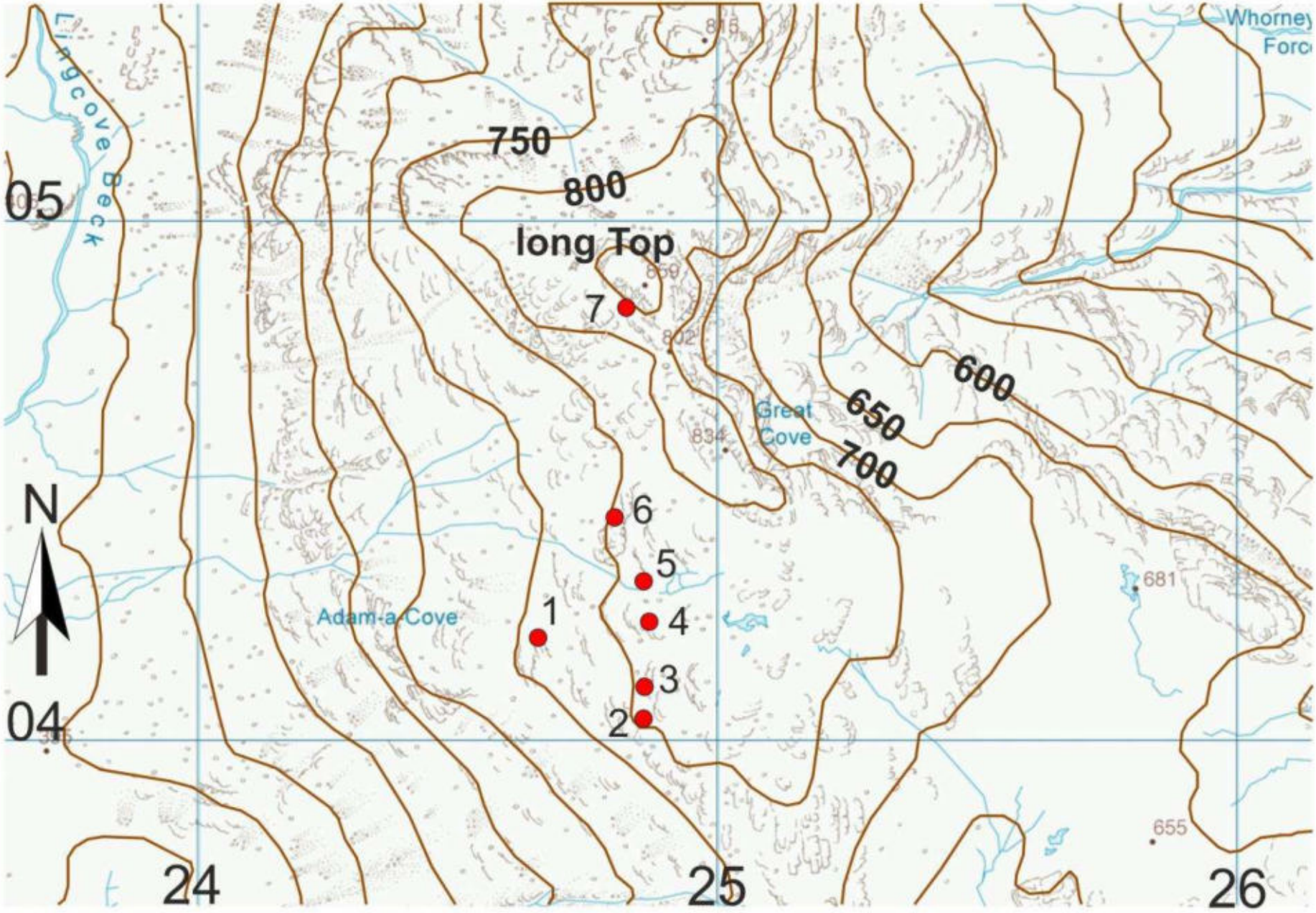


An example of welded ignimbrite. The pumice fragments [brown] have been considerably flattened and the ragged ends are broken vesicles.



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 The onset of caldera forming explosive volcanism. 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 form from the lower end of the density spectrum and they develop sedimentary structures such as cross-bedding. 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.



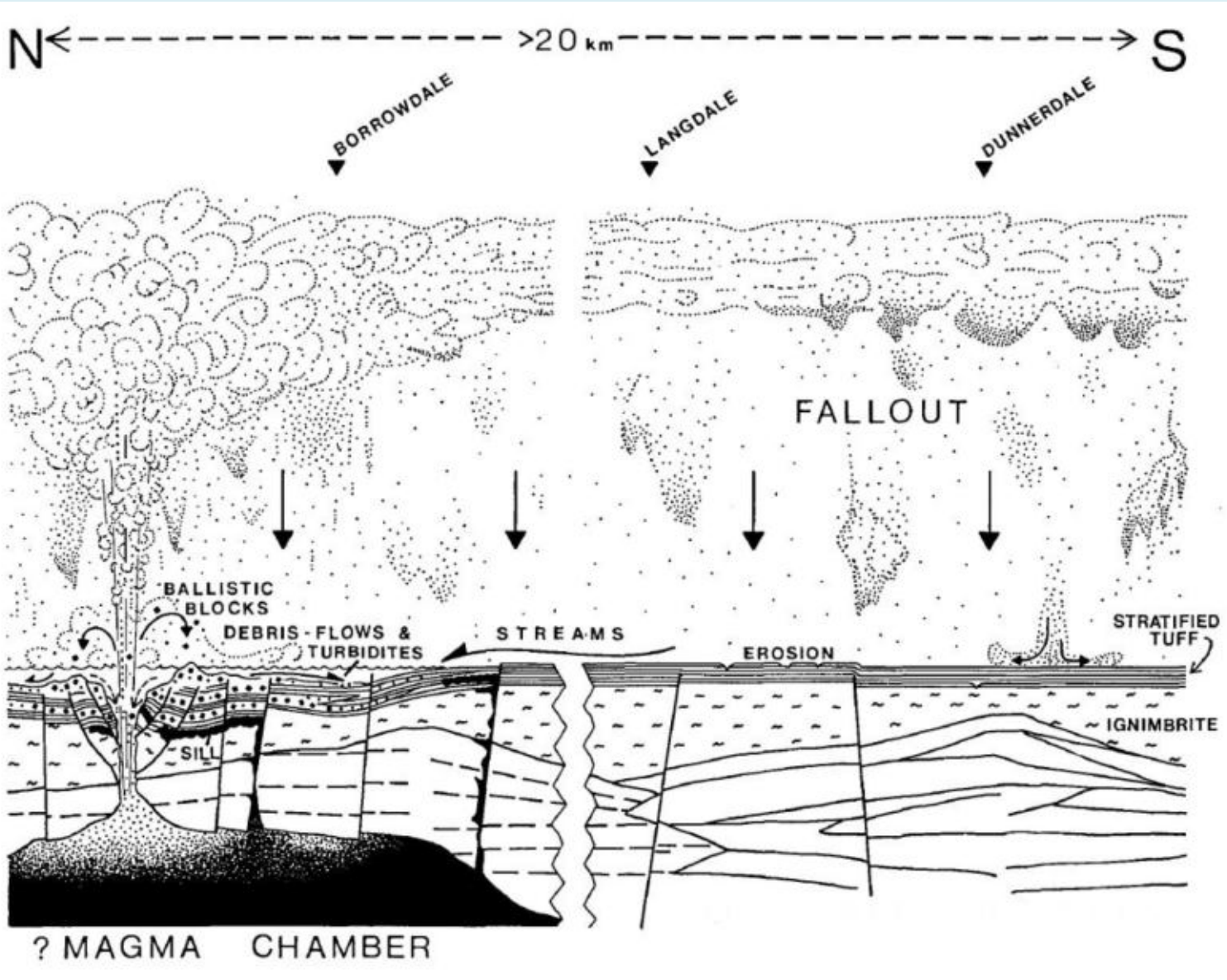
Above Locality 1 there is over 100m of andesitic welded ignimbrite – the Wet Side Edge Member of the Whorneyside Formation. In contrast to the pale weathering rhyolitic ignimbrite higher in the sequence, the andesitic variety is a bit gloomy in its weathering aspect. What were blocks of pumice have been flattened because the deposit was hot to form fiamme; here recessively weathered probably because they were hydrothermally altered.



Locality 2 [NY 2487 0403] The Whorneyside Bedded Tuff an airfall tuff deposited from an exceptionally large magnitude phreatoplinian eruption (>100 km3) caused by several tens of km3 of water entering the magma chamber. The exposure displays spectacular soft sediment deformation with several significant thrusts and many other structures in the compressional part of an inferred slide as fault blocks, defined by caldera-forming volcano-tectonic faults, tilted. The pale bed just above the book is formed of coated pellets.



Locality 2 Detail of the coated pellet bed, some showing multiple rims so are accretionary lapilli (book is 13cm).



Branney 1991

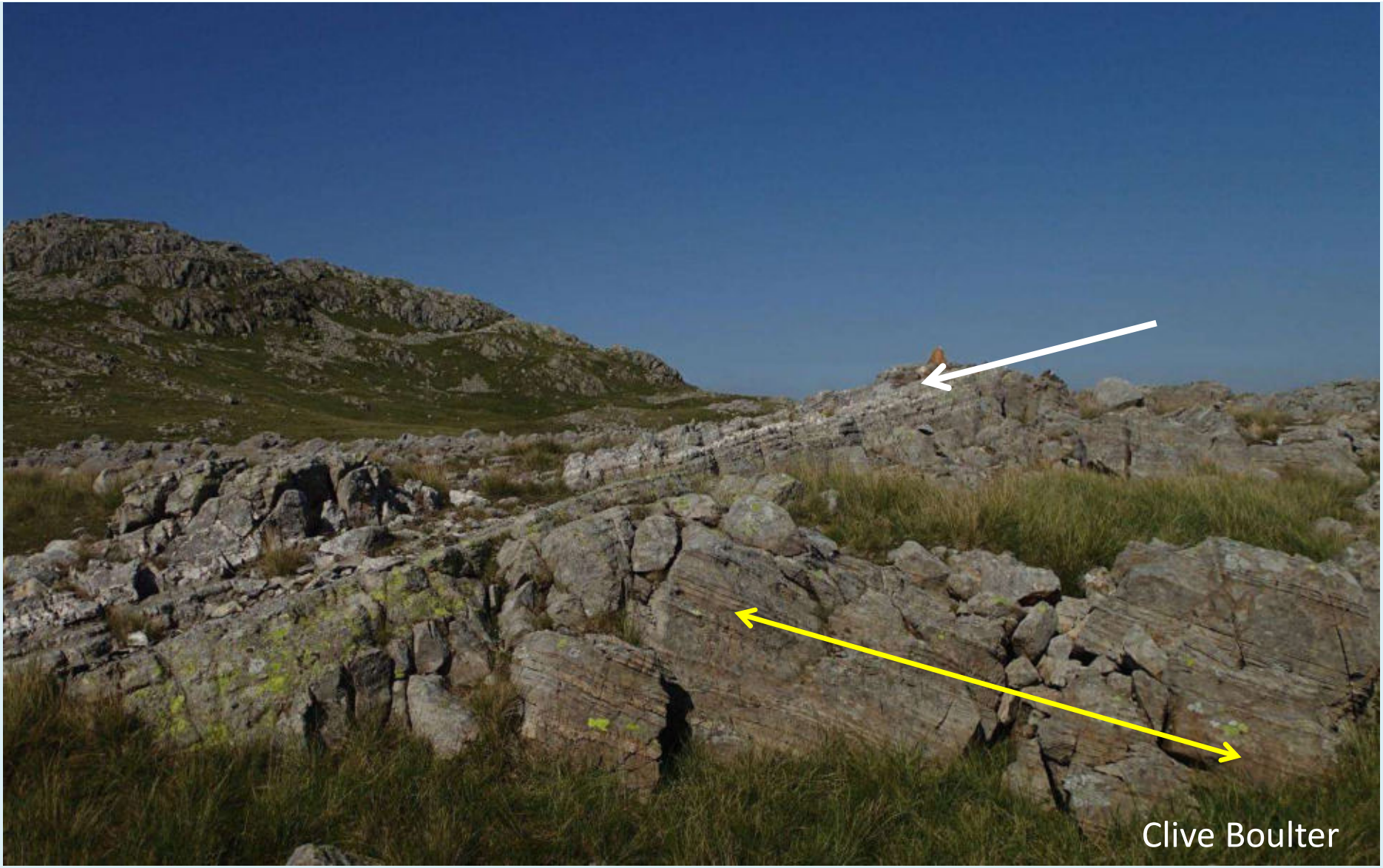
Schematic interpretation of the phreatoplinian phase of the Whorneyside eruption. The Birker Fell andesite lava plateau has been completely buried by the Whorneyside ignimbrite and are faulted during initial stages of caldera subsidence. Water has inundated proximal areas following near-vent subsidence 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). Subaqeous 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.



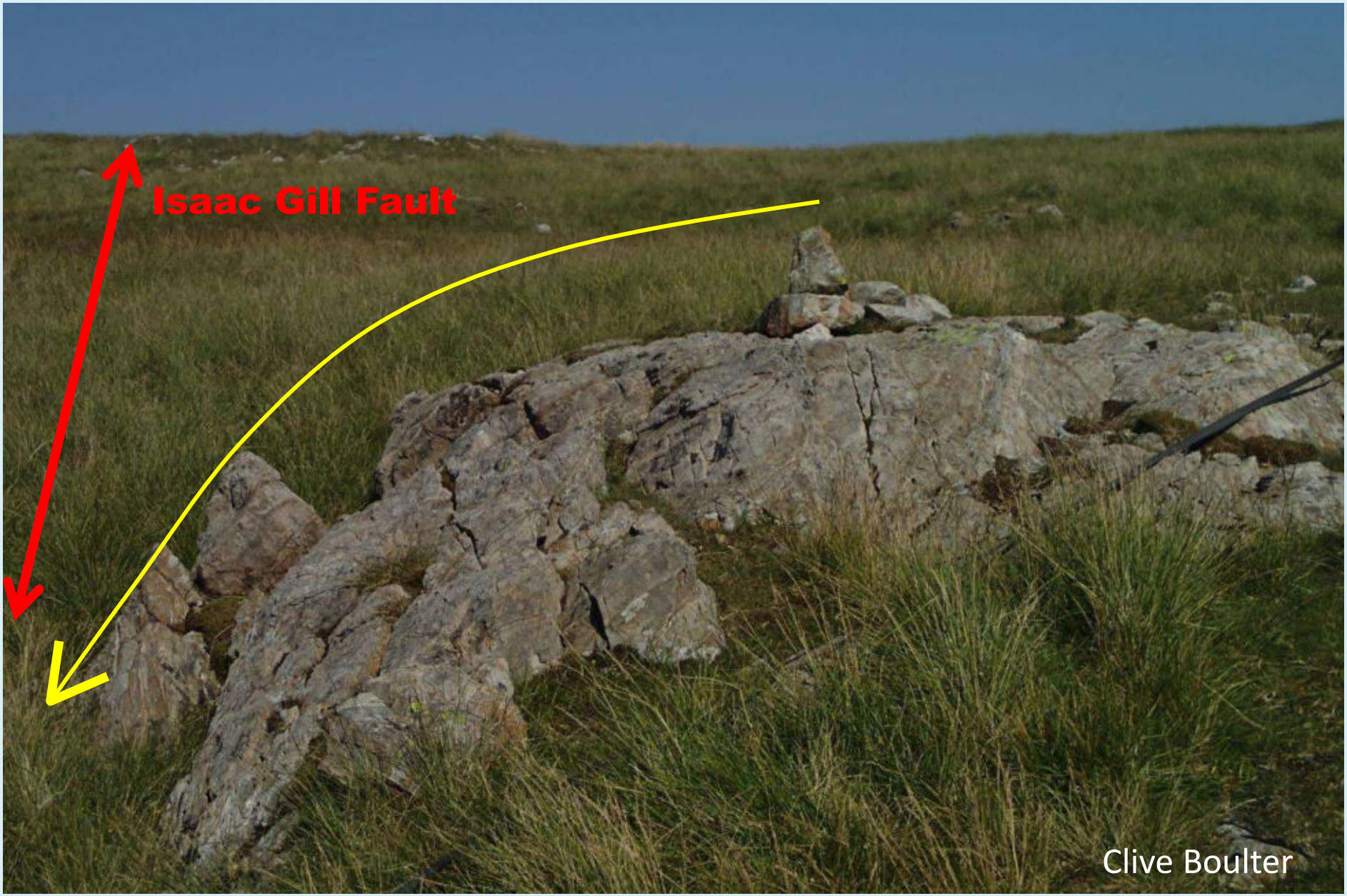
Locality 3 [NY 24867 04085] An erosional rill towards the top of the Whorneyside bedded tuff formed in a brief lull in the fall-out event. Layer thickness variations in the rill-filling material is key to distinguishing between deposits from pyroclastic currents and air fall processes.



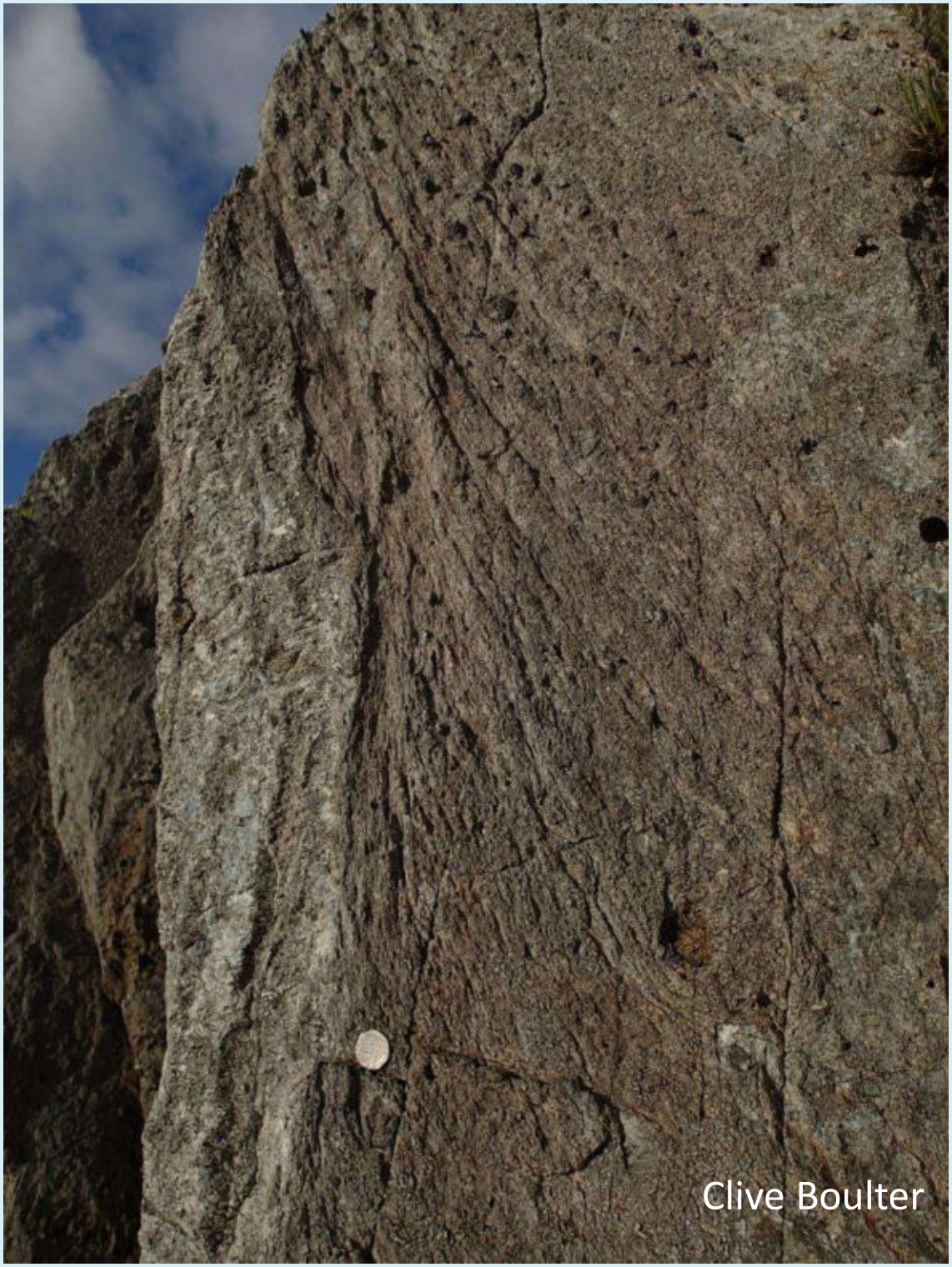
Locality 3 [NY 24867 04085] Impact sags caused by lapilli-sized fragments [not quite bomb-sags]. Whorneyside bedded tuff, scale centimetres.



Locality 4 [NY 24874 04226] 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. Since unlithified tephra is very easily eroded, the eruption of the Stonesty Tuff must have occurred very soon (months?) after the Whorneyside bedded tuff was deposited and slumped – indicating the dynamic nature of the 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] The Hanging Stone Tuff (centre) between the pale weathered Long Top Tuff and a pyroclastic breccia at the base of the Bad Step Tuff (above overhang) which 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



Locality 7 [NY 2487 0481]. The Hanging Stone Tuff is a cross-bedded accretionary lapilli 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.



Detail of the accretionary lapilli from **Locality 7**; the largest is 10mm in diameter. Note the rim fragments which show that the laminated coatings were brittle during transport and is one of the features indicating transport by a pyroclastic density current rather than airfall.



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 Crags [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 Crags. 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).