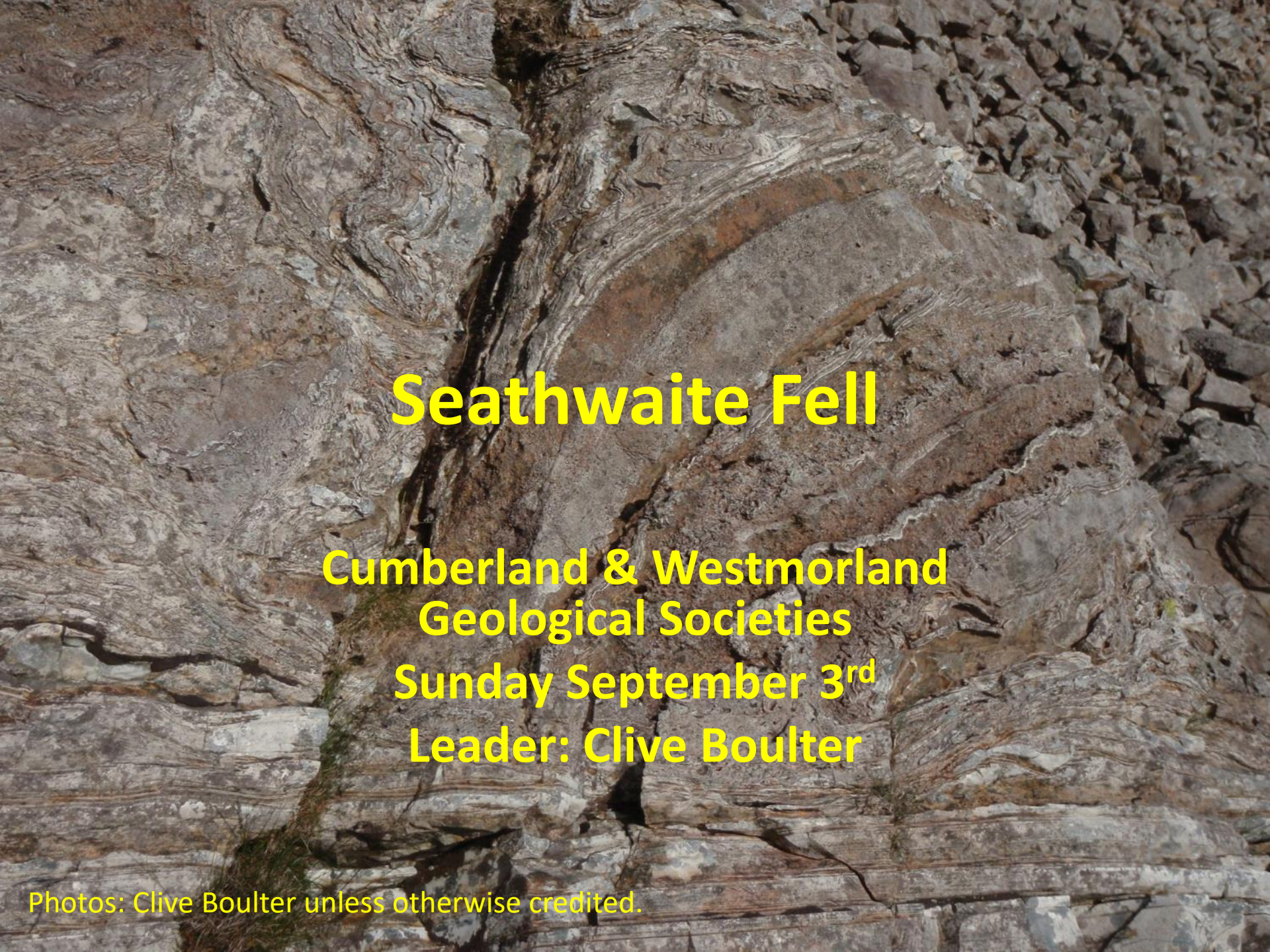


Seathwaite Fell

Cumberland & Westmorland Geological Societies

Sunday September 3rd

Leader: Clive Boulter

Photos: Clive Boulter unless otherwise credited.

Meeting Point: the south end of Seathwaite Farm NY 235122 at 10h00. The weather forecast the on the evening before the trip will be used to decide if the Seathwaite Fell trip goes ahead, or Seathwaite Slabs are used, or the day is abandoned. Notification of changes will be via the Cumberland Geological Society's web site.

Parking: on the road between Seatoller and Seathwaite Farm at no charge or at the farm [£3 per day].

Toilets: National Trust toilets at Seathwaite Farm.

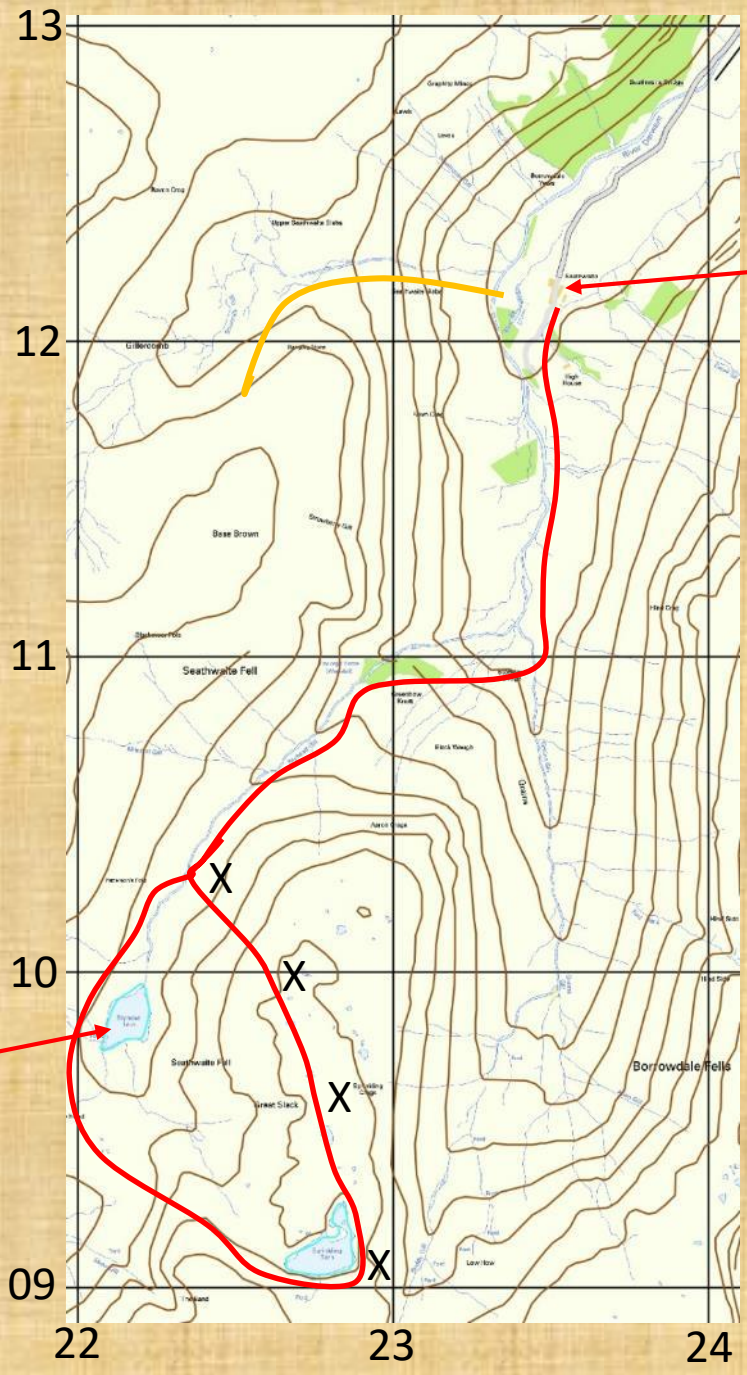
Poor weather alternative: Seathwaite Slabs to the west of the farm. It could be high winds that stop us going to the high fells and this alternative provides protection from the westerlies – see last slide.

Geological Overview

After many 100s km^3 of magma were evacuated from the Scafell magma chamber in catastrophic explosive eruptions, piecemeal collapse of the roof left an approximately 20 x 20 km depression. The uneven breakup of the magma chamber roof gave rise to a varied topography but the nature of the margins of the caldera is poorly defined and steep walls may have been subordinate to gentle slopes on inward-tilted strata. Substantial topography was present locally as indicated by boulder-grade sedimentary breccias of ignimbrite clasts [talus breccias] sourced on fault scarps generated by volcano-tectonic faults. Throughout much of the history of the caldera it was occupied by a freshwater lake that was infilled by the Seathwaite Fell Formation, a predominantly subaqueously-deposited sequence of volcanogenic sedimentary rocks. During sedimentation ongoing magmatic activity meant that faults were active from time to time and magma rising through the lake sediments would have caused distortion of the lake floor because it tended to intrude at shallow levels. Seathwaite Fell gives us a rare opportunity to examine a dissected caldera-lake sequence where 3D/4D analysis is possible in contrast to the type of information gained from drill core in modern equivalents. Water depths were at least a couple of hundred metres in large parts of the caldera at the time of the Pavey Ark eruption because the sedimentation style did not change above and below this thick ignimbrite.

The main reference for the excursion is Kneller, B.C. and McConnell, B.J., 1993, The Seathwaite Fell Formation in the Central Fells, British Geological Survey Technical Report WA/93/43.

Generalised Location Map



Seathwaite Farm

Styhead Tarn

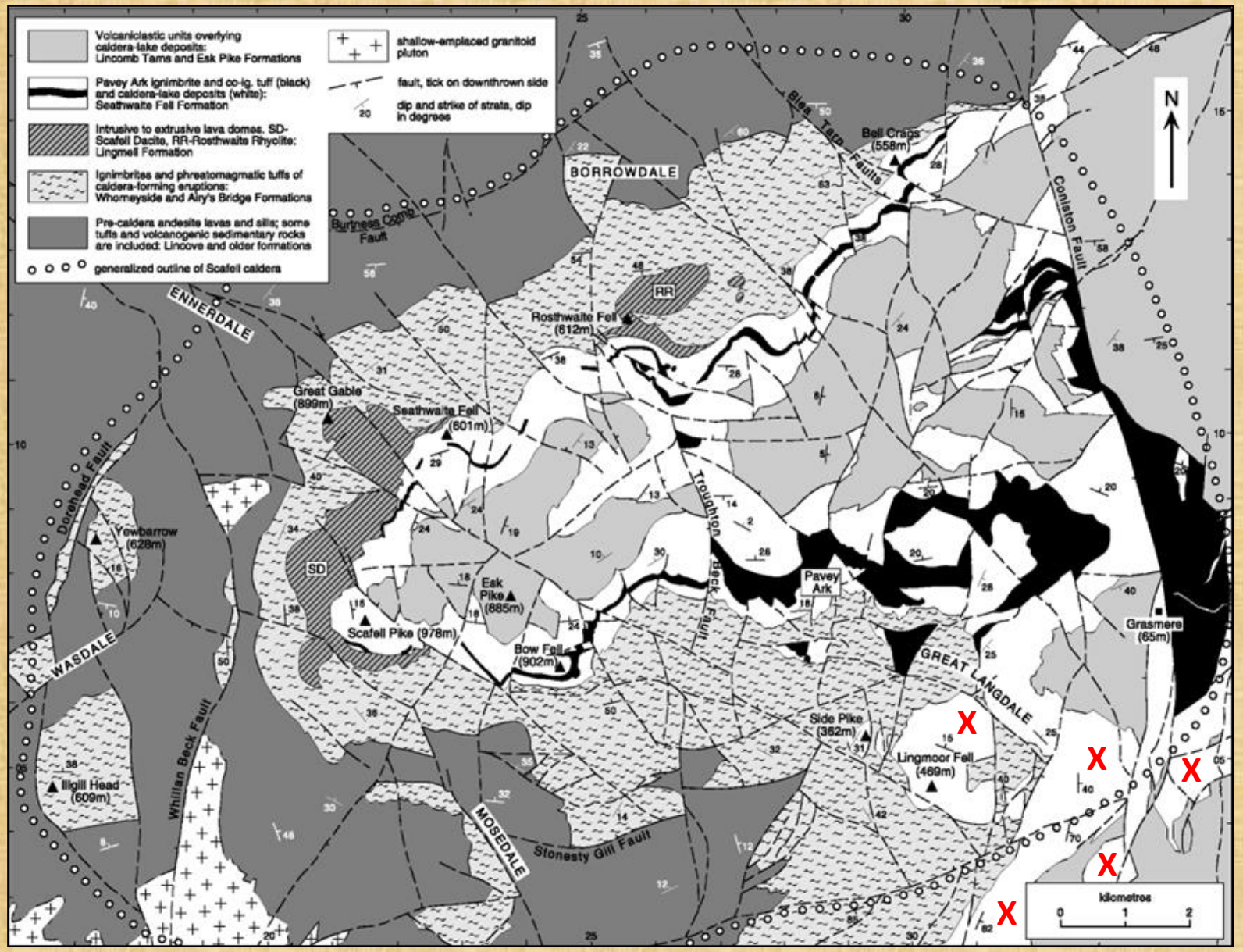
Seathwaite Fell route.

Seathwaite Slabs [poor weather alternative].

X X X Geological traverse – NO PATHS

Based on Ordnance Survey OpenData Kilometre grid.

Generalised Outline of the Scafell Caldera



Kokelaar et al. 2007 Incursion of a large-volume, spatter-bearing pyroclastic current into a caldera lake: Pavey Ark ignimbrite, Scafell caldera, England, Bulletin of Volcanology, vol. 70, pp. 23-54. X = areas incorrectly assigned to the Scafell caldera, Seathwaite Fell Formation; they belong to the Langdale caldera.

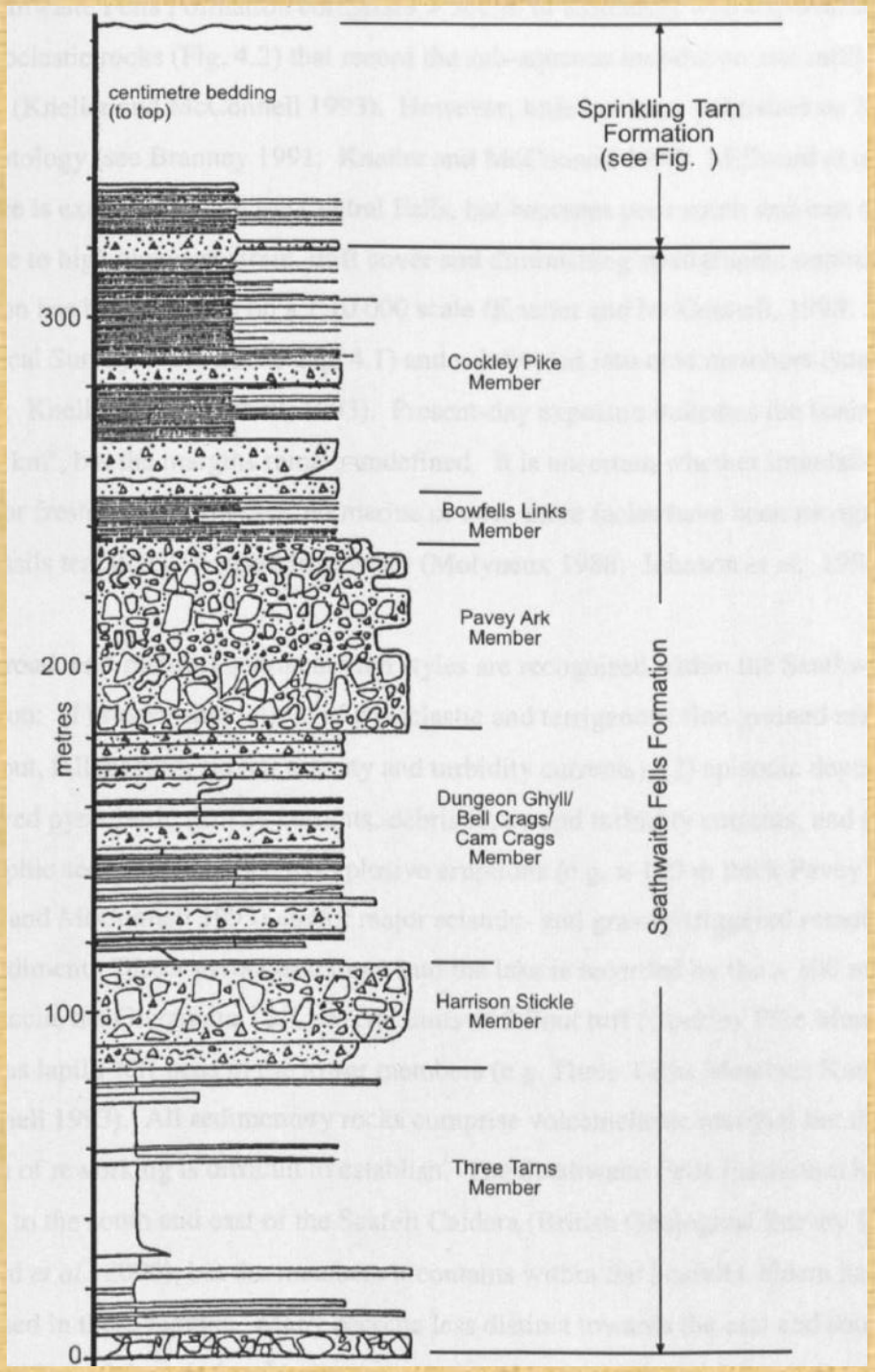
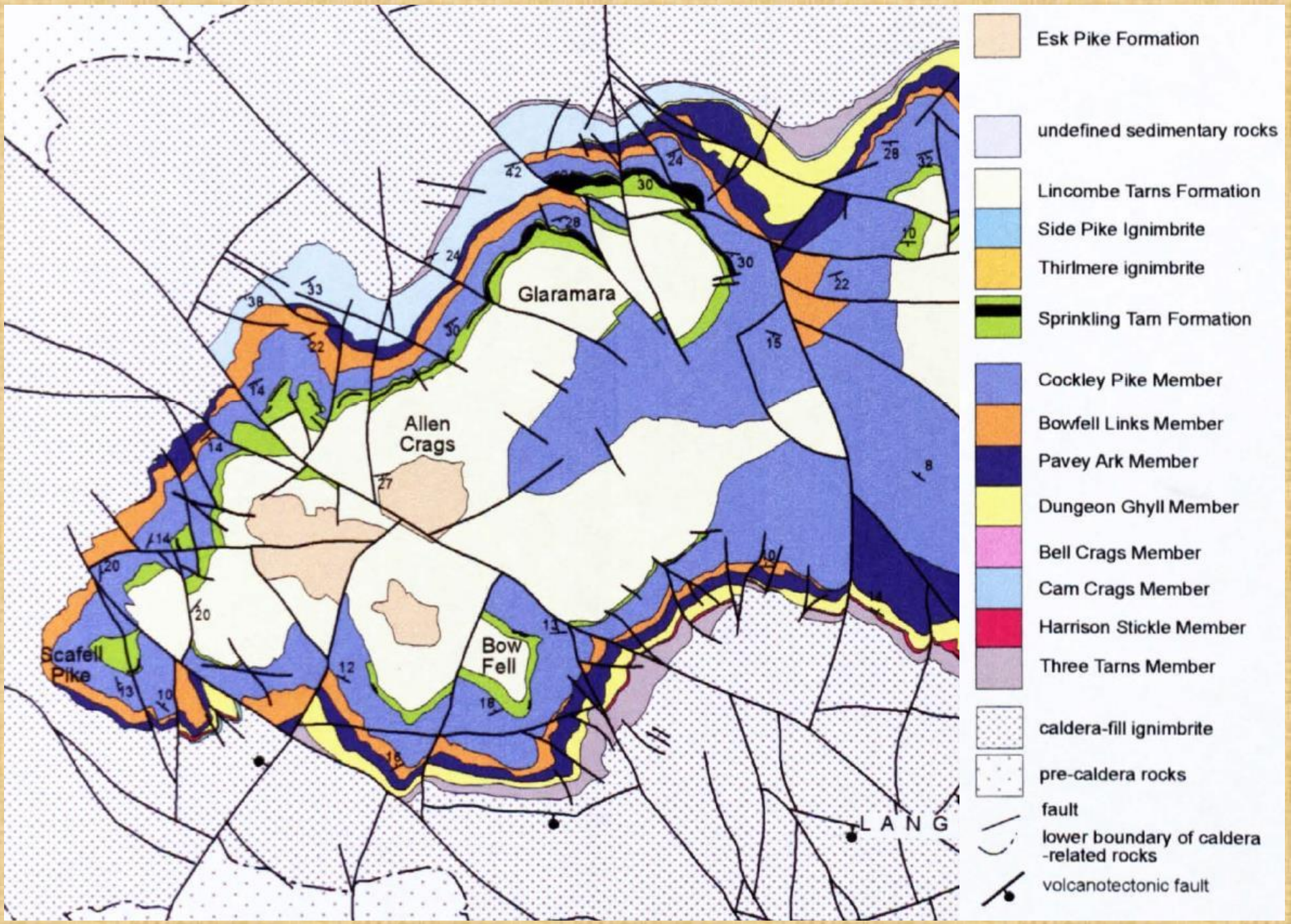


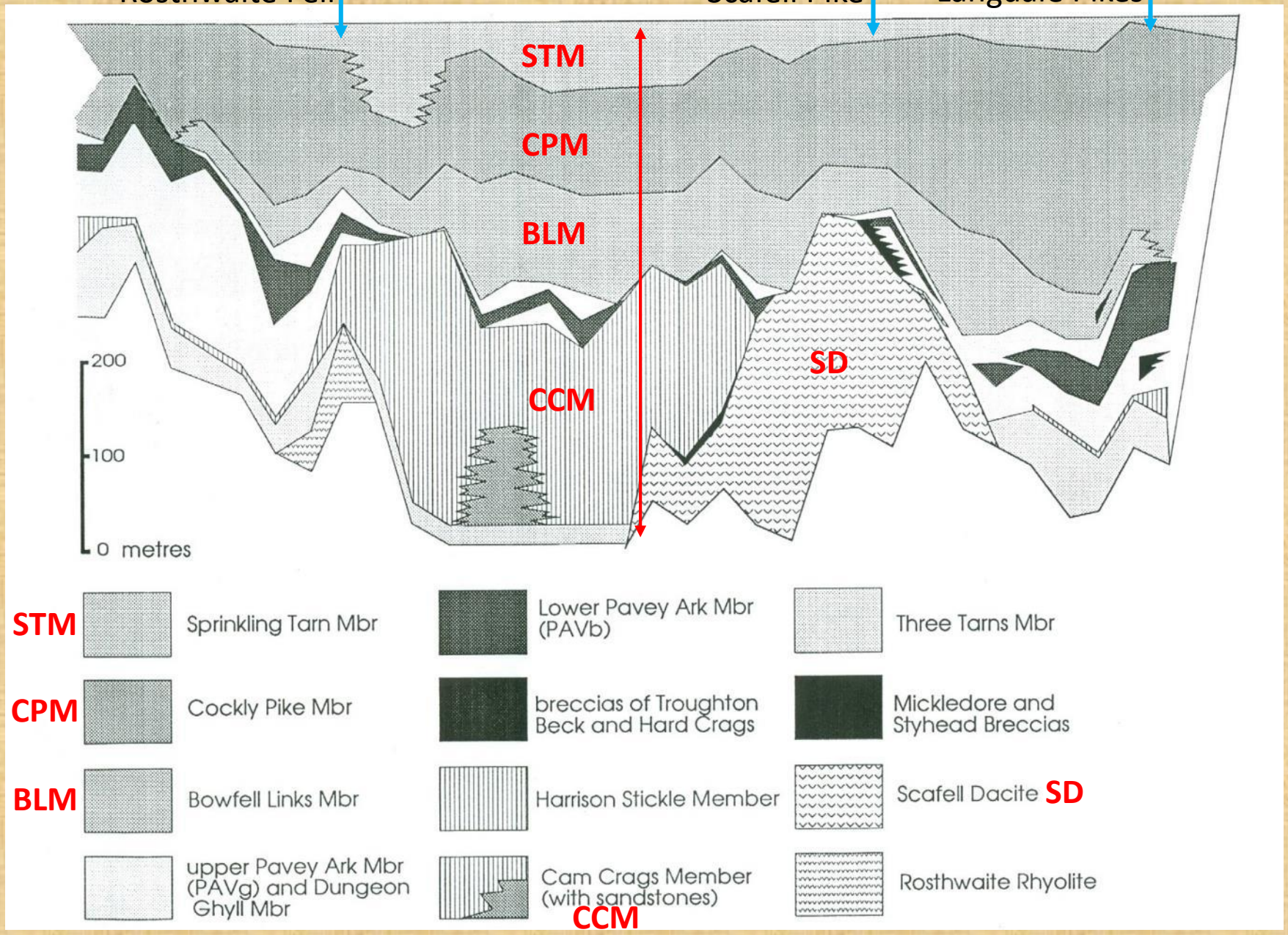
Figure 4.4. from Rich Brown's PhD thesis.

Generalised vertical succession through the Seathwaite Fell Formation as exposed in north Langdale, showing its overall character and most of the constituent members (modified from Kokelaar et al. 1990). Lateral variations mean that not all members are present in all areas.

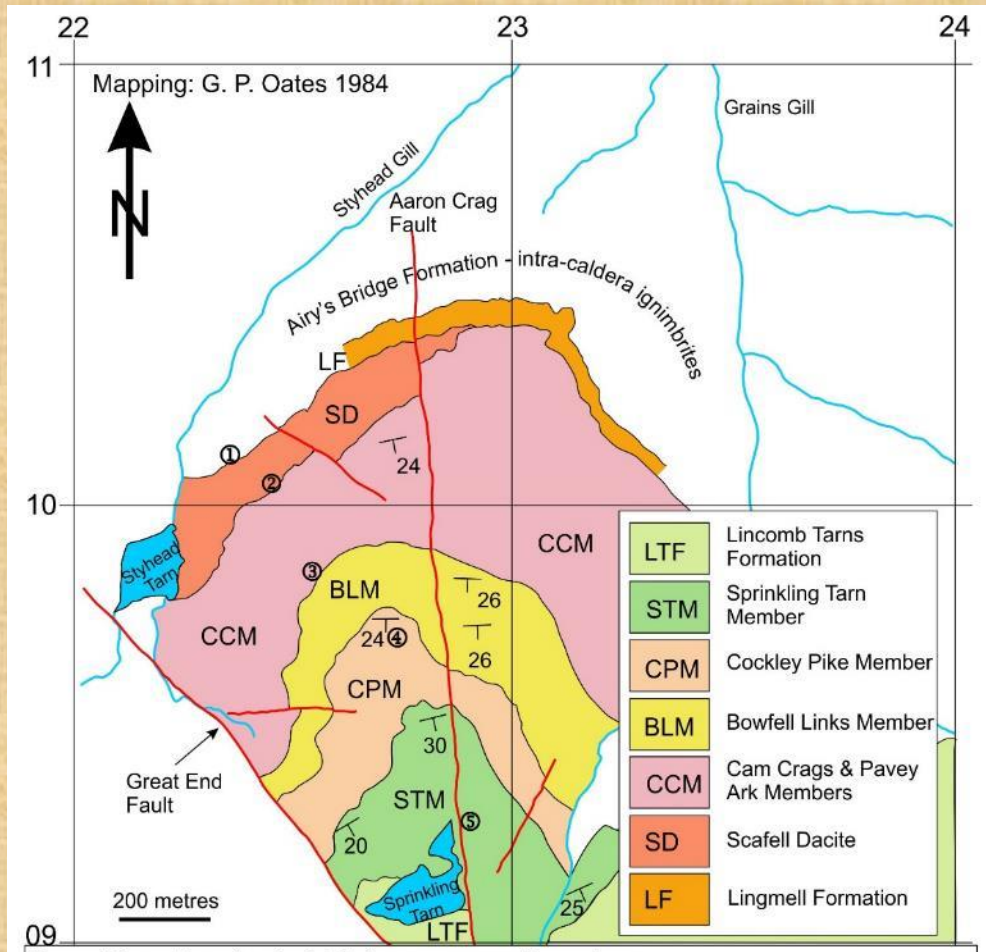
The Seathwaite Fell Formation is a dominantly sedimentary package comprising breccia, sandstone, pebbly sandstone, siltstone, and mudstone. The thick breccias (Pavey Ark and Harrison Stickle Members) record catastrophic influxes of sediment into the basin by pyroclastic density currents (Kneller and McConnell 1993).



British Geological Survey mapping of the Seathwaite Fell Formation as reported in R. J. Brown PhD Thesis.



Lateral variations in the Seathwaite Fell Formation [Kneller & McConnell, 1993, British Geological Survey, Technical Report WA/93/43]. The red line shows the succession seen on the Seathwaite Fell excursion.



Lincomb Tarns Formation: ignimbrite from a younger caldera volcano.

Sprinkling Tarn Member: alternations of several metre thick packets of perfectly-parallel air-fall deposits and pebbly coarse volcaniclastic sandstones; the latter are interpreted as Disordered Turbidite Facies [DTF] identical to the Cockley Pike Member. Glaramara Tuff near the top; a tuff-ring deposit.

Cockley Pike Member: Massive or weakly stratified coarse to very coarse-grained sandstone with minor fine-grained sandstone, siltstone, and sedimentary breccia. Poor sorting is the norm and grading is unsystematic. Interpreted as the deposits of catastrophic high-density flows [DTF].

Bowfell Links Member: Thinly-bedded parallel, and cross-bedded siltstone with fine-grained sandstone; minor coarse sandstone and diagenetically-compacted fiamme. Interpreted as a mixture of low- & high-density turbidite deposits. Much soft-sedimentary deformation near faults.

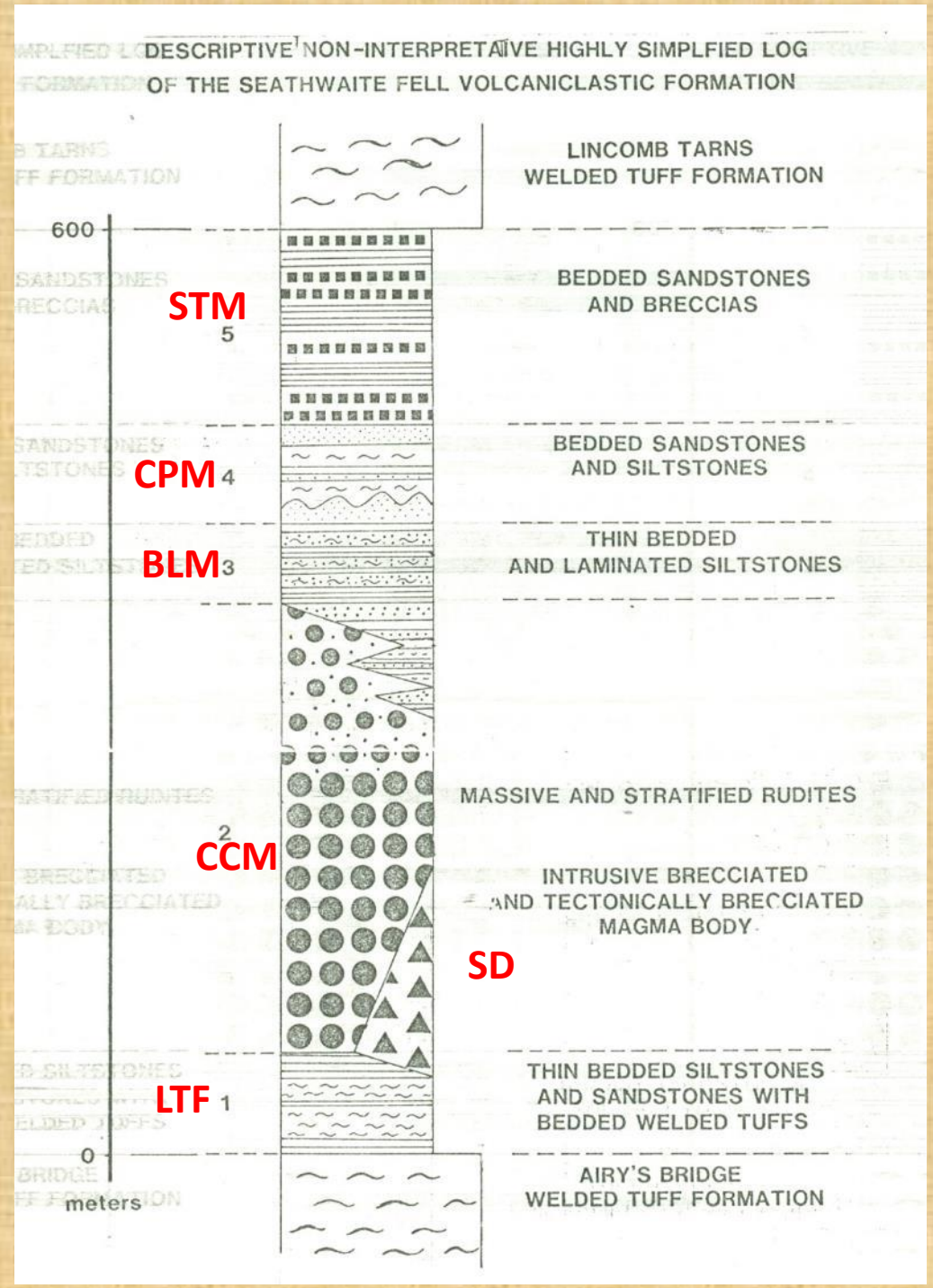
Pavey Ark & Cam Crags Members: Pebble-grade breccia and pebbly coarse-grained sandstone. The Pavey Ark is andesitic and the Cam Crags is dacite to rhyolite; the latter is interpreted as deltaic deposits.

Seathwaite Fell Formation

Scafell Dacite: Extensively autobrecciated, flow-banded, garnetiferous lavadome, lava flows, and locally intrusive. Some aprons of matrix-supported breccias.

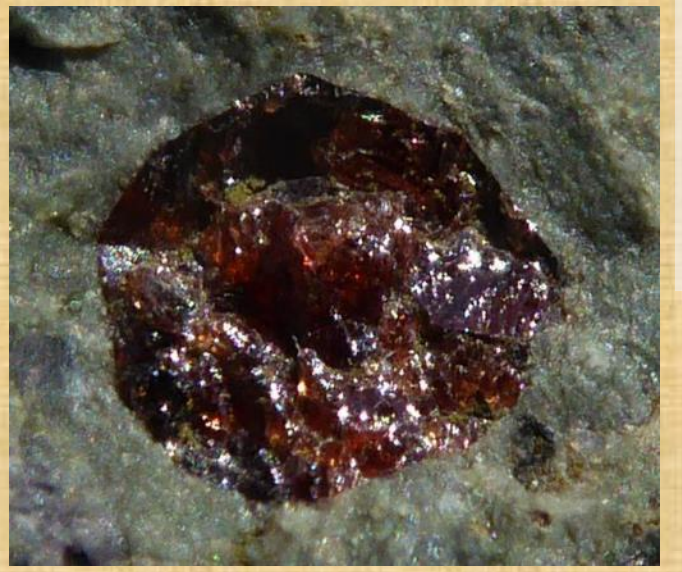
Lingmell Formation: Garnetiferous welded ignimbrite, sandstone, siltstone, pebbly sandstone, and sed. breccia. [pyroclastic density current deposits with some reworking]

Modified from G P Oates: British Sedimentological Research Group, Volcaniclastics Field Meeting, October 1984.

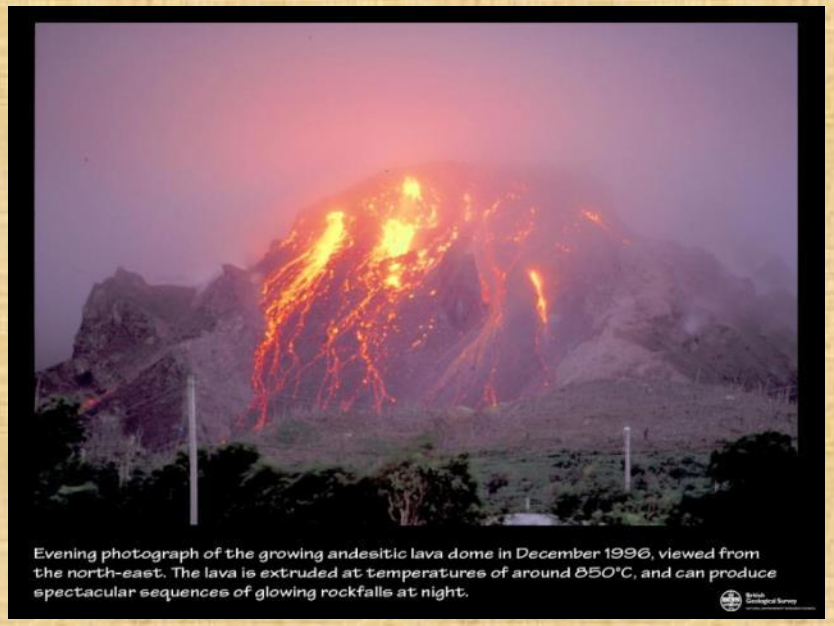


G P Oates: British Sedimentological Research Group, Volcaniclastics Field Meeting, October 1984.

Locality 1 [NY 22350 10185]: Scafell Dacite and a tiny bit of the Lingmell Formation ignimbrite.



This set of notes is organised as a series of descriptions of fixed localities but on the traverses between these points other features will be discussed on the day. For each of the formations/members on Seathwaite Fell no one locality provides all the key features.



Extrusion of the Scafell Dacite lava dome took place before the caldera lake was established. The lava dome in part was steep-sided and flanked by sandy and pebbly aprons of dacitic clasts. Elsewhere lobes of autobrecciated dacite flows spread further and their tops were infiltrated by fine-grained lacustrine deposits.

Garnet phenocrysts [see photo] are commom in Lingmell Formation ignimbrite and the Scafell Dacite though worldwide very few volcanic successions have such phyric phases. Garnet crystallises from peraluminous magmas [Al > K + Na], a condition normally taken to mean that pelitic sedimentary rocks were assimilated into the magma. For the Borrowdales the most likely source the aluminium-rich rocks is the Skiddaw Group but, as this would have happened at high crustal levels, there is some doubt that the pressure at these depths was enough to allow a high-pressure phase like garnet to be stable.

Autobrecciated Scafell Dacite with flow banding at different orientations from clast to clast. Ruc-sac for scale.



The traverse through the Scafell Dacite is almost exclusively in autobrecciated dacite. Flow banding is prominent in most clasts and its orientation varies from clast to clast.



A closer view of the autobrecciated Scafell Dacite and its disoriented flow banding.

Locality 2 [NY 22428 10012]: Contact between the Scafell Dacite and the Cam Crags Member.



The lower pale part of this exposure is brecciated Scafell Dacite with a white, extremely fine-grained, porcellaneous sedimentary matrix [?infilling autobreccia by infiltration or ?peperite intrusive top?]. The dark upper crags are pebble-grade sedimentary breccias of the deltaic Cam Crags Member [note the stratification dipping to the right].



A representative exposure [approx. three metres high] of the deltaic pebble-grade sedimentary breccias of the Cam Crags Member. Tabular cross-bedding on the several tens cm scale is seen elsewhere. The Cam Crag delta prograded into the lake from the northwest forming a 275 m thick fan delta or Gilbert-type delta. Clasts are dacite and rhyolite and are pale-weathering. The later Pavey Ark Member [a subaqueous pyroclastic-density-current deposit] was deflected around the topography created by this delta and is not preserved on the excursion traverse. Clasts in the Pavey Ark Member are mostly andesite in composition.

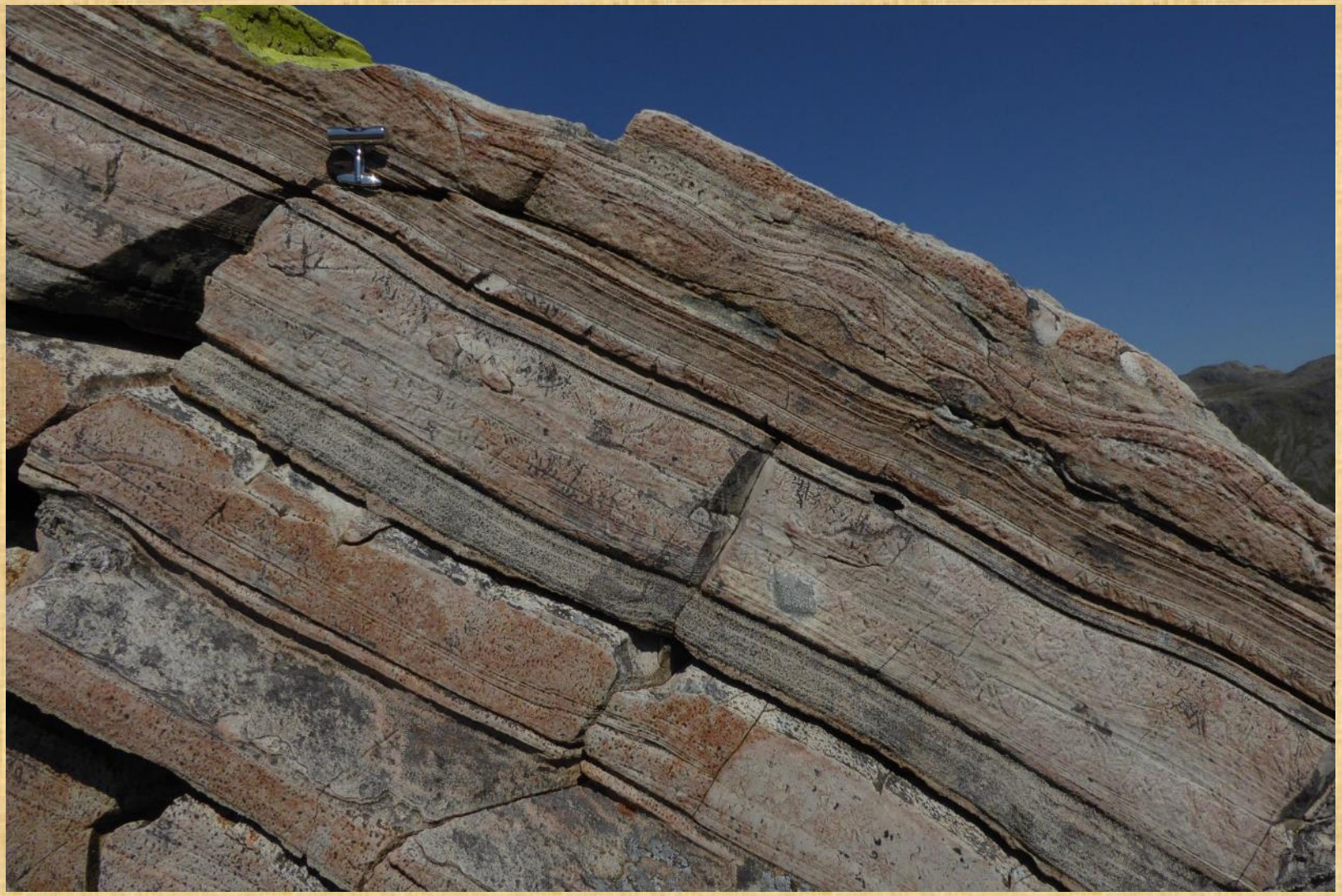


Locality 3 NY 22522 09846: Start of the Bowfell Links Member with several metres of gravelly graded beds intercalated with cm-scale sandy arenites [wackes] which are more typical of the Bowfell Links. Within ten metres, well bedded fine- to medium-grained turbiditic sandstone dominates. At locality three there is a zone of reverse-grading beds defined by pumice fragments at the tops of beds. There is also much soft-sedimentary deformation including convolute bedding, injectites [breccia dykes], and faulting [some listric]; this disruption appears to have been triggered by the arrival of the gravel layers.



Locality 3: clasts of convolute lamination in a remobilised coarse sand that has injected along the convoluted layer and isolated clasts. The extensional faulting is also penecontemporaneous. Some T_c cross-laminated units show the turbidite nature of the sedimentation.

There is a fairly abrupt change from the mainly pebble-grade Cam Crags to the well laminated sand- to silt-grade turbidite deposits of the Bowfell Links though evident Ta, Tb, etc. internal subdivisions are not common until some way into the unit. Spirit-level cuff-link for scale – 2.5 cm ↕.



The Bowfell Links Member is interpreted as the deposits of low- and high-density turbidity currents in water depths of many tens of metres to around a couple of hundred metres.



Dish structures in medium-grained wacke-sandstone indicating rapid expulsion of pore fluid on the collapse of a loosely-packed depositional framework. Dishes are typically about 2 cm long. The best dish structures in the Lake District are in the steps [Borrowdale volcaniclastic sandstone] into the Co-op in Ambleside – best seen when wet!

Locality 4 [NY 22724 09706]: Cockley Pike Member



An example of the Disordered Turbidite Facies sedimentary structures in the Cockley Pike Member which are the product of catastrophic, high-density flows. The cross-bedding shown here is on the several tens cm scale. The cross-bedding structures are not the result of traction currents as they occur in poorly sorted deposits which have much evidence of rapid deposition especially elutriation channels.



A bed of diagenetically-flattened pumice clasts in the Cockley Pike Member. Once thought to be an indicator of subaerial volcanism and hot deformation, the compaction fabric in these thin beds [typically 10-20 cm] is now regarded as being the result of normal burial compaction. The pumice probably was produced in a contemporaneous eruption and some layers in the CPM were formed of primary pyroclastics that settled through the water column in the caldera lake.

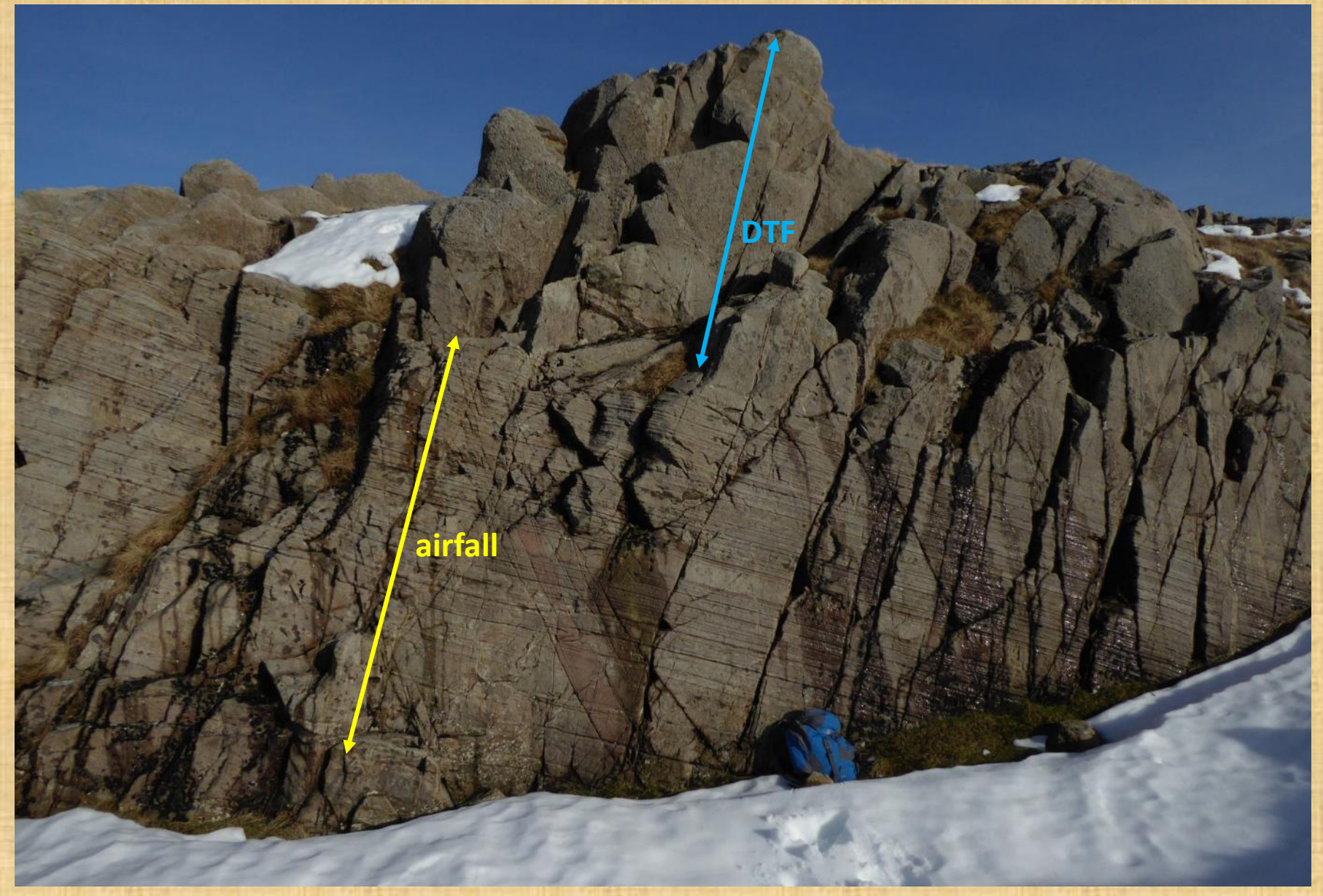


The Cockley Pike Member has abundant evidence for abrupt deposition. Elutriation channels, as seen here, are common and most probably reflect a loose depositional grain framework that collapsed to expel large quantities of pore fluid that escaped up these columns. Seismic shock could have caused the expulsion of pore fluid but they are so common in this unit, a loose packed grain framework, resulting from rapid deposition, is a much more likely cause. Compact-camera case for scale. Several serving counters in cafes/restaurants in the Lake District have been supplied with wonderful examples of these structures from the Borrowdale volcanics including Wilf's Café in Staveley and the Castle Dairy in Kendal.



Soft-sedimentary disruption in the Cockley Pike Member probably as an injectite. In the large central clast the curved surfaces are elutriation channels deformed during pre-lithification disruption showing that it happened before consolidation/lithification.

Locality 5 [NY 22866 09267]: Sprinkling Tarn Member – metric scale packages of perfectly-parallel bedded airfall tuffs alternating with metric-scale Disordered Turbidite Facies [DTF]. The former is the first evidence of emergence in the Seathwaite Fell Formation since the lake was established.



An airfall tuff package in the Sprinkling Tarn Member showing the classic Lake District field expression of phreatoplinian airfall tuffs [perfectly-parallel bedded]; the Whorneyside Bedded Tuff is the best example as seen at Stonesty Pike.



Examples of soft-sedimentary deformation in the Seathwaite Fell Formation on Seathwaite Fell.





Breccia dykes as shown above and to the left could form by more or less in situ brecciation caused by pressurised pore fluid moving through the sediment. The photo to the left shows there is much movement of sediment in these cases. Are they non-dilational?



A non-dilational diapiric sedimentary injectite has punched its way upwards through the sedimentary layering as shown by the displacement of the laminated package to the top right of the diapir.

Examples of soft-sedimentary deformation in the Seathwaite Fell Formation on Seathwaite Fell.



A couple of metres high exposure of the front of a slide block.



Close up of the deformed elutriation channels shown earlier.



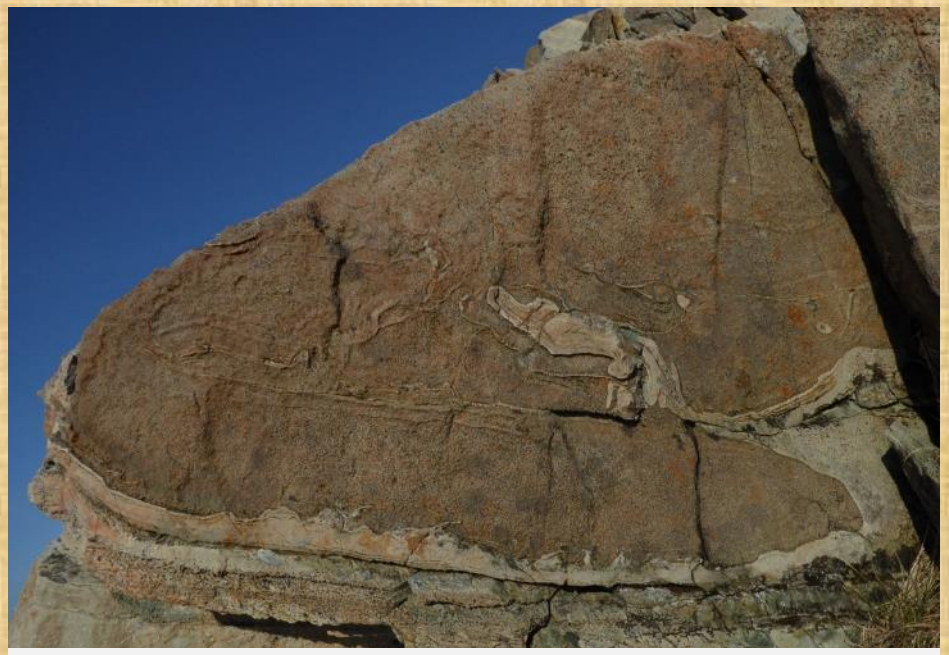
Convolute lamination on the few tens cm scale.



Small-scale soft-sedimentary contractional faults.



Pseudo nodules formed by sand settling into mud [scale: 20p coin].



Coarse sand injections disrupting sedimentary layering.



Convolute lamination on the few tens cm scale.



Soft-sedimentary contractional faults [A4 map for scale].

Poor weather alternative – Seathwaite Slabs to the west of Seathwaite Farm.

Conditions – the route of the excursion follows the path by the side of Sourmilk Gill to Gillercomb which does involve some low-level scrambling.

The Geology – a bedded sequence records the earliest phase of the Scafell caldera in an area with an intermittent shallow lake. Here the Whorneyside Formation contains bedded airfall tuffs that both fell on dry land and into the lake, fluvial reworking of the airfall tuffs, deeper water turbidity currents acting on the pyroclastics, and a collection of classic debris flow deposits. This stratified collection of deposits is intruded by sheets of peperitic andesite. The final part of the traverse will study the start of the main rhyolitic phase of caldera evolution – cross-bedded ignimbrite from dilute pyroclastic currents and the overlying high-grade welded ignimbrites.



Photo: a 15 cm wide clast in a debris flow deposit in Gillercomb. Small accretionary lapilli in the clast show that it is a typical piece of airfall tuff from the Whorneyside Bedded Tuff which was incorporated into the debris flow probably in a subaerial environment.