Seathwaite Fell

The best traverse through the best-exposed caldera-fill sedimentary sequence in the world

Author: Clive Boulter

Photos: Clive Boulter unless otherwise credited.

Photo: soft-sedimentary fold, Seathwaite Fell

Facing the prevailing wind the exposures on this traverse show in exquisite detail sedimentary structures that would otherwise only be revealed by sawing and polishing samples.

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

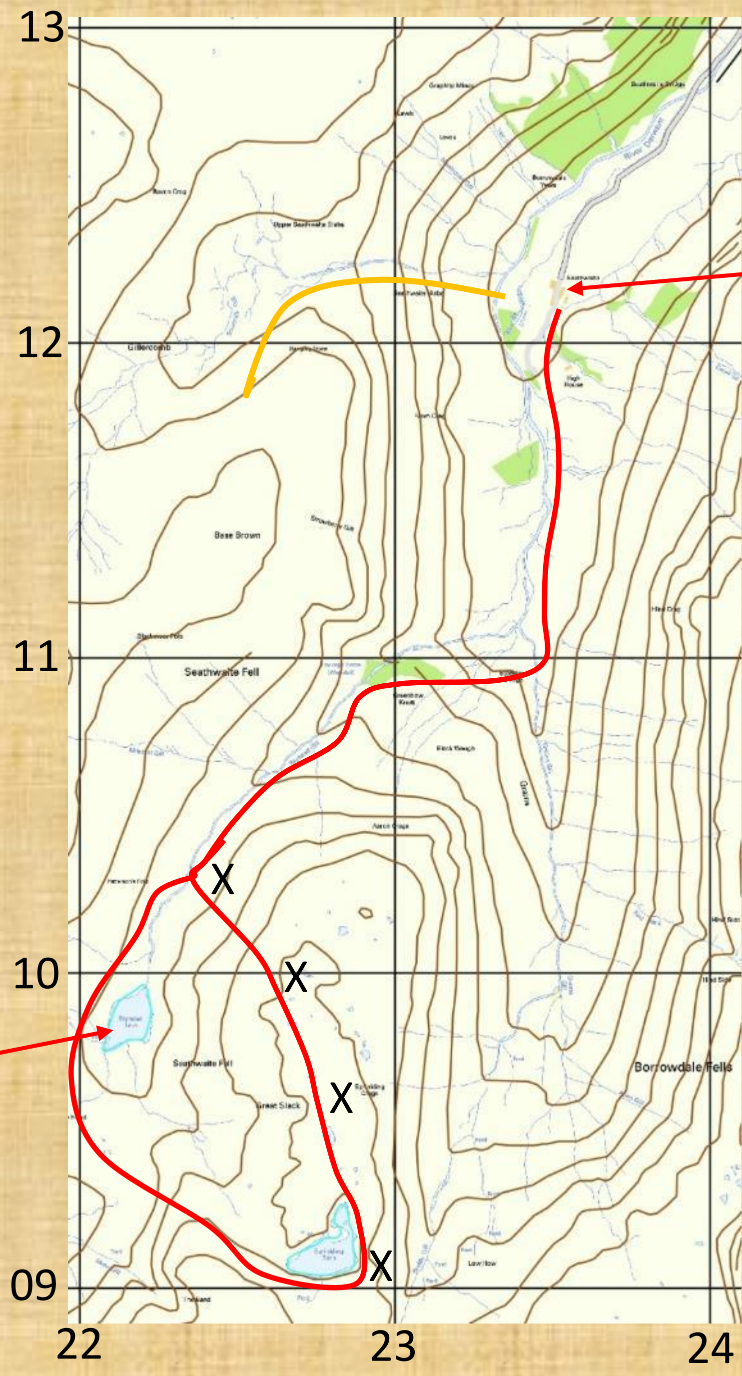
Toilets: National Trust toilets at Seathwaite Farm.

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 17 x 14 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; it is claimed that steep walls may have been subordinate to gentle slopes on inward-tilted strata but steep margins have been documented between Blea Tarn and Pike o' Blisco. 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, an overwhelmingly 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 [Guaymas scenario] 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 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. The topic is also covered in some detail in the Ambleside Memoir [Millward *et al.* 2000].

Generalised Location Map



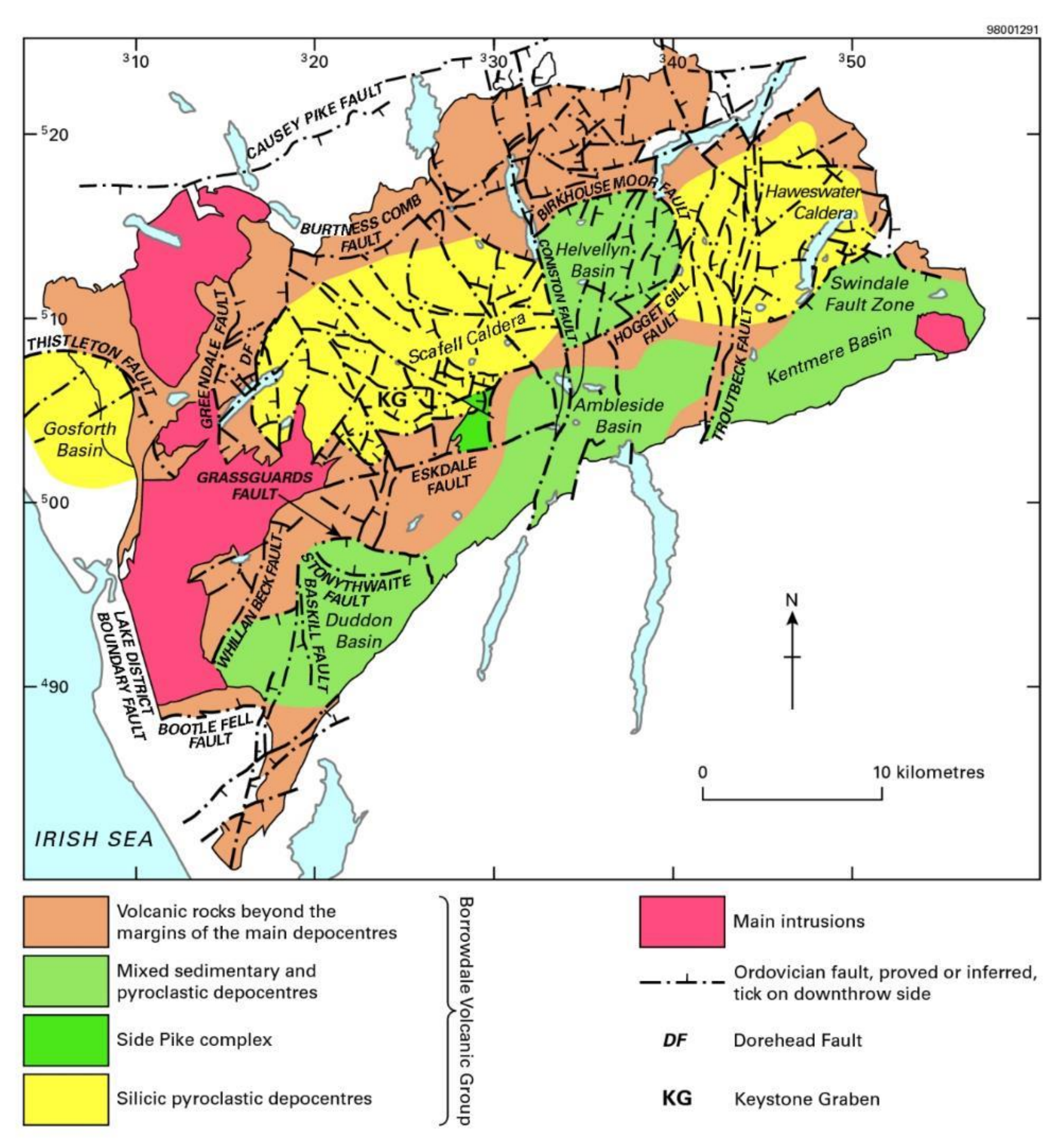
Seathwaite Farm

Styhead Tarn

Seathwaite Fell route.

X X X Geological traverse – NO PATHS

Based on Ordnance Survey OpenData Kilometre grid.



The central yellow area shows the scale and location of the Scafell Caldera and the approximate size of the caldera lake subsequently filled with the Seathwaite Fell Formation.

Map of the Borrowdale Volcanic Group showing the main depositional centres and principal faults with displacements inferred to have occurred during accumulation of the volcanic succession. Figure 15 in Stone, P, Millward, D, Young, B, Merritt, J W, Clarke, S M, McCormac, M and Lawrence, D J D. 2010. British regional geology: Northern England. Fifth edition. Keyworth, Nottingham: British Geological Survey.

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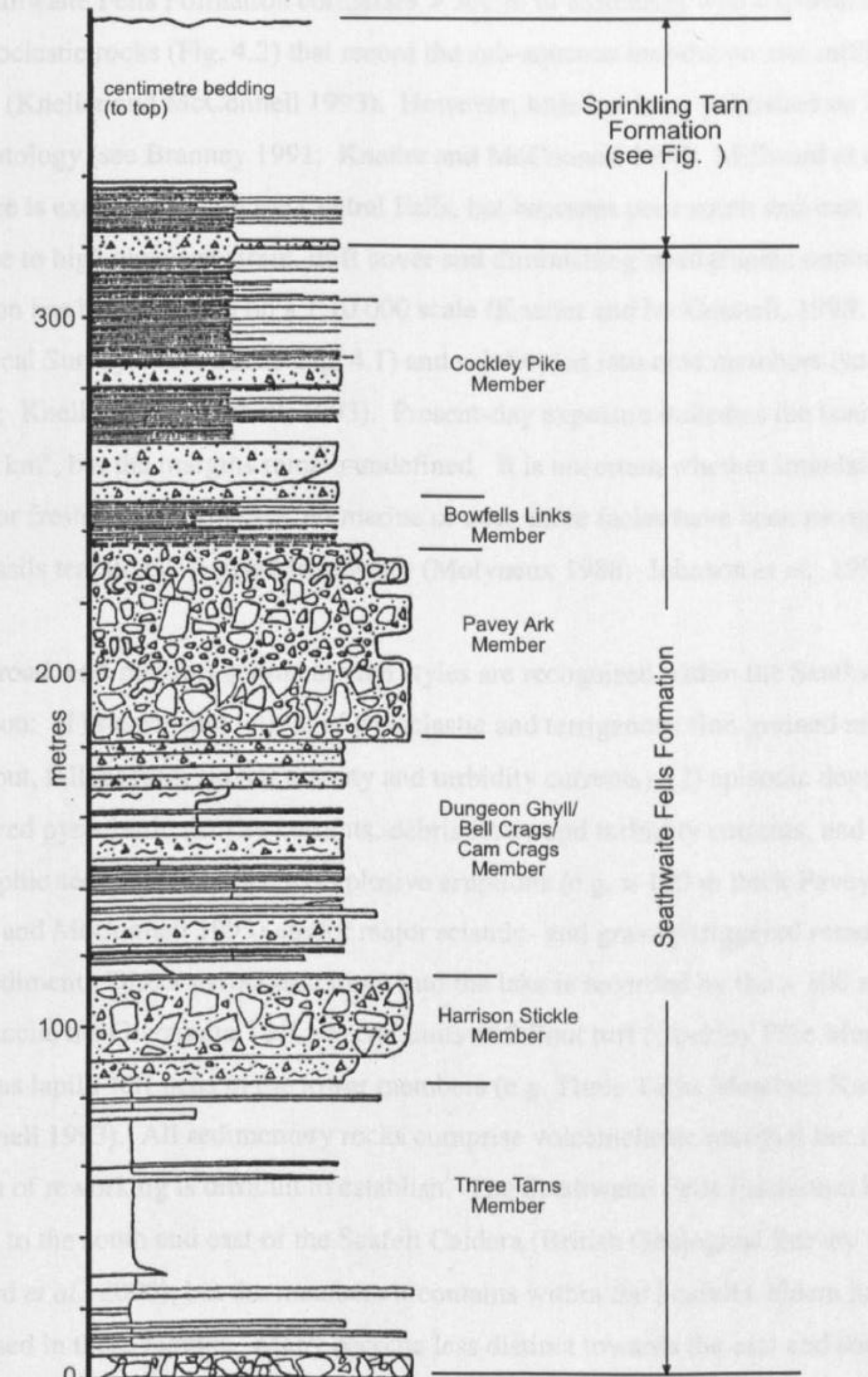
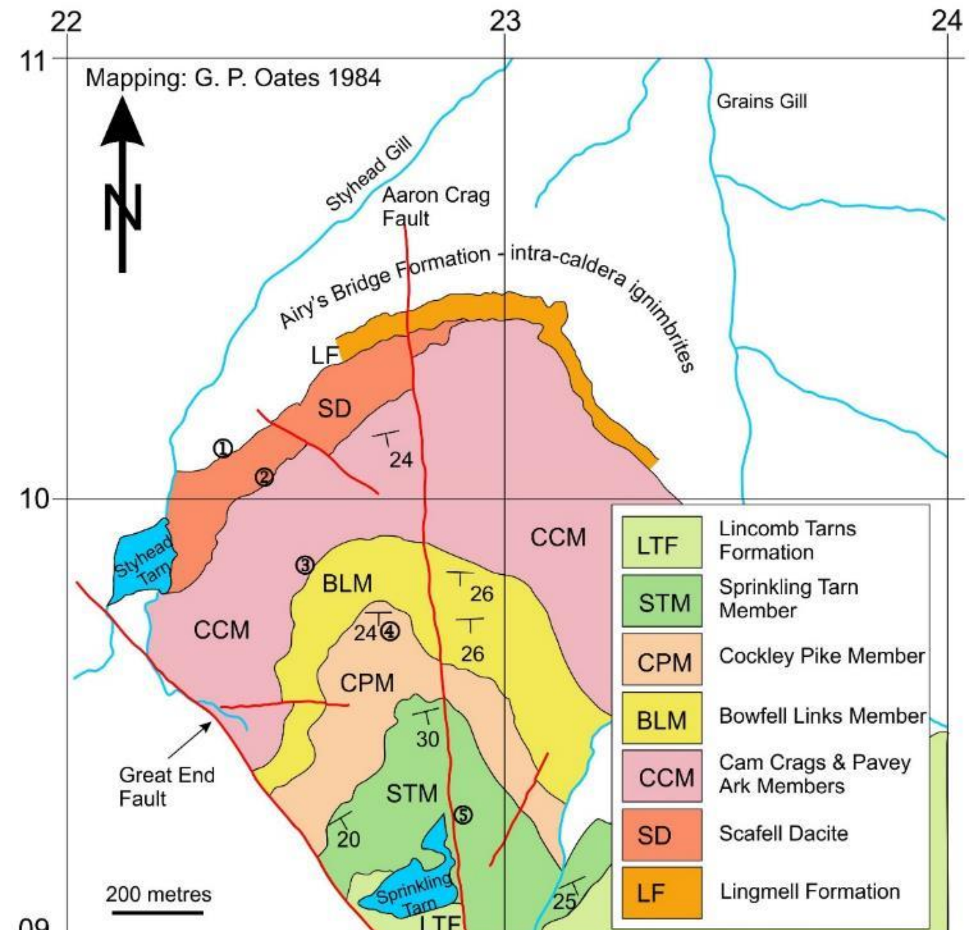


Generalised vertical succession through the Seathwaite Fell Formation as exposed in north Langdale, showing its overall character and most of the constituent members (modified from Kokelaar et al. 1990 by Brown 2001, Fig. 4.4). Lateral variations mean that not all members are present in all areas.

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).

Several members of the Seathwaite Fell Formation are lenticular and hence not all traverses have all members present. On this itinerary we have Cam Crags, Bowfell Links, Cockly Pike, and Sprinkling Tarn, members.

Locality map for the traverse.



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.

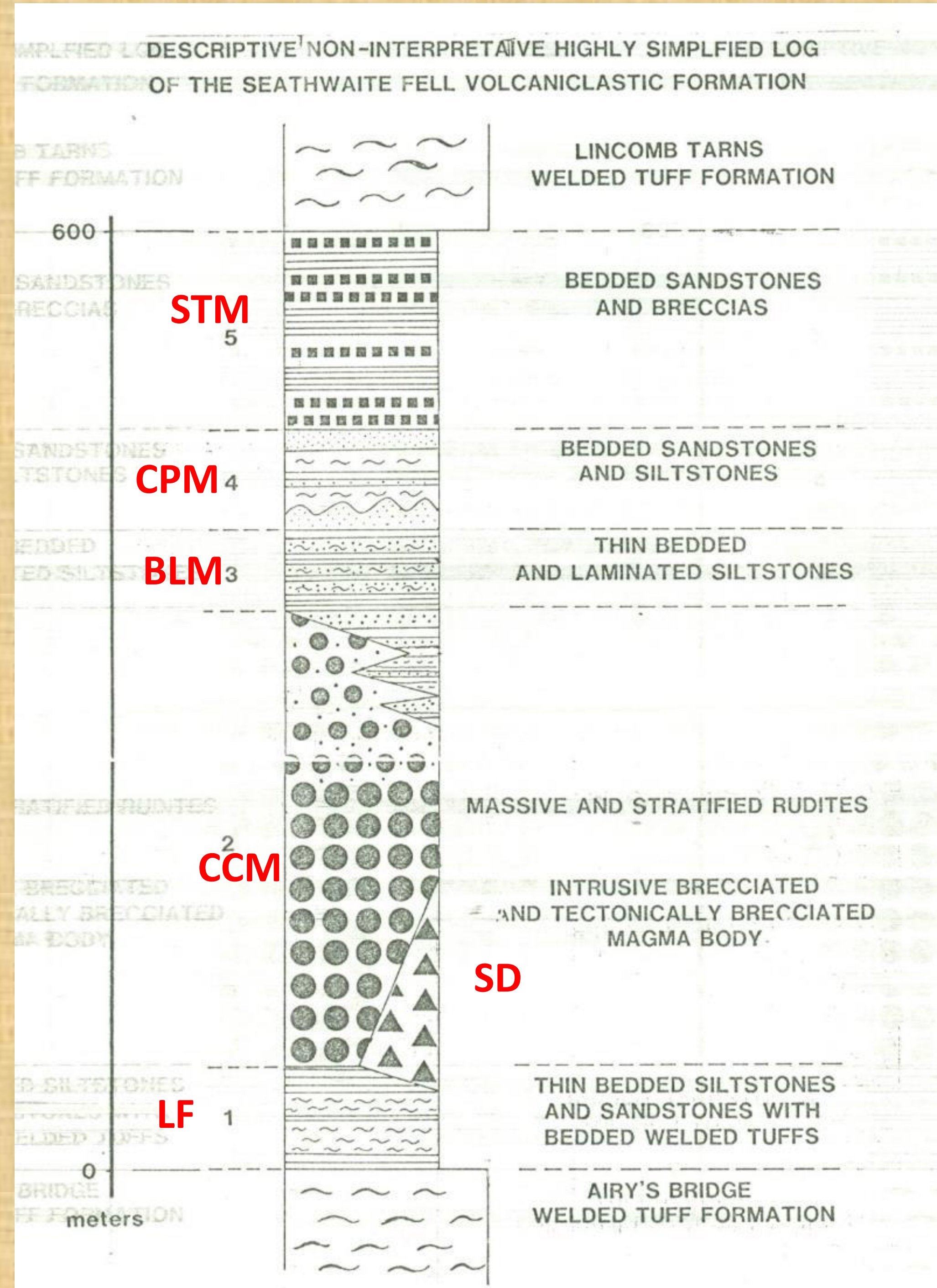
Pavey Ark & Cam Crags Members: Pebble-grade breccia and pebbly coarse-grained sandstone. The Pavey Ark is andesitic and the Cam Crags is dacite to rhyolite; the latter is interpreted as deltaic deposits.

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.



STM Sprinkling Tarn Member

CPM Cockly Pike Member

BLM Bowfell Links Member

CCM Cam Crags Member

SD Scafell Dacite

LF Lingmell Formation

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 features between these points will be mentioned. For each of the formations/members on Seathwaite Fell no one locality provides all the key features.

Evening photograph of the growing andesitic lava dome in December 1996, viewed from the north-east. The lava is extruded at temperatures of around 850°C, and can produce spectacular sequences of glowing rockfalls at night.

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. Rucksack for scale.

The Scafell Dacite seen on the traverse 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. The dishes here 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]: Cockly Pike Member

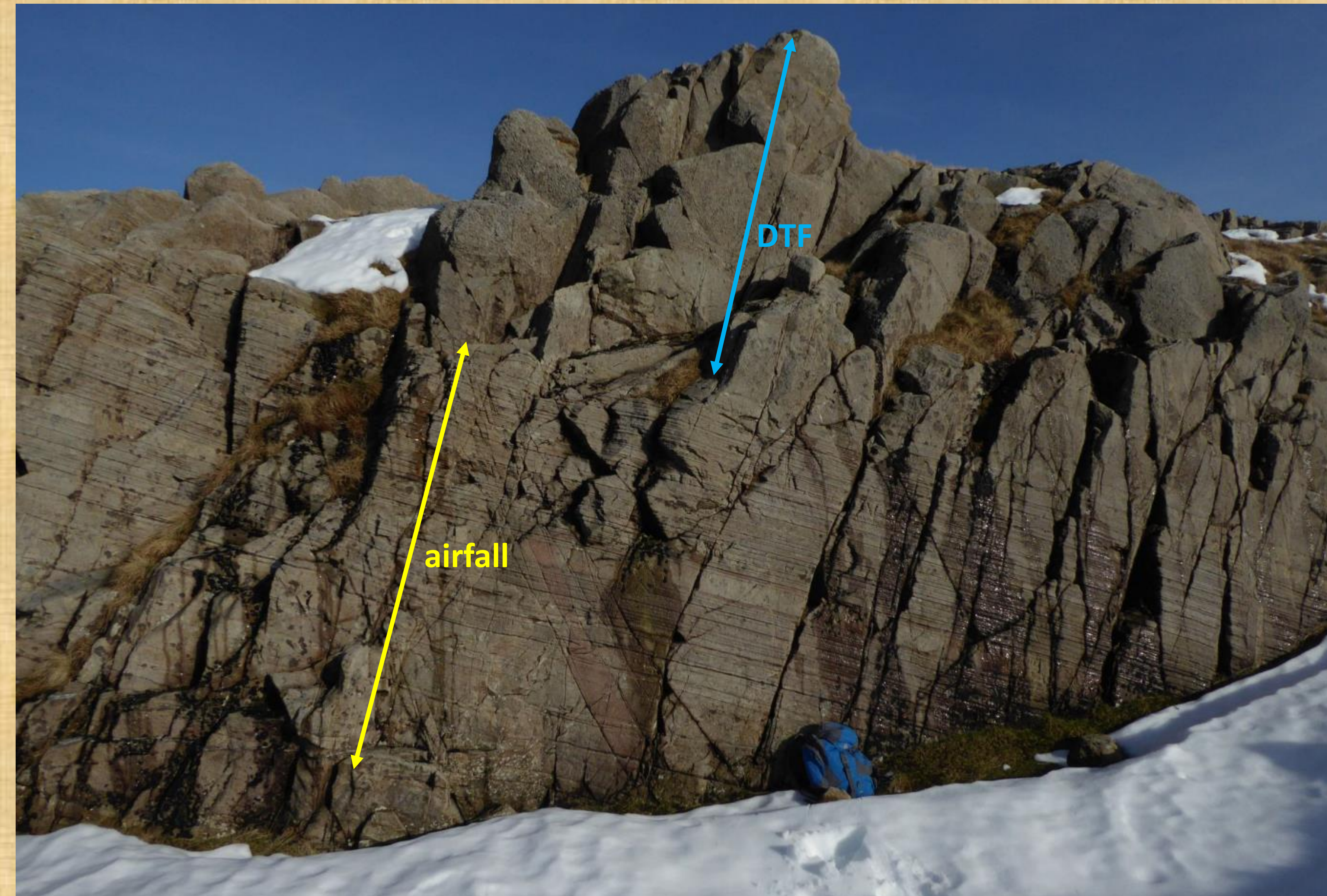
An example of the Disordered Turbidite Facies sedimentary structures in the Cockly Pike Member which are the product of catastrophic, high-density flows. The cross-bedding shown here is on the several tens cm scale. The cross-bedding structures are not the result of traction currents as they occur in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

A bed of diagenetically-flattened pumice clasts in the Cockly 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. Care has to be exercised in using flattened pumice fabrics to distinguish between primary pyroclastics [ignimbrites] and other origins.

The Cockly 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 now-closed Castle Dairy in Kendal.

Soft-sedimentary disruption in the Cockly 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.

The following slides are 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 many examples.

A 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.

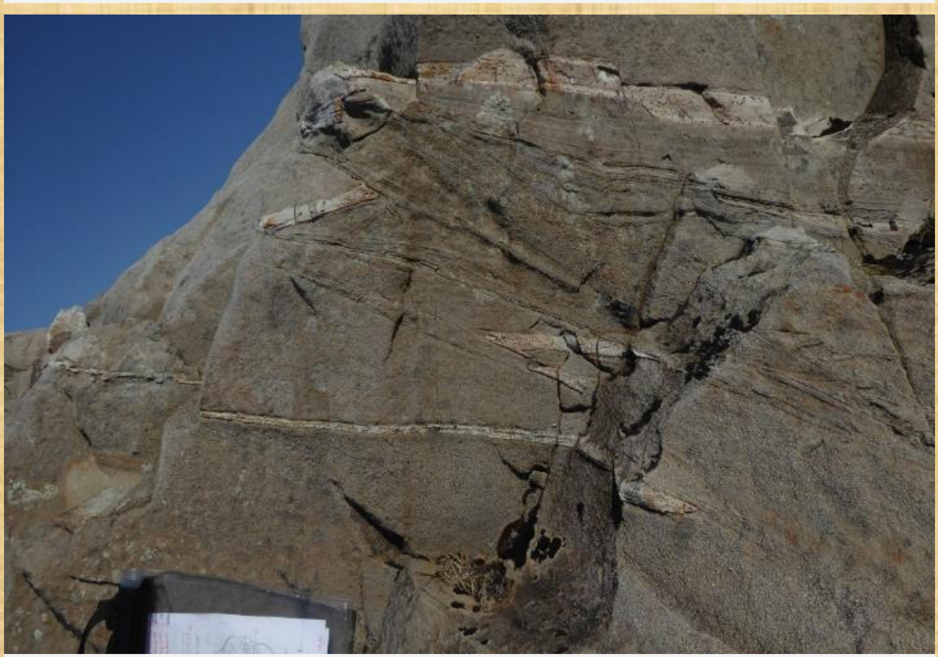
Convolute lamination on the few tens cm scale.

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].

Soft-sedimentary fold [hinge line right-hand side] that has folded a stratigraphically-inverted bedding interface with load & flame structures which require the mud or both the mud and sand to lose strength. The liquefaction that generated the load & flame features pre-dated the folding but it could have been a progressive process.

Sources

Brown, R. J., 2001, Eruption History and Depositional Processes of the Poris Ignimbrite of Tenerife and the Glaramara Tuff of the English Lake District. PhD Thesis, University of Leicester [https://lra.le.ac.uk/handle/2381/7825].

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