Three Shire Stone to Side Pike [The Langdale Caldera]

A reassessment of the Side Pike Complex concept.

Cumberland Geological Society Excursion Saturday July 7th 2018

Meet at 10h00 at Three Shire Stone NY 2770 0273 [arrangements need to be made to leave some cars at Side Pike to take drivers back to vehicles]

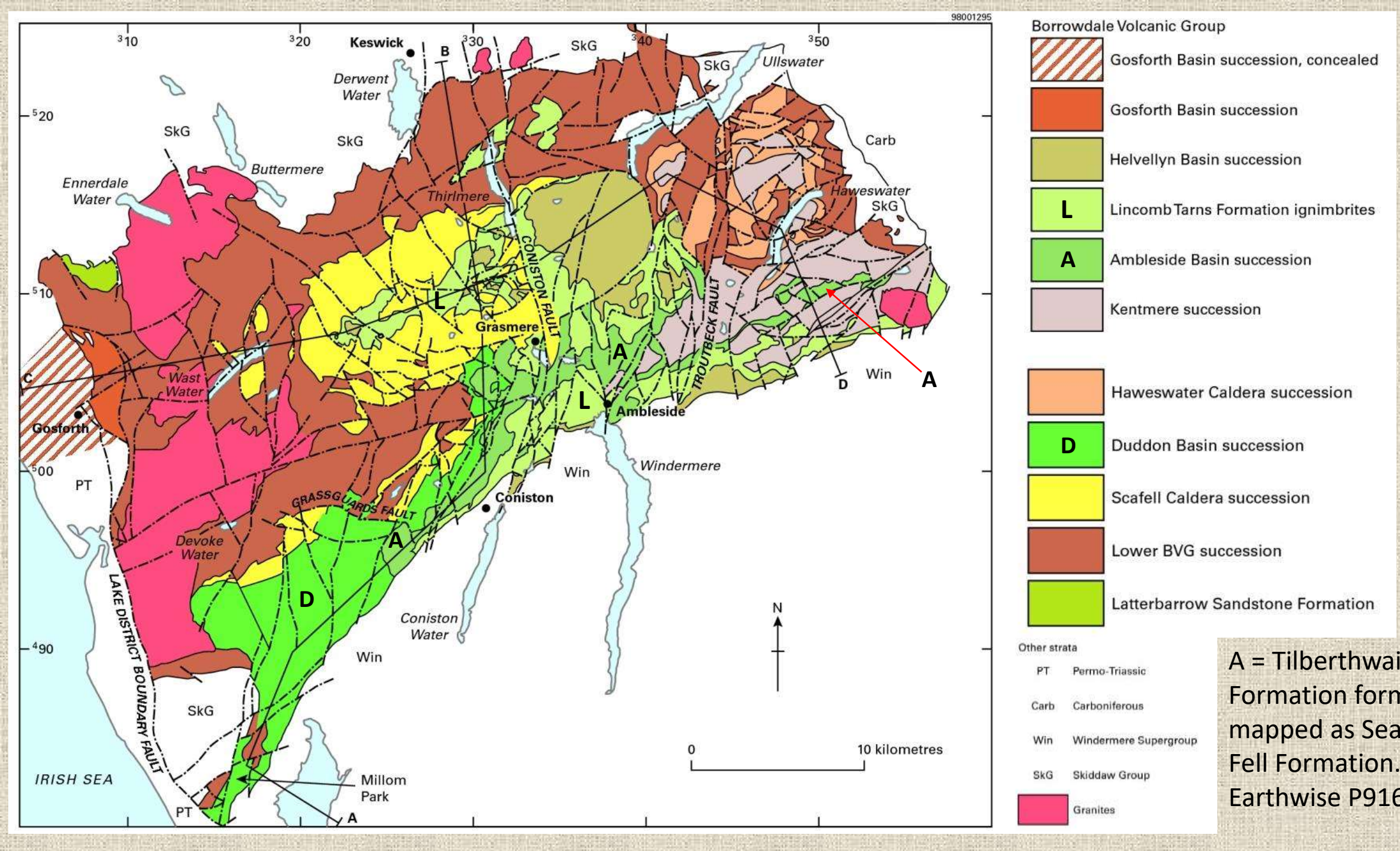
INTRODUCTION

Initially the excursion route will take us through familiar stratigraphy from the Birker Fell Formation andesites into the two components of the Whorneyside Formation: the lower Wet Side Edge Member [andesitic welded ignimbrite] and the upper bedded tuff [air fall deposits from a gigantic phreatoplinian eruption]. We then move into uncharted territory where, in the 1980s/1990s resurvey, the deposits in a 5 km^2 area could not be tied into the regional stratigraphy and the notion of the Side Pike Complex was introduced [Branney 1988]. It was believed that the differences between this small area and its surrounds were created when flank failure of the volcanic edifice led to blocks, 100s of metres to around a kilometre in size, sliding in from parts of the stratigraphy no longer exposed. The blocks in this megabreccia were considered to be exotic.

However, very detailed work on part of the established stratigraphy of the Scafell Caldera was extended to the excursion area with dramatic consequences for the stratigraphy of the Borrowdale volcanics and its volcanological model [Brown 2001]. At Excursion Stop 4, within the Side Pike Complex, five metres of stratigraphy are so distinctive that Brown [2001] could identify them as being part of the uppermost Seathwaite Fell Formation which is the sedimentary infill of the Scafell Caldera. In this few metres a welded ignimbrite is overlain by accretionary lapilli tuff, a pairing of rock types not uncommon in the Borrowdales but to someone who has spent many weeks getting thoroughly acquainted with the sequence by doing bed by bed logging, their characteristics were unmistakable! Having got this reference point it was apparent that the underlying twenty or so metres of water-lain volcaniclastics are the equivalent of the Seathwaite Fell Formation which is typically 100s of metres thick and at its maximum is 540 metres. Below this there is a 70 metre thick sheet of rhyolite before encountering the Whorneyside andesitic pyroclastics. Again a massively reduced section compared to the Scafell Caldera section just a short distance away on Crinkle Crags because the rhyolite is the equivalent of the Airy's Bridge Formation rhyolitic ignimbrites which are typically close to a kilometre in thickness. These major thickness variations could have been caused by erosion of typical accumulations of Scafell Caldera deposits but they are more likely the result of limited deposition on topographic highs. Whichever explanation is correct these massive differences explain why it was so hard initially to correlate these much reduced units with their much thicker equivalents in the Scafell Caldera. Such dramatic lateral differences over such a short distance are not uncommon in volcanic terrains but they make the job of mappers very difficult.

IMPLICATIONS OF THE REASSESSMENT OF THE SIDE PIKE COMPLEX

1. Because the stratigraphy is no longer exotic Brown [2001] has recommended that the use of the term Side Pike Complex be discontinued even though the area has yet to be remapped in light of the new knowledge.
2. In the resurvey, when the uncertain stratigraphy was projected through the Side Pike Complex onto Lingmoor Fell, an incorrect stratigraphic assignment was made from here eastwards [see next slide]. This led to a large area of the southern strip of the Borrowdale volcanics [Ambleside 1:50,000 BGS Map] being wrongly assigned to the Seathwaite Fell Formation when it is much younger. The only published map that corrects this significant error is by Millward in the Proceedings of the Yorkshire Geological Society [2004, vol. 55, pp. 73-105]. This new formation has been named the Tilberthwaite Formation but it does not appear on any published BGS maps even though it covers a large area. On Earthwise P916047 [see two slides on] this new formation is shown as the Ambleside Basin Succession.
3. In the Coniston area the Tilberthwaite Formation, which was erroneously thought to be the Seathwaite Fell Formation, overlies, at an angular unconformity, major ignimbrite units such as the Lag Bank Formation and the Paddy End Member of the Lickle Formation and hence these were placed much lower in the regional stratigraphy than they should have been.
4. Welded ignimbrites, younger than the Seathwaite Fell Formation, in what was the Side Pike Complex, probably were generated in a caldera-forming explosive eruption which means that earlier work did not identify the associated Langdale Caldera.
5. What seemed to be a good stratigraphic marker, the accretionary lapilli-rich horizon at the top of a thick sedimentary sequence and just below the Lincomb Tarns Formation, is in reality two units of very different ages; the Glaramara Tuff is near the top of the Scafell Caldera sedimentary infill and the Swinescar Pike Tuff is near the top of the Tilberthwaite Formation, the sedimentary infill of the Langdale Caldera. Both probably represent deposits from very large tuff rings.
6. The regional implications are that a second silicic caldera [the Langdale Caldera] is present in the south Lake District and that the succession of ignimbrite eruption, probable caldera collapse, aqueous inundation, and sedimentary infill (as seen in the Scafell caldera), is repeated here by the eruption of the Lingmoor Fell, Lag Bank and Low Water Formation ignimbrites, followed by subsidence and sedimentary infill in the form of the Tilberthwaite Formation [Brown, 2001].



A = Tilberthwaite Formation formerly mapped as Seathwaite Fell Formation. Earthwise P916047

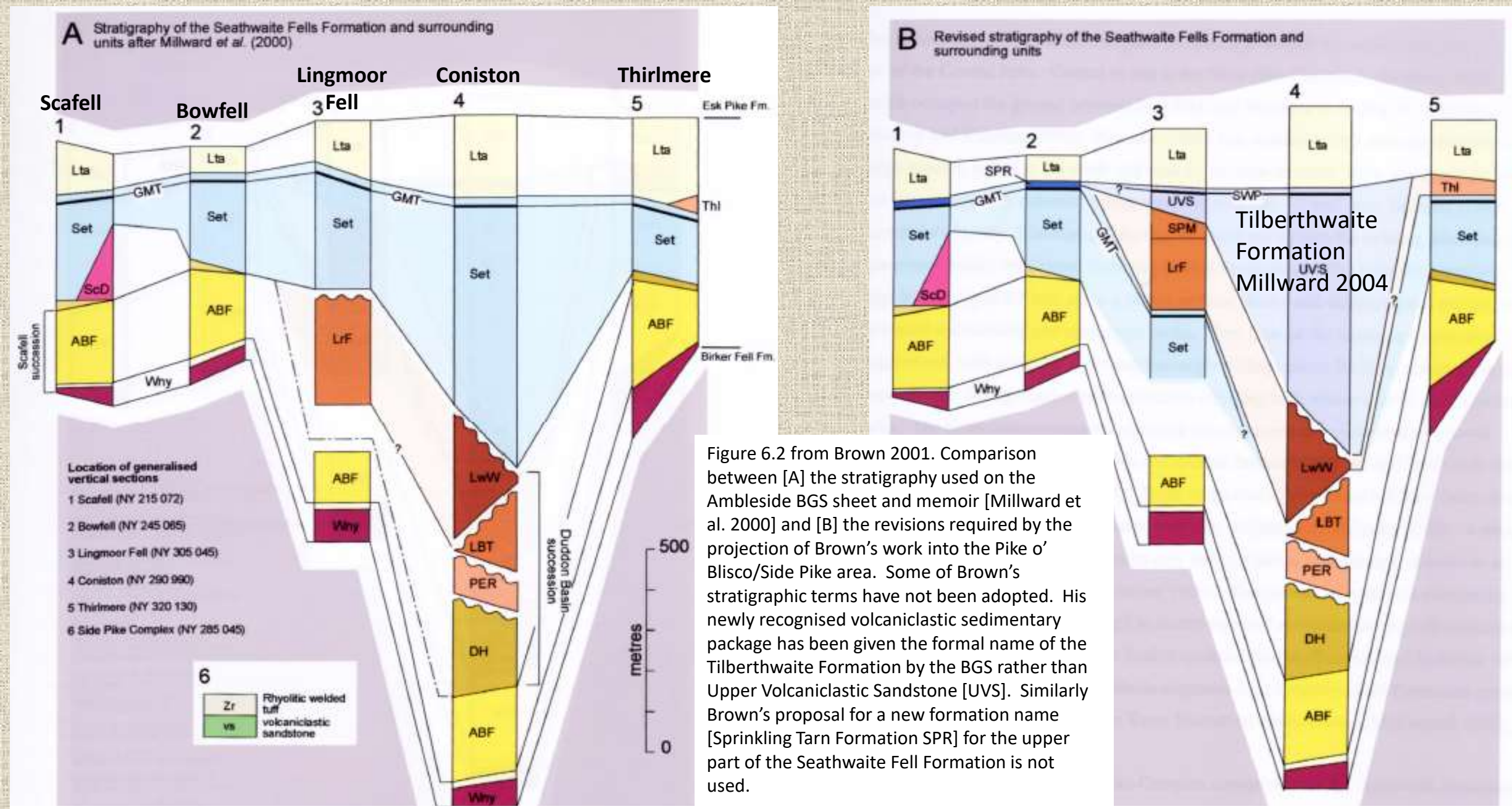
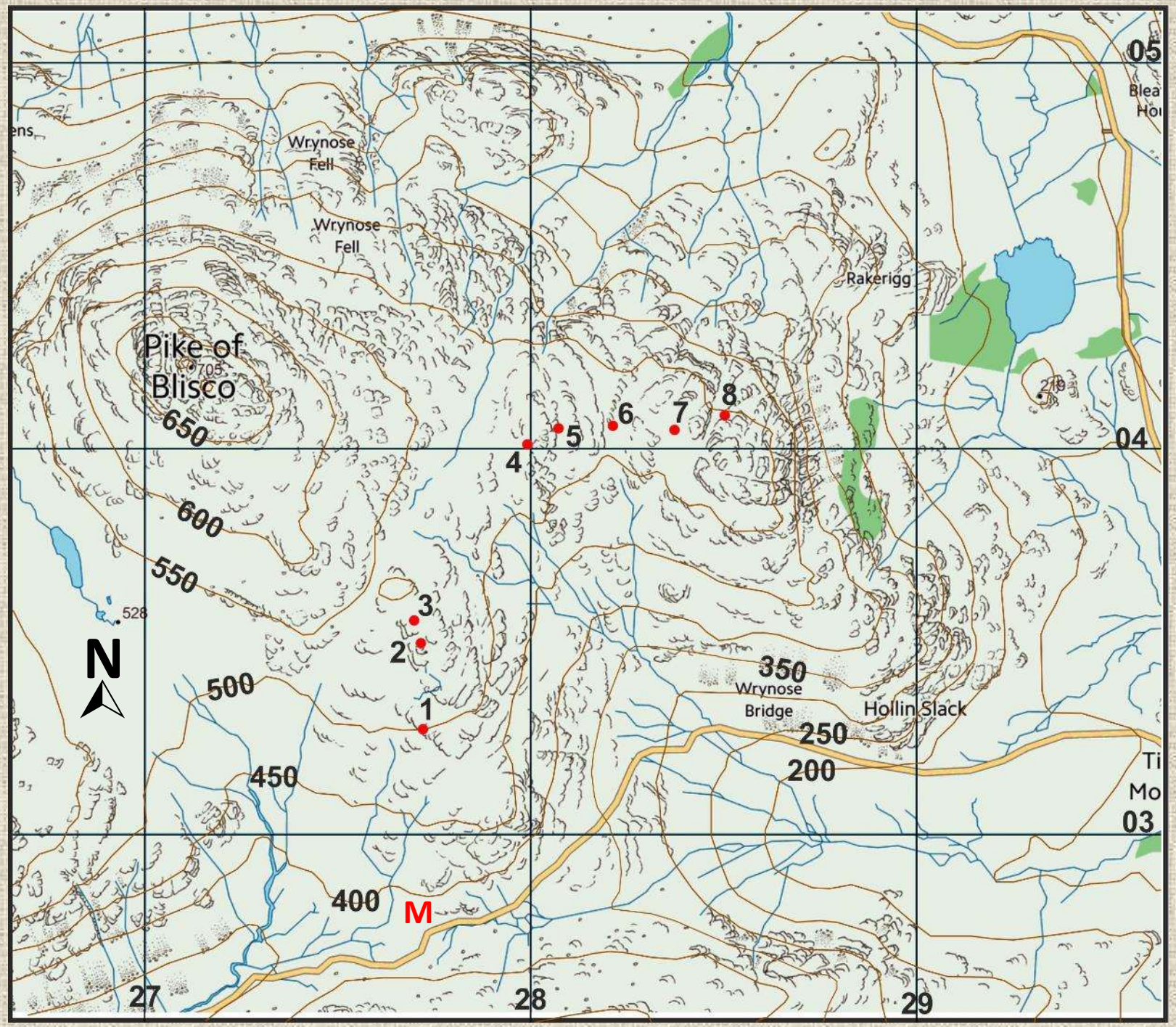


Figure 6.2 from Brown 2001. Comparison between [A] the stratigraphy used on the Ambleside BGS sheet and memoir [Millward et al. 2000] and [B] the revisions required by the projection of Brown's work into the Pike o' Blisco/Side Pike area. Some of Brown's stratigraphic terms have not been adopted. His newly recognised volcaniclastic sedimentary package has been given the formal name of the Tilberthwaite Formation by the BGS rather than Upper Volcaniclastic Sandstone [UVS]. Similarly Brown's proposal for a new formation name [Sprinkling Tarn Formation SPR] for the upper part of the Seathwaite Fell Formation is not used.

Wny - Whorneyside F^{mn}; ABF - Airy's Bridge F^{mn}; Lme - Lingmell F^{mn}; DH - Duddon Hall F^{mn}; PER - Paddy End M^{br}; Set - Seathwaite Fell F^{mn}; GMT - Glaramara Tuff; LBT - Lag Bank F^{mn}; LwW - Low Water F^{mn}; LrF - Lingmoor Fell F^{mn}; SPM – Side Pike M^{br}; UVS - Tilberthwaite F^{mn}; SWP - Swinescar Pike Tuff; Lta - Lincomb Tarns F^{mn}



Excursion Localities

M = Meeting Point at Three Shire Stone

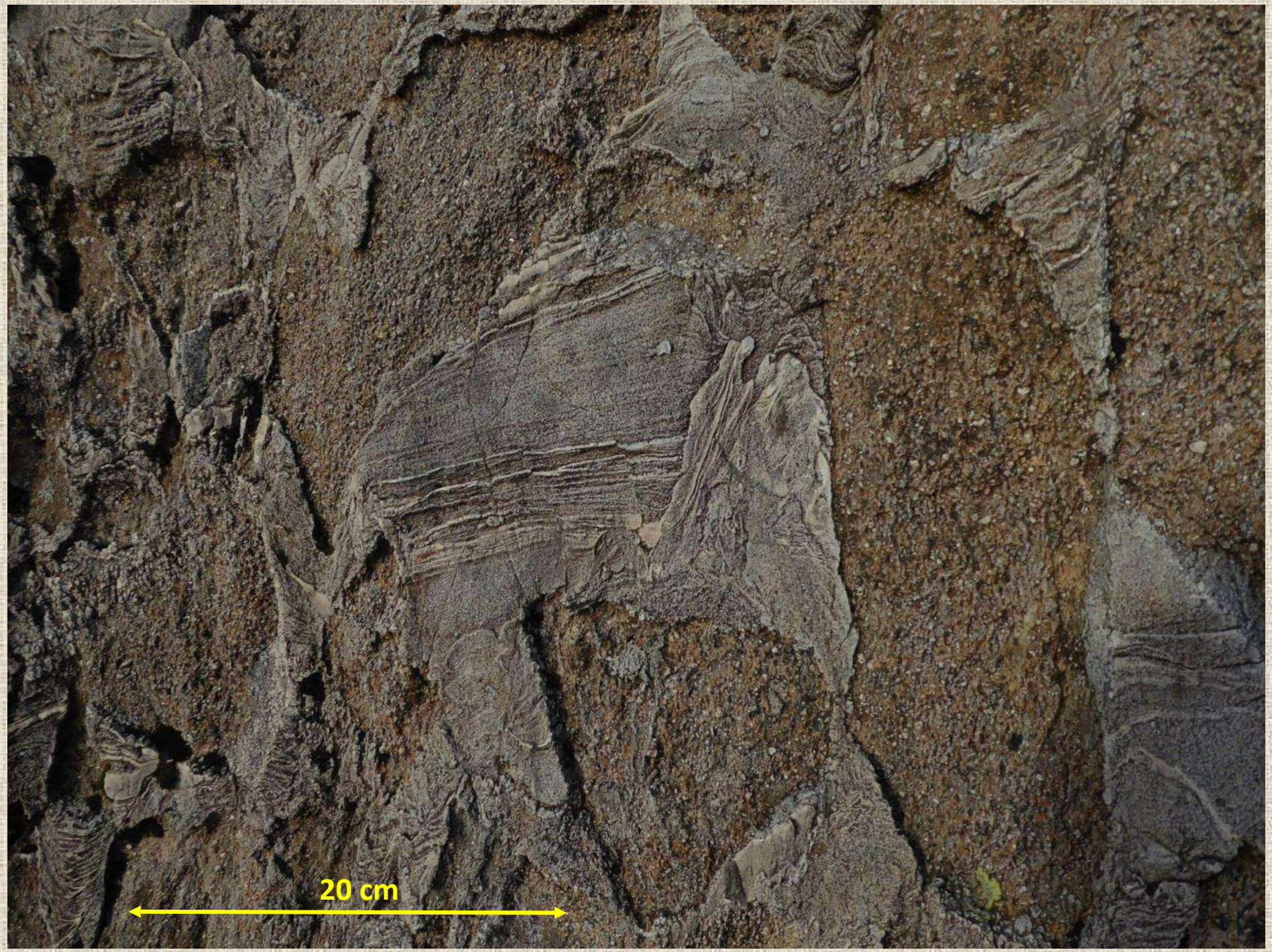
Base map from Ordnance Survey Open Data.

Kilometre grid.

Locality 1 NY 27736 03273
Birker Fell Formation

Top of an andesite sheet where a sedimentary network infills the gaps between feldspar-phyric andesite blocks. Is this the rubbly top of a lava flow where sediment was washed into the gaps between the andesite blocks? Or is it the top of a peperitic sill and unconsolidated sediment was injected into the andesite which fragmented on contact with the cool wet sediment?

Lava flows and peperitic sills have the same sheet-like overall shape and, if you are unsure which of the two possibilities you are dealing with, then it is best to hedge your bets by saying it is an andesite sheet.



Locality 1 NY 27736 03273

A closer look at the relationships between the sedimentary and andesite components. At this scale the phenocrysts in the andesite give an almost granular texture which might be mistaken for a sedimentary texture.

At this locality the sedimentary component stands proud and the andesite is recessive. If this is the top of an autobrecciated lava flow the reverse weathering response might be expected comparable to igneous fragments in the sedimentary matrix of debris flow deposits.

Lava Flow vs High Level Sill Discrimination

Diagrams in text books make this task look simple but in practice it is a significant challenge. You have to concentrate on the top contact because the base of a lava flow can produce a peperitic interaction with the underlying soil or sediment. The tops of most lava flows are rubbly and brecciated and, if there is a time gap before the next flow, sediment can be washed between the broken pieces of lava producing a mixed sedimentary/igneous zone. For a high level intrusion the top contact will produce a similar sediment/igneous mixture. The igneous component is chilled by the cold wet sediments and fragments by cooling contraction granulation. Transfer of heat from the intrusion means that the pore fluid in the sediment wants to massively expand and the space created by the shrinking magma gives it somewhere to go! This all takes place in situ and the characteristic texture is jigsaw fits between igneous blocks. Contact metamorphism is typically restricted to millimetre thick zones because most of the energy of the intrusion goes in heating the sediment pore fluid.

Peperite in the River Sprint, Longsleddale.

Locality 2 NY 27721 03506
Wet Side Edge Member of the Whorneyside Formation

Andesitic welded ignimbrite with a weak welding fabric. Coin is 21.4 mm in diameter.

Locality 3 NY 27697 03564
Whorneyside bedded tuff

Perfectly parallel-bedded airfall tuff from the massive andesitic phreatoplinian eruption that immediately pre-dated the rhyolitic Airy's Bridge component of the Scafell Caldera.

Extensional features are widespread in this vicinity and impact sags are common. During piecemeal caldera collapse blocks of this tuff were tilted. The headwalls of the slide blocks were extended and the toes developed compressional structures such as thrust faults.

Conjugate normal faults create horst & graben patterns as can be seen in the background of this photo.

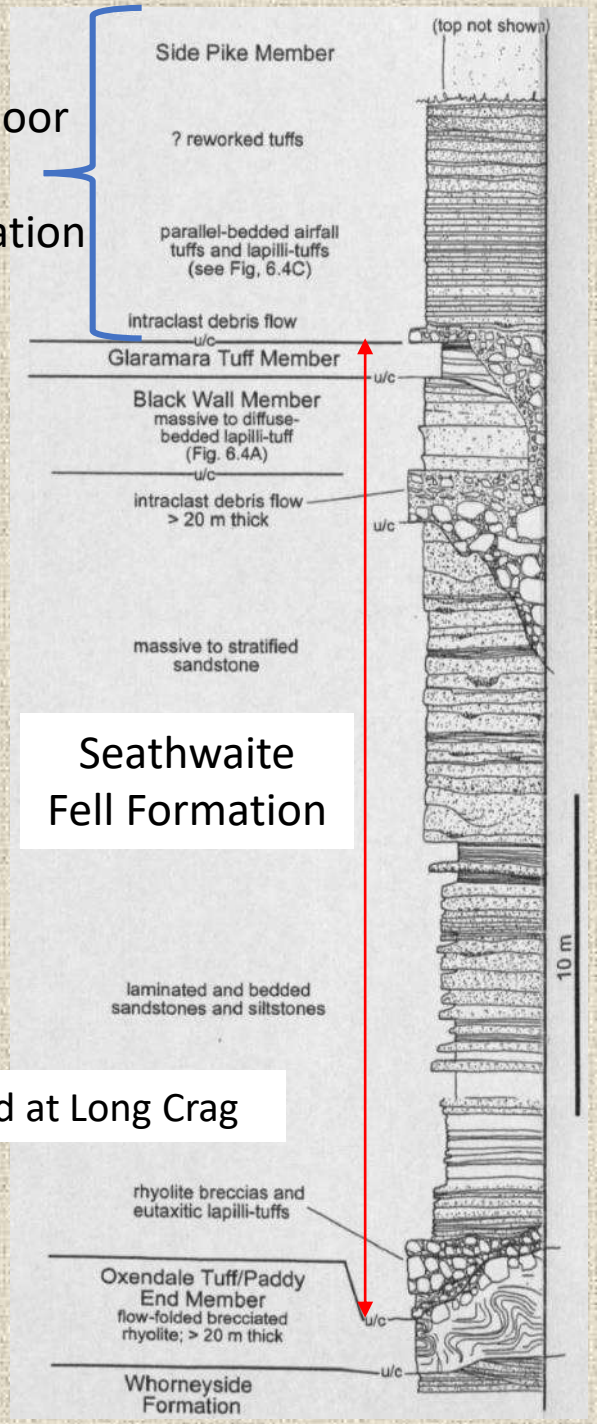
Locality 4 NY 27992 04002
Black Wall “Member” and Glaramara Tuff at Long Crag

Perhaps the most important locality in the region because distinctive units could be recognised. The crag is about 4.5 metres high and the pale unit at the top is the Glaramara Tuff. The lower darker portion [Black Wall “Member”] is a diffuse-stratified welded-ignimbrite that can be almost continuously traced from Seathwaite Fell via Scafell Pike to Coledale Head above Easedale Tarn. A feature of the ignimbrite is that the pumice clasts [fiammé] are mostly less than 2 cm long.

The Glaramara Tuff is the product of multiple eruptions in a very large tuff ring characterised by abundant accretionary lapilli.

These two units occur close to the top of the Seathwaite Fell Formation and are a definitive reference point for identifying stratigraphy in this challenging area formerly known as the Side Pike Complex.

Lingmoor Fell Formation



Seathwaite Fell Formation

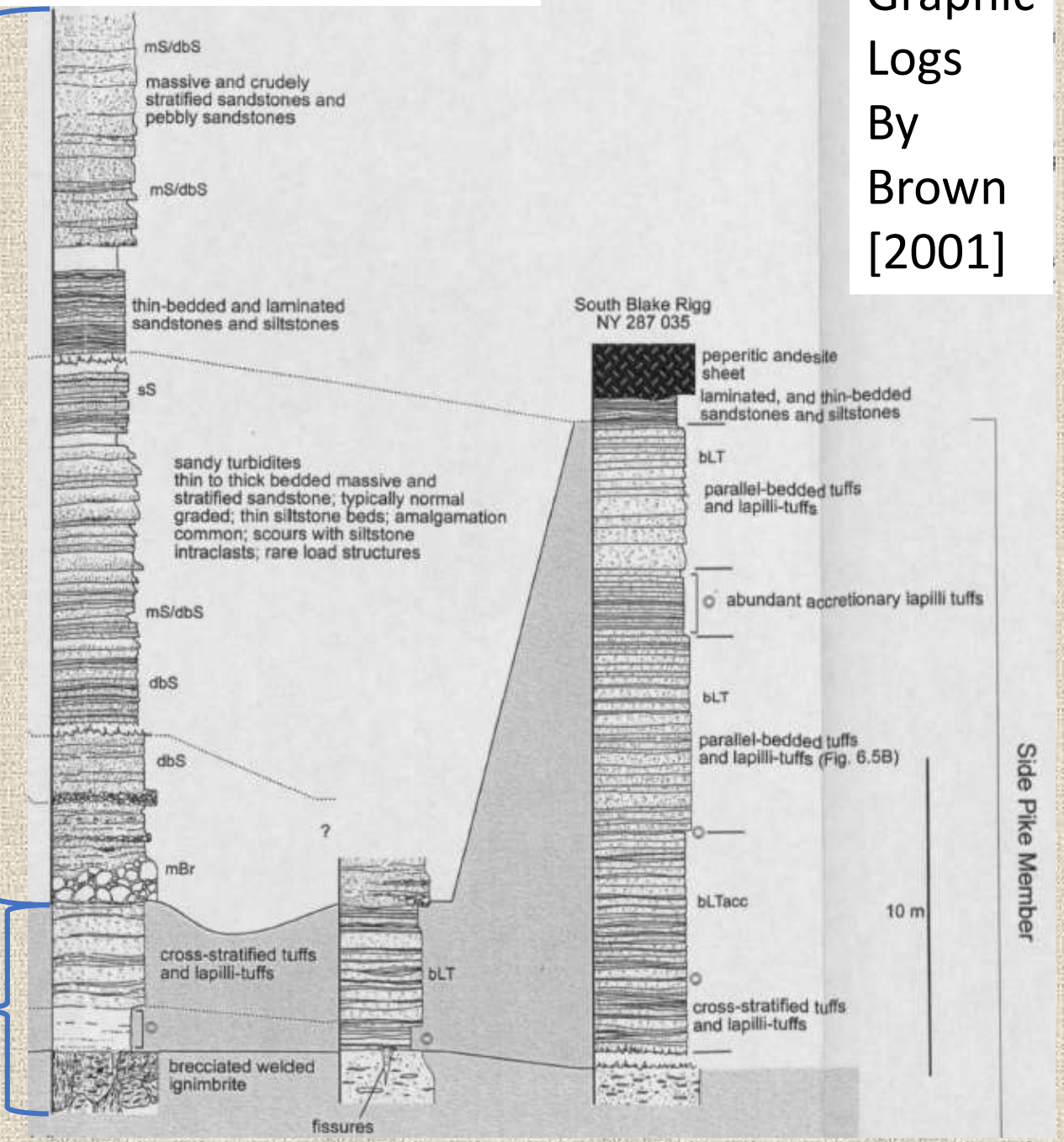
Logged at Long Crag

Logged between Long Crag & Bleaberry Knott

Graphic Logs By Brown [2001]

Tilberthwaite Formation

Lingmoor Fell Formation



Locality 4 NY 27992 04002
Glaramara Tuff at Long Crag

The whole of the field of view is rich in accretionary lapilli and the stratification plus the cross-stratification show that this unit was deposited from a low-concentration pyroclastic density current.
Brown et al. [2007] have demonstrated that the Glaramara Tuff was produced by multiple explosions at an exceptionally large tuff ring.

Coin: 21.4 mm in diameter.

Locality 4 NY 27732 03270
Glaramara Tuff at Long Crag

Closeup view of the multiply rimmed accretionary lapilli up to 1 cm long.

Traversing south along Long Crag takes you through continuous exposure of the massively reduced Seathwaite Fell Formation section most of which is seen in this photograph **[NY 28010 03892]**. The well-developed bedding is mainly turbiditic in origin but none of the distinctive members seen in the Scafell Caldera can be identified. Some of the layers have reverse graded pumice fragments a few cm in size and one layer has 50 cm pumice clasts possibly from subaqueous eruptions.

Just below this point is the hugely reduced equivalent of the Airy's Bridge Formation which here is a flow-folded rhyolite.

The southerly traverse from Locality 4 will go a little way into the Airy's Bridge correlate. The contact is at NY 28020 03845 where the rhyolite is flow banded and a little further south there is flow folding [NY 28037 03776] on a metric-scale.

The lower contact of the rhyolite is a minor fault but the total thickness of this equivalent to the Scafell Caldera fill ignimbrites is only a few tens of metres partly explaining the problems of recognising regional stratigraphy in the former Side Pike Complex.

Immediately above Locality 4 is the **Lingmoor Fell Formation** which starts as a 20 metre thick pebble/boulder sedimentary breccia with an erosional base.

Shown in this view is the following eight metres of mainly parallel-bedded airfall tuffs, some of which has been aqueously reworked, overlain by a distinctive rhyolitic welded-ignimbrite which is about 30 metres thick. The silicic ignimbrite is much repeated by faulting in this area and is seen on Side Pike itself.

Within the former Side Pike Complex the Lingmoor Fell Formation is represented by the Side Pike Member [Brown, 2001]. This has been subdivided into four units. **Unit 1** is the basal breccia, **Unit 2** is the predominantly airfall component, and **Unit 3** is the rhyolitic ignimbrite seen at locality 5. **Unit 4** is another predominantly airfall unit seen at locality 6.

Locality 5 NY 28079 04060
Unit 3 Side Pike Member, Lingmoor Fell Formation

This ignimbritic unit has several subdivisions not all of which will be examined on the excursion. Much of it is a very distinctive strongly-welded ignimbrite and typically virtually all of the fiammé are one to two cm long. Some exposures have flattened pumice fragments 10 to 20 cm long forming up to 5%. Small lithic fragments are wrapped by the welding foliation giving an indication of the amount of flattening. Coin is 21.4 mm in diameter.

The basal couple of metres of the ignimbrite are stratified with low angle cross stratification. This formed from a low density pyroclastic current that may have had a phreatic component to the explosivity. This is seen at NY 28079 04060 but probably will not be visited on the day.

The top of the ignimbrite is fissured as seen at NY 28169 04159.

Locality 6 NY 28215 04070
Unit 4 Side Pike Member, Lingmoor Fell Formation

The uppermost unit in the Lingmoor Fell Formation in this area is a mainly parallel-bedded set of airfall tuffs. Accretionary lapilli are distributed through the unit though only locally abundant. There is evidence of some fluvial reworking of the pyroclastics towards the top of the unit.

Tectonic cleavage of Acadian age is now apparent in some lithologies but it does not obscure original features.

The GPS unit is 5 x 10 cm.

Locality 7 NY 28382 04062
Boundary Lingmoor Fell/Tilberthwaite Formations

This boundary is normally marked by the presence of a sedimentary breccia which contains fragments of many of the pyroclastics below this contact. At its most distinctive the breccia is dominated by large clasts of highly-welded ignimbrite as seen on Lingmoor Fell. At locality seven clasts of accretionary tuff are evident.

From here to the top of Bleaberry Knott [NY 28419 04062] turbidites [e.g. at NY 28402 04083] show that depositional conditions have significantly changed from subaerial with fluvial reworking to lacustrine. A few metres before the summit cairn is the base of a dolerite sheet which locally is laced with sedimentary stringers showing it to be a peperitic sill.

Locality 8 NY 28541 04119 to 28512 04068
Soft-sedimentary deformation - Tilberthwaite Formation

Steeply dipping volcaniclastic sandstones as an expression of soft-sedimentary deformation.

Supporting evidence for the megabreccia nature of the Side Pike Complex came from the common development of soft-sedimentary deformation. Branney & Kokelaar [1994] inferred the presence of disaggregated chaotic material between megablocks and interpreted the deformation as being the result of competent megablocks driving into less competent ones. They described severe soft-state deformation and at locality eight considered it to be an example of “spectacular soft-state deformation”. This zone has soft-sedimentary faulting and metric scale folding, locally producing steep dips, but it is not particularly intense when compared to many of the sedimentary packages in the Borrowdale volcanics.

The best example [NY 28682 04301] of this style of deformation on the descent from Bleaberry Knott is a bit of a detour so will not be visited.

A4 map case for scale.

REFERENCES

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