

Tranearth Group succession, Windemere Supergroup, late Ordovician to Silurian, Northern England

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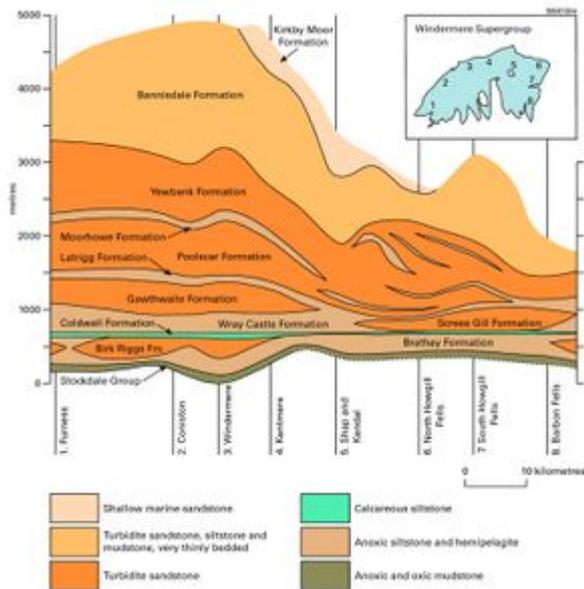
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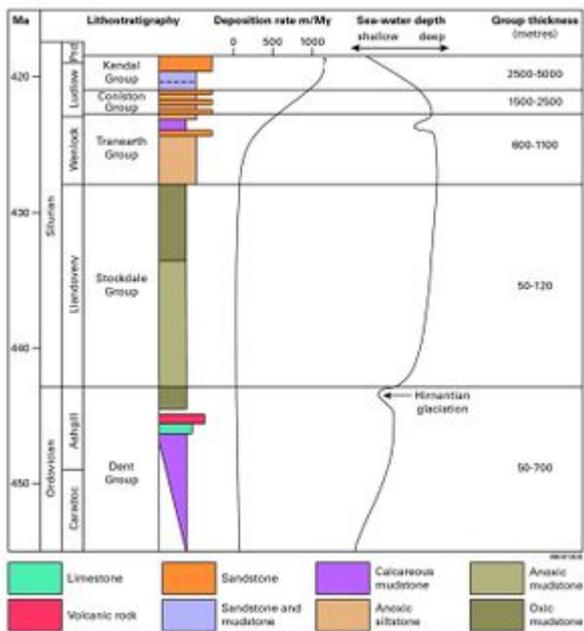
Introduction



Brathay Formation laminated hemipelagite with thin siltstone and mudstone interbeds was worked here at Applethwaite Quarry, Troutbeck [NY 4234 0338] for building slates. The thin white bed (arrowed) near the base of the rock face in the centre of the photograph is a bentonite (altered volcanic ash) band. (P223322).



Lateral stratigraphical variation through the Silurian sector of the Windermere Supergroup (after Rickards and Woodcock, 2005).:). P916056.



Variations in sedimentation rate and sea level during deposition of the Windermere Supergroup (after Rickards and Woodcock, 2005). Prd = Pridoli.26). P916057.

Above the Stockdale Group lie several hundred metres of strata dominated by a distinctively laminated, hemipelagic silty mudstone. Two formations composed almost entirely of this lithology mark the base and top of the group (Brathay and Wray Castle formations respectively) and are separated by a development of calcareous siltstone (Coldwell Formation) widely (but not invariably) preceded by an underlying sand turbidite unit (Birk Riggs Formation). The varve-like lamination of the dominant hemipelagite is interpreted as the result of periodical (possibly annual) fluctuations in clastic input interrupting a background accumulation of organic material. The hemipelagite is almost exclusively anaerobic, with a pelagic fauna of graptolites and orthocones.

The Brathay Formation, at the base of the Tranearth Group, was deposited mostly during the early

Wenlock (Sheinwoodian). It consists almost entirely of laminated hemipelagite, with a few silt and mud turbidite beds becoming more abundant near the top of the formation ([P223322](#)). This trend is particularly apparent in the west of the Lake District outcrop where the Brathay Formation is overlain by the sandy turbidites of the Birk Riggs Formation. It is less pronounced in the Howgill Fells where the latter formation is missing and instead the Brathay Formation extends upwards to the base of the Coldwell Formation. The characteristic hemipelagite lamination is defined by alternating layers rich either in quartz silt or in organic carbon. The silt-carbonaceous couplets have a spacing of about 2 mm, but this compacted spacing may double where the lamination passes through one of the fairly widespread, diagenetic carbonate nodules that become more common and larger up-sequence. Rare bentonitic claystone layers, a few mm thick and derived from volcanic ash, occur throughout. At the base of the formation there is a 10–30 m interval in which the distinctive hemipelagite is interbedded with pale grey, bioturbated siltstone. This transition from the underlying Far House Member (Browgill Formation) has been defined as the Dixon Ground Member and appears consistently across the southern Lake District and in the Howgill Fells. The distinctive hemipelagite lithology of the Brathay Formation is also seen in the Cross Fell inlier but there the biostratigraphical evidence proves only the middle part; neither the base nor the top of the formation are seen. This isolated section of the Brathay Formation is the highest part of the Windermere Supergroup preserved at Cross Fell.

The sandy turbidite beds of the Birk Riggs Formation, up to about 380 m thick, were deposited during the *lundgreni* graptolite Biozone (Homerian, late Wenlock). They are most thickly developed to the west of Ambleside ([P916056](#)) but thin westwards and are not seen across the south-west Lake District, before reappearing in Furness. From its maximum development, the formation also becomes thinner eastwards until, in the Howgill Fells, the Brathay Formation extends upwards through the same biostratigraphical interval to the base of the Coldwell Formation. Throughout the Birk Riggs Formation, sand-rich sections alternate with intervals of laminated hemipelagite in which there may be only a trivial proportion of thin sandy beds. The sandstone beds show the range of features characteristic of deposition from turbidity currents: flute and groove casts on their bases, graded bedding, and an upward progression to parallel- and cross-laminated, silty tops. In general, the highest of the turbidite sandstone beds is separated from the base of the overlying Coldwell Formation by about 25 m of laminated hemipelagite.

An abrupt change of lithofacies is represented by the Coldwell Formation, which consists of two units of intensely bioturbated, calcareous siltstone separated by laminated hemipelagite. The two siltstone units are afforded member status and consist largely of graded units with a sporadic basal coquina of reworked shelly material: the Randy Pike Member lies at the base of the formation, the High Cross Member at the top. The total thickness of the formation is in the 50 to 80 m range in the southern Lake District where a significant proportion of the formation, up to about 50 m, is contributed by the central zone of hemipelagite. Thence the formation thins eastwards towards the Shap area, where it is not present, before reappearing with a 10 m thickness in the Howgill Fells. Some additional lithological variation is apparent within the thin, Howgill Fells succession where slumped mudstones, and limestone clasts contained in a hemipelagite matrix, suggest mass-flow deposition. There are also indications from that area of a lateral transition from calcareous to non-calcareous but bioturbated mudstone. Throughout the outcrop, the calcareous siltstone components of the formation contain a shelly fauna, notable particularly for the trilobites, whilst graptolites are widespread in the hemipelagite interval. The biostratigraphical range that these fossils define spans the boundary between the late Wenlock, Homerian Stage and the early Ludlow, Gorstian Stage. The facies and oxicity changes marked by the Coldwell Formation and its fauna probably reflect a eustatic fall in sea level ([P916057](#)).

The topmost formation of the Tranearth Group, the Wray Castle Formation, marks a return to

laminated hemipelagite with only minor intercalations of mud or silt turbidite. The lithology is very similar to that seen in the Brathay Formation, but the Wray Castle Formation has a higher proportion of silt and slightly larger lamination spacing than its older counterpart. Rare bentonitic claystone layers, derived from volcanic ash and usually only a few mm thick, occur throughout. Deposition of the Wray Castle Formation was entirely within the earliest Ludlow, *nilssoni* graptolite Biozone but nonetheless, between 280 and 350 m of strata are preserved in the southern Lake District. The formation thins eastwards so that in parts of the Howgill Fells only a few metres of laminated hemipelagite separate the top of the Coldwell Formation from the thick beds of turbiditic sandstone at the base of the Coniston Group.

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