

limestone from the Applethwaite Member of the Kirkley Bank Formation. The beds dip moderately to the right and are cut by a strong, near-vertical cleavage. Moor Head, Troutbeck [NY 4243 0365]. The hammer head is 17 cm long. (P223319).

The formal stratigraphical name acknowledges the thick and almost unbroken Caradoc to Ashgill sequence present in the Cautley and Dent inliers, in the south-east Lake District. In contrast, the successions further west are interrupted by non-sequences and show much local variation in lithofacies, the likely result of topographical interaction with the post-volcanic marine transgression. The Dent Group successions and their regional correlation are summarised in ([P916055](#)). Note that additional Dent Group strata crop out further south in the Craven inliers; they are described in the British Regional Geology guide to the Pennines and adjacent areas.

The oldest component strata of the Dent Group in the Lake District are found in the north and east of the region. In an outlier faulted between the igneous rocks of the Carrock Fell Complex and the Eycott Volcanic Group are the shales of the Drygill Formation, calcareous ashy mudstone containing a Longvillian fauna of trilobites and brachiopods. Rocks of very similar age are also found further east, in the Cross Fell inlier, where they form the base of the Dufton Shale Formation, a more extensive succession consisting mostly of dark grey, calcareous mudstones with sporadic limestone nodules, that ranges up into the Ashgill and contains a varied shelly fauna. In places, the lowermost part of the Dufton Shales sequence, of early Longvillian age, is dominated by volcanoclastic siltstone and fine-grained sandstone known as the 'Corona' Beds. Above these beds, the Dufton Shale Formation continues up into the Ashgill, Cautleyan Stage, but with a reappearance of the sandy facies towards the top (Billy's Beck Member), albeit with a more quartzose composition. In the Cross Fell inlier, the Dufton Shale Formation is overlain with slight unconformity by the decalcified but richly fossiliferous carbonate rocks of the Rawtheyan, Swindale Formation, with the succeeding shales of the Ashgill Formation extending into the Hirnantian. At this level in Cross Fell the localised Keisley Limestone is the best example of an Ordovician, calcareous mud-mound in England and contains a diverse shelly fauna rich in trilobites.

By Hirnantian time, Windermere Supergroup sedimentation had commenced across most of the southern Lake District, with basal strata commonly of Cautleyan age. A mixture of clastic and carbonate facies prevails, interrupted by non-sequences and erosional breaks. These combine to produce a laterally variable lithostratigraphy with an abundance of local names.

The most continuous sequence is seen in the Cautley and Dent inliers, where up to about 370 m of calcareous mudstone contains interbeds of nodular limestone from which has been recovered a benthic shelly fauna of trilobites, brachiopods, bryozoans and corals. This is the Cautley Mudstone Formation. The fauna is characteristic of the Cautleyan and Rawtheyan stages of the Ashgill Series, the stratotype of which is located in one of the inliers (Westerdale) near Cautley. The traditional correlation of these Ashgill stages has been with the *anceps* graptolite Biozone, but recent graptolite discoveries in the Cautley district suggest that correlation with the earlier, Caradocian, *linearis* Biozone might be more appropriate. The full implications of this have yet to be assessed but are likely to require wide-ranging stratigraphical revisions. At the local level it introduces considerable uncertainty into the ages and correlations of the Dent Group's component units.

Across the southern Lake District outcrop the Dent Group has a highly variable basal clastic facies consisting of volcanoclastic sandstone and conglomerate. These deposits are discontinuous (and probably diachronous) and represent a variety of littoral and fluvial environments. They are associated together as the Longsleddale Member of the Stile End Formation, which is otherwise

composed of calcareous marine siltstone with intermittent developments of nodular limestone. The Stile End Formation ranges up to more than 400 m in thickness and its distribution probably reflects topographical control on the Late Ordovician transgression.

Overlying the Stile End Formation with apparent conformity are up to 185 m of pale grey and pink, flow-folded rhyolitic rocks that were probably emplaced as a rheomorphic ignimbrite. In places, along both the upper and lower margins of the ignimbrite, are thin clastic accumulations composed mainly of ash, pumice and felsitic rock fragments. This Cautleyan volcanic unit has become widely and informally known as the 'Stockdale Rhyolite', but recent stratigraphical formalisation has re-established the original terminology and defined it as the Yarlside Volcanic Formation. It is broadly co-extensive at outcrop with the underlying Stile End Formation, suggesting that both were depositionally constrained by topography, with the rhyolitic ignimbrite filling a pre-existing valley that had already been partially filled with sediment deposited during marine transgression. Variation in the thickness of the ignimbrite can be related to residual topography within the confining valley. The top of the ignimbrite shows evidence of subaerial erosion and has been locally reworked into the base of the overlying Kirkley Bank Formation.

In the south-east of the Lake District, the calcareous siltstone, nodular limestone and fine-grained sandstone of the Kirkley Bank Formation overlie the erosion surface at the top of the Yarlside Volcanic Formation. Farther south-west, and in Furness, the Kirkley Bank Formation rests directly and unconformably on either the Borrowdale Volcanic Group or the Skiddaw Group, though it is uncertain whether basal volcanoclastic units (e.g. the Low Scales Member) should be regarded as parts of the Kirkley Bank Formation or more properly assigned to the Longsleddale Member of the Stile End Formation.

Several local members are defined for the Kirkley Bank Formation, based on the local dominance of the constituent lithologies that combine to a thickness of between 5 and 140 m. In general, a high proportion of concretionary limestone, sporadically crystalline, occurs near the base of the formation ([P223319](#)) and is succeeded by graded units of fine sandstone to siltstone with basal accumulations of shelly detritus, extensive parallel- or cross-lamination, and locally pervasive bioturbation. The relationship with the overlying, nodular and bioturbated micritic limestone of the Broughton Moor Formation (up to 6 m thick, where present) is unclear. There is no biostratigraphical evidence for the upper part of the Cautleyan Stage, and instead the fossil evidence indicates a mid Rawtheyan age for the Broughton Moor Formation. This would suggest, at least, a stratigraphical hiatus, but in places there is evidence for continuous deposition from Kirkley Bank to Broughton Moor, and it is possible that the latter formation should more correctly be regarded as a condensed sequence. A possibly equivalent limestone unit faulted against the Dufton Shales in the Cross Fell inlier (the Swindale Formation) is richly fossiliferous and spans the Cautleyan-Rawtheyan stage boundary. In the Furness area, southwest of the Lake District, an assemblage of pebbly mudstone and matrix-supported conglomerate with limestone clasts, the Lumholme Member, rests conformably on Broughton Moor Formation strata. It was deposited as a debris flow and contains reworked mid Rawtheyan conodonts, but has also been assigned to the stratigraphically higher Ashgill Formation.

Closely above the Broughton Moor Formation limestone in biostratigraphical terms is a thin (up to 6 m) volcanoclastic unit. It consists of sandy, pyroclastic material resedimented by gravity flows and is suggestive of contemporaneous volcanic activity. It is variously known as the Appletreeworth Formation (south-west Lake District) or the High Haume Volcanic Formation (Furness) and in these guises it ranges up to about 6 m in thickness. It is not present in the southeast Lake District but reappears further east in the Cautley and Dent inliers. There, as the Cautley Volcanic Member, it comprises up to 25 m of rhyolitic tuff interbedded towards the top of the Cautley Mudstone Formation where a mid Rawtheyan age can be firmly established.

At the top of the Dent Group, spanning the Rawtheyan to Hirnantian stage boundary and present across the full breadth of the outcrop from Furness to Cross Fell, is a pervasively bioturbated, laminated mudstone/siltstone unit, the Ashgill Formation, commonly with a more calcareous and fossiliferous basal facies. Across the southern Lake District, the latter appears as a calcareous siltstone with some nodular limestone interbeds, the Troutbeck Member, but in the Cautley and Dent inliers it is an argillaceous limestone, the Cystoid Limestone Member. A unit of sandstone and pebble conglomerate towards the top of the formation has been identified variously as the Rebecca or Wharfe Member, and may be an equivalent of the stratigraphically ambiguous Lumholme Member mentioned above in the context of Broughton Moor Formation. The Ashgill Formation ranges up to 25 m thick in the southern Lake District, but attains 60 m at Cautley and Dent; the basal calcareous member usually represents between 1 and 3 m of the total whilst the Rebecca and Wharfe members rarely exceed 4 m in thickness. The Furness area appears anomalous in this respect, with the Rebecca Member alone apparently attaining a thickness of 50 m.

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