River Rawthey

[SD 7087 9785]–[SD 6984 9696]

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Introduction

The River Rawthey section, between its confluences with Wandale Beck and Backside Beck, lies 7 km north-east of Sedbergh, Cumbria, on the eastern flank of the Howgill Fells (Figure 3.49). It exposes the most complete section through the 250 m thick Wenlock succession of the Howgills. Watney and Welch (1911) first subdivided this succession using graptolites, but Rickards (1967) established a full graptolite biostratigraphy that was capable of correlation with the Shropshire type area for the Wenlock Series (e.g. Cocks *et al.,* 1992). This biostratigraphy was later extended to the main Lake District outcrop (Rickards, 1969, 1970b, 1989a).

The Howgill Fells lie along strike from the thick succession of Ludlow and P■ídolí rocks that forms the southern Lake District. However older Silurian rocks (Wenlock and Llandovery) and uppermost Ordovician (Ashgill) rocks crop out in the eastern Howgills in a series of inliers, structurally related to Variscan displacement on the Dent Fault zone. The NNE-striking fault zone lies about 1 km east of the Rawthey section.

The Rawthey section contains three formations within the Windermere Supergroup, the nomenclature of which has been fully reviewed by Kneller *et al.* (1994). The Browgill Formation is of upper Llandovery (Telychian) age and has at its top the Far House Member, the Grey Beds of Rickards (1967). These pass up into the Brathay Formation through the basal Dixon Ground Member. Above the Brathay Formation is the Coldwell Formation, which spans the Wenlock–Ludlow boundary in this area (Rickards, 1970b).

Description

Wenlock rocks are exposed along the length of the Rawthey section, although the most informative segments are at its northern (Figure 4.58) and southern ends. Rocks of Wenlock age also crop out in Near Gill, Middle Gill and Far Gill, which join the central portion of the main Rawthey valley section on its south-eastern side and which also form part of this site.

The lithological transition from Llandovery to Wenlock rocks is seen in the north-west bank of the River Rawthey, 50 m upstream from its junction with Wandale Beck [SD 7073 9778]. Southward-dipping light grey mudstones with thin beds of green-grey ash, the Far House Member of the Browgill Formation, pass up into bioturbated blue-grey mudstones with intercalations of finely laminated graptolitic mudstone. These lowest 20 m of the Brathay Formation comprise the Dixon Ground Member. A 0.1 m thick limestone near the top of the member forms a useful lithological marker across the Howgills and the Lake District. The Dixon Ground Member lies entirely within the *centrifugus* Biozone. Rickards (1967) recorded the following graptolite assemblage from this horizon: *Monoclimacis vomerina vomerina, M. vomerina basilica, Monoclimacis shottoni, Monoclimacis linnarssoni, Monoclimacis griestoniensis nicoli, Pristiograptus watneyae, Pristiograptus* cf. *praedubius, Monograptus priodon, Monograptus minimus cautleyensis, Monograptus danbyi, Monograptus simulatus, Cyrtograptus centrifugus, Cyrtograptus insectus, Cyrtograptus murchisoni, Retiolites geinitzianus geinitzianus,* and *R. geinitzianus angustidens.* There are rare cephalopods, crinoids, conulariids and, in the bioturbated mudstone units, brachiopods and trilobites (*Aulacopleura* sp.).

Followed up section, the lithology becomes dominated by the finely-laminated mudstone that characterizes the main part of the Brathay Formation. The top of the Dixon Ground Member is taken above the last thick intercalation of bioturbated mudstone, near the mouth of Wandale Beck [SD 7067 9778]. The distinctive lamination in the Brathay Formation is defined by alternation of carbonaceous laminae, hosting graptolites, with silty mud laminae. The thickness of each silty mud–carbon couplet is remarkably regular, and averages about 0.2 mm (King, 1992). This facies has been described

extensively from other Lower Palaeozoic sequences, often by the term 'laminated hemipelagite' (e.g. Dimberline *et al.,* 1990; Kemp, 1991). Other lithologies only sporadically interrupt the uniformity of the laminated mudstone between the top of the Dixon Ground Member and the base of the Coldwell Formation: very thin homogeneous mudstone layers, thin-graded fine sandstone to mudstone layers (in the *riccartonensis* Biozone), and calcareous nodules.

Between Wandale Beck and Handley's Bridge [SD 7056 9764] the south or SW-dipping units of the Brathay Formation span the *murchisoni* to *lundgreni* graptolite biozones. About 200 m of strata are represented, cut by occasional small faults, particularly within the *linnarssoni* Biozone. The *murchisoni* Biozone is represented by 3 m of laminated mudstone exposed in the left bank and bed of the Rawthey at the mouth of Wandale Beck [SD 7067 9778]. This level yields C. *murchisoni, M. vomerina sensu lato, M. vomerina basilica,* and *M. priodon.* The *riccartonensis* Biozone is marked by the incoming of *Monograptus riccartonensis* at [SD 7068 9777]. This species typically occurs with *M. vomerina basilica* throughout the lowest 18 m of the biozone, joined by *Monograptus antennularius* and *Pristiograptus dubius* at its top. These latter two species continue through the succeeding 7.5 m of strata, but are joined by *Monoclimacis flumendosae* marking the *antennularius* Biozone. Some 5 m of strongly cleaved rocks yield no graptolites, but above them are about 9 m of strata assigned to the *rigidus* Biozone, although without finds of the eponymous fossil. The *linnarssoni* Biozone is characterized by *Cyrtograptus linnarssoni, Cyrtograptus rigidus cautleyensis, Monograptus flemingii flemingii, Monograptus flexilis flexilis,* and *Monoclimacis flumendosae flumendosae.* The biozone has a thickness of at least 33 m [SD 7061 9766]. The succeeding *ellesae* Biozone is probably about 5 m thick here, characterized by *Cyrtograptus ellesae.* This is followed, upstream of Handley's Bridge [SD 7062 9768], by the lower part of the 135 m thick *lundgreni* Biozone. The lowest 60 m of this biozone yield *Cyrtograptus lundgreni, M. flemingii flemingii, M flemingii primus, Monoclimacis flumendosae kingi, P. dubius, Pristiograptus pseudodubius* and species of *Favosites.* Above this level, C. *lundgreni* and *M. flumendosae kingi* are absent.

At Handley's Bridge, and for 400 m downstream, the Brathay Formation is affected by E–W folds, which repeat the *lundgreni* Biozone. The next 400 m, from the confluence with Middle Gill [SD 7043 9734] to the mouth of Backside Beck [SD 7005 9710], is a strike section of *lundgreni* Biozone rocks, cut by a NE-striking fault zone. Downstream from the fault, between Backside Beck and the river footbridge, the bed of the Rawthey exposes some 15 m of slumped calcareous siltstones. These are the lithostratigraphical equivalent of the Coldwell Formation, which, in unslumped sequences in the Howgills, comprises two limestone units separated by graptolitic mudstones. The Coldwell Formation in the Lake District is assigned to the *nassa* and *ludensis* biozones at the top of the Wenlock (Rickards, 1970b). However Rickards (1967) reported a Ludlow (*nilssoni–scanicus* biozones) fauna from below the upper limestone in the Howgills sequence, and suggested that the poor development of the *nassa* and *ludensis* biozones here may indicate a local non-sequence.

Collectively, the Wenlock exposures in Near, Middle and Far gills include *centrifugus to lundgreni* biozone strata, with the graptolite successions of Near and Middle gills having been documented in detail (Rickards, 1967). Further, some of these exposures represent graptolite type localities, for example for *Cyrtograptus rigidus cautleyensis* Rickards (1967), *M. flumendosae kingi* Rickards (1965b) and *P. dubius pseudolatus* Rickards (1965b).

Interpretation

The laminated mudstones that form the bulk of the Wenlock strata occur in many successions around the former Iapetus Ocean (Kemp, 1991) and their origin has been much debated. Earlier views on the examples in the Howgills are summarized by Rickards (1964), who developed the idea of Marr (1927) that each couplet of silt and carbon laminae may represent an annual cycle of deposition. Rickards envisaged a constant rain of algal organic carbon deposited in anaerobic bottom waters, interrupted periodically, though not necessarily annually, by silt deposition from low concentration turbidity currents. Kemp (1991) suggested alternatively that a number of carbon and silty-mud laminae could be deposited during one turbidity flow event. The carbonaceous laminae would represent discontinuous films of algal organic material deposited in intimate association with clay and fine silt, their apparent continuity being enhanced by later compaction. In support of the first hypothesis of discrete lamina-by-lamina deposition, Dimberline *et al.* (1990) drew analogies between the Wenlock hemipelagites in Wales and recent sediments in basins on the California Borderland (Thornton, 1984). There the lamination represents an annual climatic cycle of high warm-season productivity with high wet-season sediment runoff. The silt component of the lamination may be sedimented by vertical fallout from nepheloid

suspensions rather than directly from turbidity flows. On either hypothesis, the lack of bioturbation in the laminated mudstone implies a sparse or absent benthic fauna, and probable dysaerobic to anaerobic bottom waters.

Estimates of the lamination frequency in the Brathay Formation of the Howgills, using graptolite biozonation and its chronometric calibration (King, 1992), suggest a periodicity of three or four years. A near-annual driving influence is not precluded by this observation, given the potential for erosion and non-preservation of laminae. The Rawthey section offers one of the best opportunities for refining this time calibration in the future.

The basal Dixon Ground Member to the Brathay Formation represents alternating periods of marine basin anoxia with better oxygenated conditions characteristic of the underlying Browgill Formation. The green-grey siliceous mudstones of the Browgills become progressively less common through the Dixon Ground Member, reflecting a waning source of siliceous debris, possibly volcanic ash, as well as a change in oxicity.

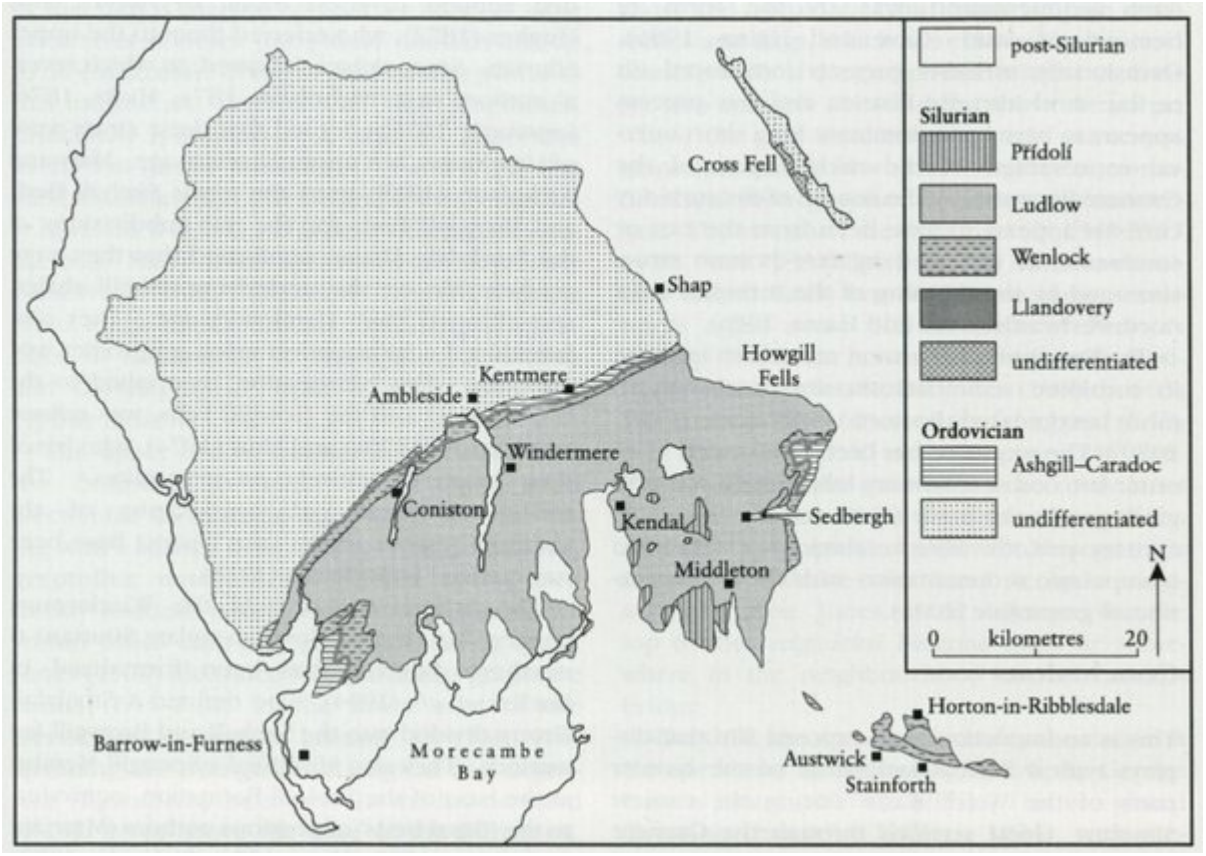
The Coldwell Formation, overlying the Brathay Formation, also records a period of oxygenated marine bottom waters. Preservation of organic carbon was suppressed and of carbonate was enhanced. Burrowing organisms and a shelly benthos colonized the sea floor and, for reasons poorly understood, soft-sediment slumping of the oxic muds was promoted. The *nassa* and *ludensis* biozones of the late Wenlock coincide with a eustatic marine lowstand that probably initiated the overturn of marine basin waters and the onset of the oxic environment. Anoxic bottom conditions returned with the rise in sea level at the beginning of Ludlow time (*nilssoni* Biozone) and the succeeding Wray Castle Formation is dominated by laminated hemipelagic mudstones similar to those in the Brathay Formation.

The Rawthey GCR site demonstrates the refinement in graptolite biozonation that is possible in the continuous sequences of laminated mudstone that typify basinal marine deposits of Wenlock age. This site provides a regional reference for northern England and southern Scotland, correlatable with the shallower marine sequences of the world stratotype area for the Wenlock Series in the Wenlock district of the Welsh Borderland. Together with the other Wenlock sites in the Lake District (Torver–Ashgill and Brathay Quarries), the Rawthey section offers a contrast with sites in areas that during this time have a more voluminous sediment supply, containing more abundant sandstone turbidites. Sites with the latter type of sedimentary regime are Arcow Quarry in the nearby Horton-in-Ribblesdale area, and the Balmae and Borgue coasts in the Scottish Southern Uplands.

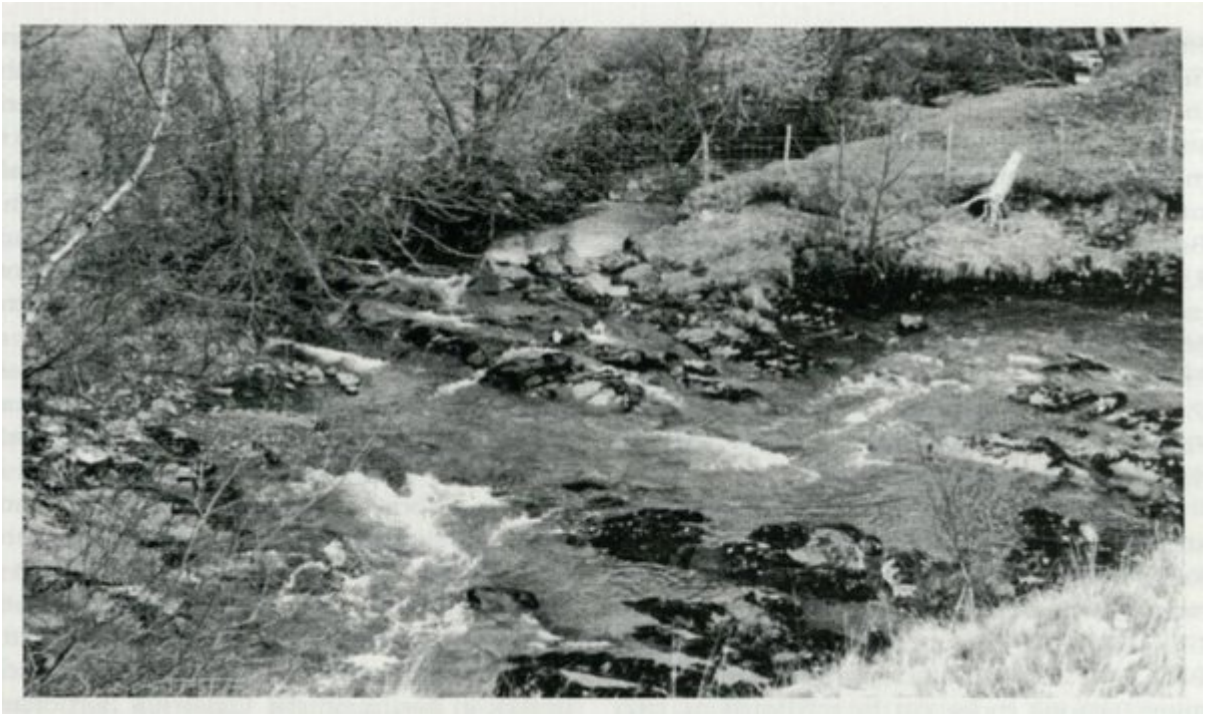
Conclusions

The Rawthey section provides near-continuous exposure through much of the Wenlock strata of the Howgill Fells, and it has much biostratigraphical and sedimentological importance. Together with numerous subsidiary sections in the same area, it has allowed Wenlock time to be finely subdivided into ten biozones using graptolites, thus allowing correlation with other areas in Britain and abroad. Future refinement of this subdivision will rely on this section above all others in northern England. The section also displays the typical laminated mudstone facies of Wenlock sedimentary rocks deposited in anoxic marine basins. It is important in the debate about the origin of this facies, and of the more oxic mudstones at the base and top of the Wenlock succession. The site also contains the type localities of various graptolite species.

References



(Figure 3.49) Outline geological map of the Lake District and Howgill Fells (modified after Rickards, 1989a).



(Figure 4.58) River Rawthey, Howgill Fells. Basal strata of the Wenlock Series at the junction of Wandale Beck and the River Rawthey. (Photo: Derek J. Siveter.)