Hills Quarry

[SD 5960 8803]

Potential GCR Site

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Introduction

The disused, roadside Hills Quarry, 2 km WSW of Killington, about 9 km south-west of Kendal, Cumbria (Figure 3.49), provides clean faces through the Underbarrow Formation, part of the Windermere Supergroup. The unit is up to 690 m thick and was erected as the Underbarrow Flags (Shaw, 1971a); it is approximately equivalent to the Passage Beds of Aveline and Hughes (1872, 1888). Moseley (1984) distinguished the Underbarrow Flags and the overlying Kirkby Moor Flags as members within a Kendal Formation (Figure 5.76), whereas Lawrence *et al.* (1986) recognized both members as full formations. Kneller *et al.* (1994) chose Hills Quarry as the body stratotype for the Underbarrow Formation and King (1994) included it within a Kendal Group that comprised both the overlying Kirkby Moor Formation and the underlying Bannisdale Formation (Figure 5.76).

Shaw (1971a, 1971b) recognized formal Lower and Upper divisions to the Underbarrow Formation based on biostratigraphy, but subsequently their lithostratigraphical use has been discontinued (Kneller *et al.,* 1994; King, 1994). However, the distribution of early and late Ludfordian faunas, corresponding to Shaw's Lower and Upper divisions, shows that both lower and upper boundaries of the formation are diachronous; they are older in the north, in Kentmere, and younger in the south, around Hills Quarry (Figure 5.77).

Description

Hills Quarry exposes about 30 m of strata; a typical section has three different lithofacies (King, 1992, 1994; see (Figure 5.78), (Figure 5.79)).

1. *Unbioturbated graded fine siltstones and sandstones* form beds 0.5 to 10 cm thick, grading up into mudstone. Bed bases are sharp, often with groove marks and load structures. Beds contain common unidirectional ripple cross-lamination, often arranged in fading ripple sets. Occasional intervals contain parallel or convolute lamination. This lithofacies also comprises most of the underlying Bannisdale Formation.
2. *Bioturbated graded fine siltstones and sandstones* represent beds of lithofacies 1 that have been variably affected by *Chondrites* bioturbation. Bioturbation is strongest in the mudstone top to each graded bed, where it gives an irregularly laminated appearance to the rock. The sandstone and siltstone intervals weather to a buff colour, reflecting the presence of a carbonate cement. This lithofacies dominates the Underbarrow Formation.
3. *Thin- to medium-bedded graded sandstones* occur in beds 5 to 30 cm thick. These beds are sharply based, and comprise moderately sorted, micaceous fine sand grading up into silt and clay. The sandstone intervals preserve planar lamination, low-angle cross-lamination, ripple cross-lamination and occasional convolute lamination. The mudstone tops are often bioturbated. This lithofacies increases in frequency towards the top of the Underbarrow Formation.

Palaeocurrent data from this area of the Underbarrow Formation suggest south-east-directed flow based on grooves, and south-east to SSW flow based on ripple cross-lamination (King, 1994).

Fossils in the Underbarrow Formation occur irregularly scattered through the graded beds of any lithofacies; or as thin concentrations within the basal parts of lithofacies 1 and 2; or as lensoid lags at the base of lithofacies 3. The fauna is presumed to be predominantly transported, probably from shallower depths. The shelly fauna is more abundant than in the Bannisdale Formation and is typical of Ludfordian faunas elsewhere in southern Britain.

The lower part of the Underbarrow Formation in the Hills Quarry area is characterized by the brachiopods *Atrypa reticularis, Aegiria grayi, Shagamella ludloviensis, Dayia navicula* and *Isorthis clivosa,* the ostracods *Neobeyrichia lauensis, Neobeyrichia nutans* and *Nodibeyrichia scissa* and the trilobites *Encrinurus stubblefieldi* and *Proetus* spp. (Shaw, 1971a). Also recorded at this level are bryozoans, crinoid ossicles, starfish, bivalves, nautiloids, a conodont, a gastropod, a solitary coral and fish debris. Shaw (1971a, b) correlated this fauna with that of the Leintwardine Formation (*Saetograptus leintwardinensis* Biozone) of the Welsh Borderland. Elements of this fauna occur progressively higher in the Underbarrow Formation to the north, thus demonstrating its diachroneity (Figure 5.77).

The upper part of the Underbarrow Flags, cropping out to the east and south-east of Hills Quarry (e.g. at Park Hill: [SD 6030 8730]), records a loss of about 50% of the fauna, including *A. reticularis, A. grayi, S. ludloviensis, N. nutans, N. scissa* and *E. stubblefieldi.* Some seven new species appear, including the ostracod *Neobeyrichia confluens* and the trilobite *Acastella prima.* Shaw (1971a, b) correlated this change with that at the base of the Whitcliffe Formation in the Welsh Borderland. Faunas of this age become progressively restricted to the overlying Kirkby Moor Formation further north, due to the diachroneity of the lithostratigraphical boundaries.

Interpretation

The graded beds of lithofacies 1 and 2 are interpreted as the products of deposition from dilute waning flows, probably turbidity flows generated by storm suspension of sediment (King, 1994). However, the absence of wave ripples or bi-directional cross-lamination in these beds precludes their deposition above storm wave base. They probably accumulated in an outer shelf or upper slope setting (Figure 5.81). The thin to medium-bedded sandstones (lithofacies 3) are transitional to those in the overlying Kirkby Moor Formation, where they show wave-generated features (see site report for Benson Knott). They represent more concentrated density flows, some probably deposited above storm wave base. The more abundant shelly fauna and bioturbation in the Underbarrow Formation indicates better oxygenated and probably therefore shallower water than the underlying Bannisdale Formation (King, 1994).

The diachroneity of the Underbarrow Formation implies that it was deposited between shallower water environments to the north, accumulating Kirkby Moor Formation, and deeper water environments to the south, accumulating Bannisdale Formation (Figure 5.81). These environments prograded rapidly southwards through late Ludlow and P■ídolí time, as the Lake District Basin was transformed first into an alluvial plain, and, by the mid-Devonian time, into an upland area experiencing erosion.

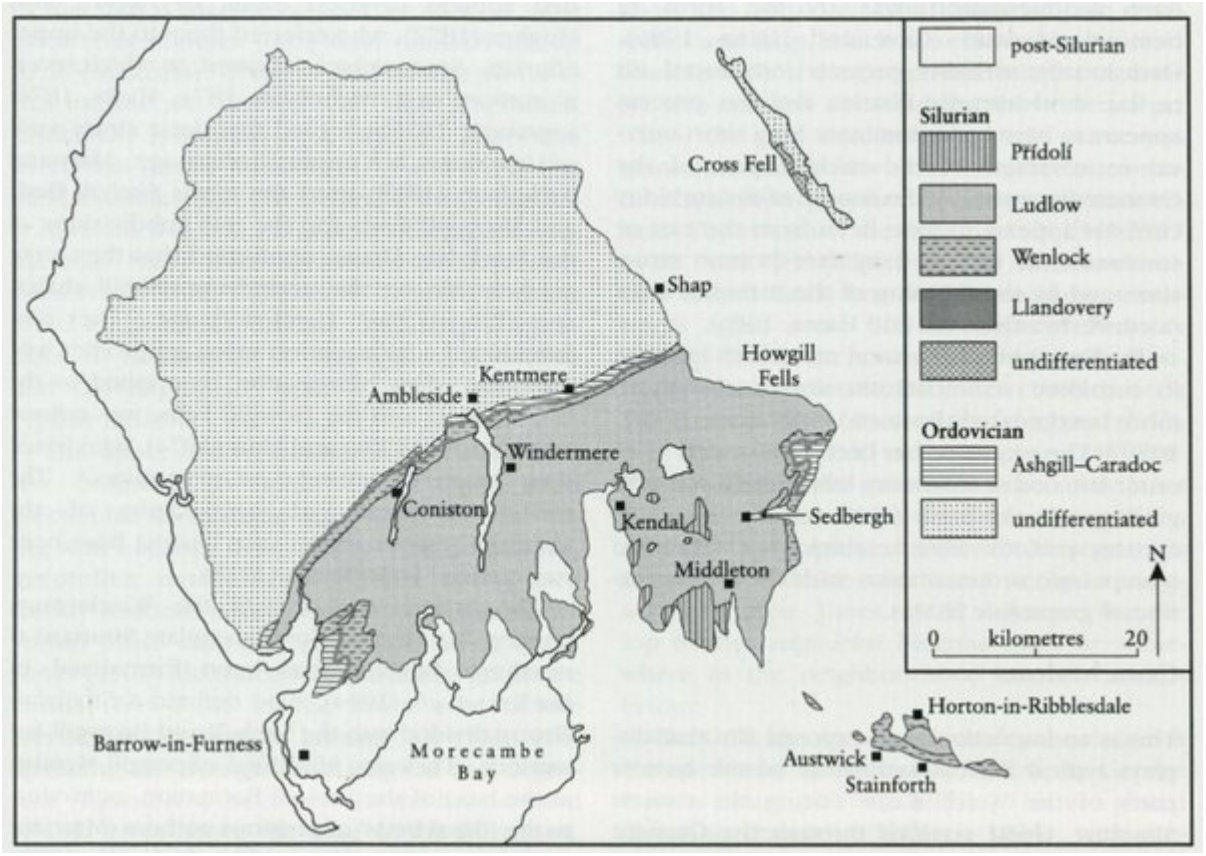
Thus, the Underbarrow Formation represents an early stage in the shallowing and eventual uplift of the Lake District Basin (Shaw, 1971a; Ingham *et al.,* 1978; Lawrence *et al.,* 1986). The diachronous progradation of shallow and marginal marine environments during the late Silurian demise of the basin is the clearest of any comparable transition in the Lower Palaeozoic of Britain. This transition is important in marking the onset of one of the great revolutions in British geological history; the transformation of the marine basins of the early Palaeozoic into the Caledonian mountain belt.

Hills Quarry, together with Benson Knott and The Helm, are proposed as GCR sites in order to demonstrate stages in the late Silurian (–Devonian) demise of the Lake District marine basin.

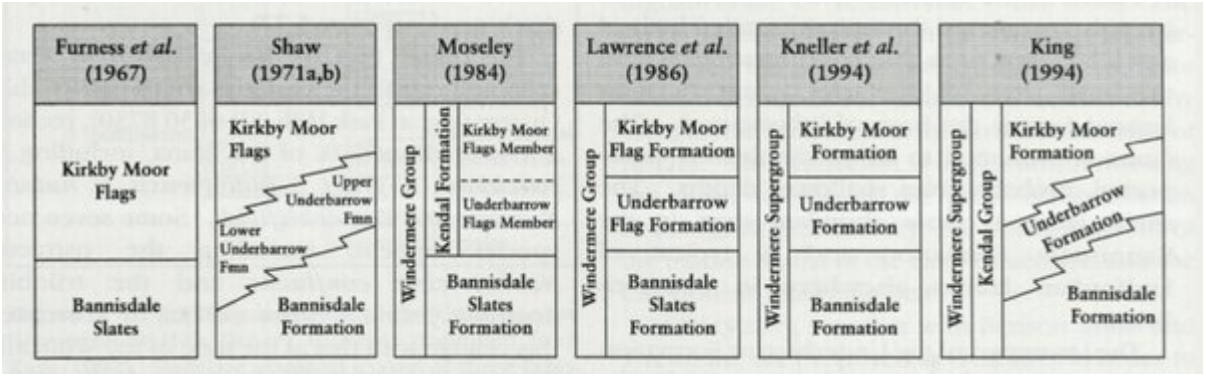
Conclusions

Hills Quarry provides good exposure of the type section of the Underbarrow Formation (Ludfordian Stage, Ludlow Series). This unit records the first phase of a regionally important late Silurian transition from the deep-marine Lake District Basin to shallow marine then marginal marine sedimentary rocks. Both bioturbation and shelly fossils are more common than in the underlying Bannisdale Formation, and turbidites give way progressively to coarser and more calcareous sediments. This locality has research potential for refining faunal and sedimentological parameters and their inter-relationship.

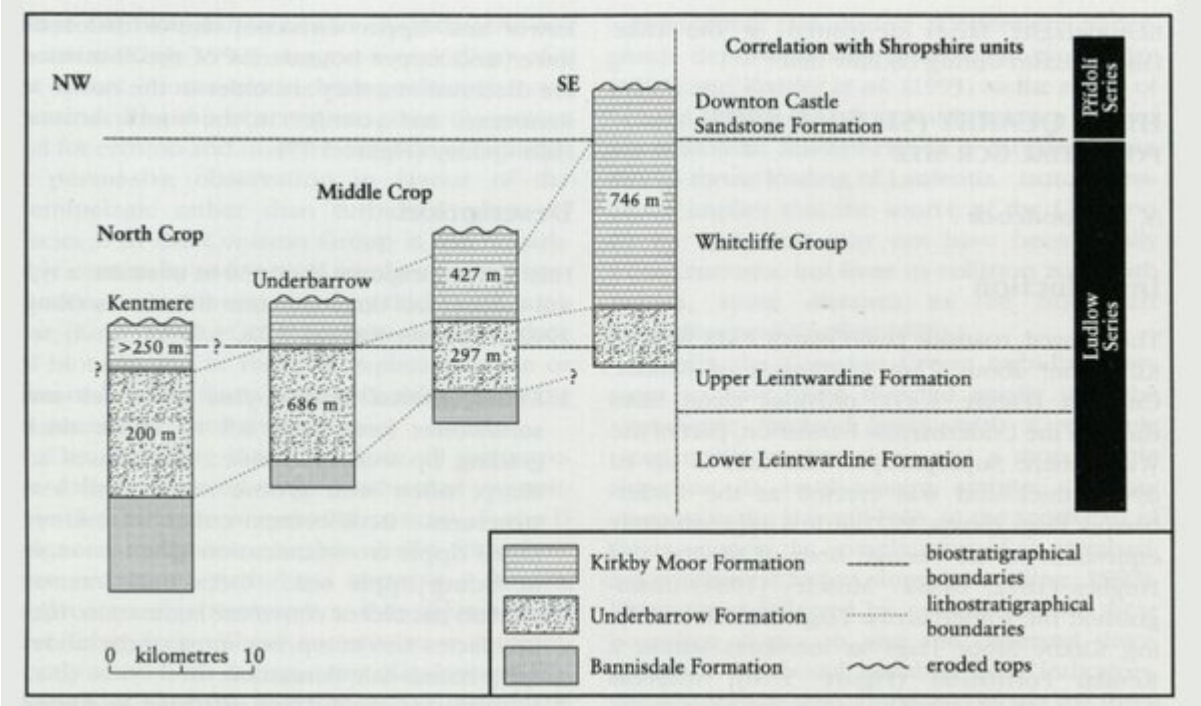
References



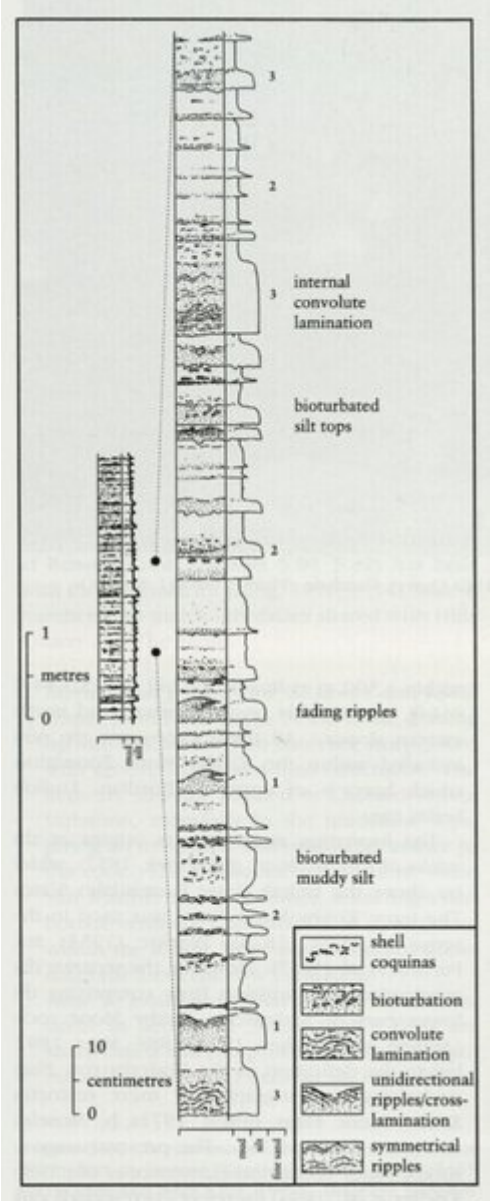
(Figure 3.49) Outline geological map of the Lake District and Howgill Fells (modified after Rickards, 1989a).



(Figure 5.76) Evolution of lithostratigraphical nomenclature in the Kendal Group, upper part of the Windermere Supergroup (after Lawrence et al., 1986). This nomenclature is relevant to Ludlow Series sites at Hills Quarry and Benson Knott, and to the P■ídolí site at The Helm, Cumbria.

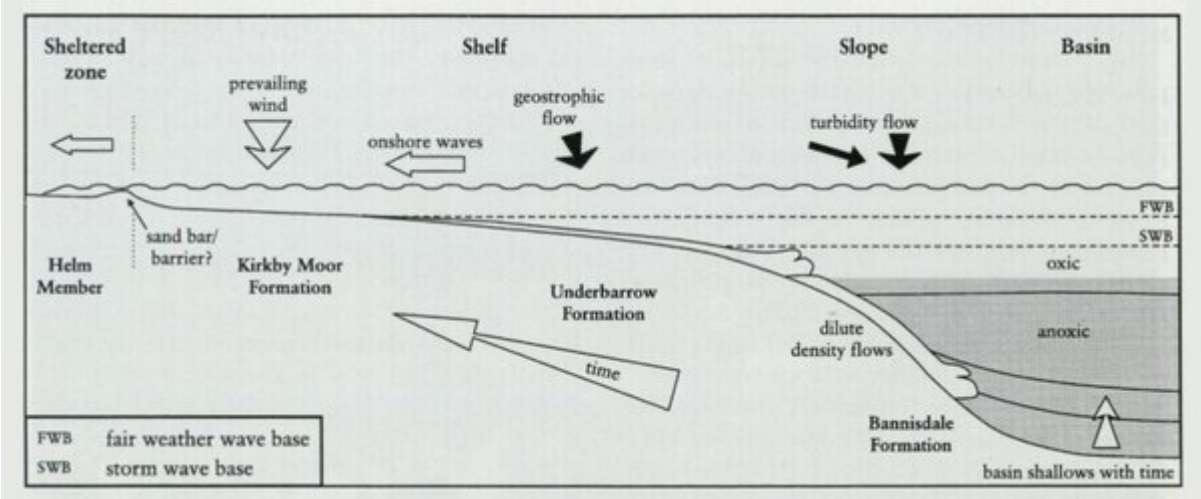


(Figure 5.77) Diagram illustrating the diachroneity of the lithostratigraphical units of the Kendal Group (after King, 1994).



(Figure 5.78) Representative log of the Underbarrow Formation at Hills Quarry, Cumbria (modified from King, 1992). Beds are assigned to one of three lithofacies (see text).

(Figure 5.79) The Underbarrow Formation at Hills Quarry, Cumbria. (Photo: David J. Siveter.)



(Figure 5.81) Hypothetical reconstruction of the northern margin of the Lake District Basin and its associated depositional environments, for formations spanning the Ludfordian-early P■ídolí time interval (after King, 1992). No absolute depths or scale are implied.