Arcow Quarry

[SD 802 705]

Potential GCR Site

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Introduction

Arcow Quarry is a working roadstone quarry 2 km south of Horton-in-Ribblesdale and 7 km north of Settle, Yorkshire (Arthurton *et al.,* 1988; Johnson, 1994). It exposes most of the Wenlock part and the lowest Ludlow part of the sequence of Lower Palaeozoic rocks forming the Craven inliers. These inliers have an Ordovician and Silurian stratigraphy that can be correlated with the Howgill Fells and the Lake District to the west. However, they show significant differences, particularly in a Wenlock sequence dominated by coarse elastic rocks. The inliers are the most easterly outcrops of Lower Palaeozoic rocks in northern England, before they are totally covered by Carboniferous and later rocks farther east.

The quarry exposes three formations, the nomenclature of which has been reviewed most recently by Arthurton *et* al. (1988) and Kneller *et al.* (1994). The Austwick Formation is wholly of Wenlock (Sheinwoodian to Homerian) age, whilst the Arcow Formation, although mostly of latest Wenlock (late Homerian) age, probably spans the Wenlock–Ludlow boundary (see Rickards, 1989a). The overlying Horton Formation is wholly of lower Ludlow (Gorstian) age. The description that follows concentrates on the Wenlock part of the succession.

Description

Arcow Quarry cuts the southward-dipping fold limb between the Crag Hill Anticline to the north and the Studrigg–Studfold Syncline to the south (Figure 4.56). The north part of the quarry exposes a gently ESE-plunging anticline, parasitic to the major structures. The anticline and the main part of the quarry are in the Austwick Formation (Figure 4.57). This comprises two main lithological components. Predominant are packets of medium- to thick- bedded sandstones, mainly of fine- to medium-grained sand grading up to mud, but with occasional coarse bases to the thicker beds. The sandstone beds have flute moulds on their bases, indicating flow from the ESE and internal ripple cross-lamination recording currents from the WSW The sandstone packets are intercalated with intervals of dark grey finely-laminated siltstones, each some metres thick. The lamination in the siltstones is defined by alternation of silty mud lam inae with carbonaceous laminae hosting graptolites. This facies has been described extensively from other Lower Palaeozoic successions, often by the term 'laminated hemipelagite' (e.g. Dimberline *et al,* 1990; Kemp, 1991). Thin-bedded non-laminated mudstones are sporadically intercalated with the laminated facies.

The basal 80 m of the Austwick Formation, as defined by McCabe (1972) following King and Wilcockson (1934), is dominated by laminated siltstones and has been reassigned to the Brathay Formation by Kneller *et al.* (1994). Their Austwick Formation begins at the incoming of the first sandstone beds, no later than the *rigidus* Biozone and possibly as early as the *centrifugus* Biozone (King and Wilcockson, 1934; Arthurton *et al.,* 1988). The Brathay Formation siltstones are exposed to the north of the quarry [SD 8015 7113]. The redefined Austwick Formation has yielded graptolites diagnostic of the *rigidus* and *lundgreni* biozones. A more continuous sedimentary record through Wenlock time is probable, but remains to be proved. About 100 m of the Austwick Formation are exposed in Arcow Quarry, out of a total thickness of about 220 m in this area.

The top of the Austwick Formation is marked by a 25 m thick laminated siltstone unit. The overlying Arcow Formation (McCabe, 1972) comprises 9 m of light grey, calcareous siltstone, previously (King and Wilcockson, 1934) included with the overlying Horton Formation. The lowest metre of the Arcow Formation is thin-bedded, with some ripple cross-lamination, but bioturbation has destroyed the lamination in the remainder of the interval so that massive or

burrow-mottled, thick-bedded units remain. Orthoconic nautiloids dominate a sparse shelly fauna. Graptolites have not been found, and dating rests on correlation with the Coldwell Formation, formerly the Middle Coldwell Beds, of the Howgill Fells and Lake District. Here, Rickards (1970b) dated the formation as latest Wenlock (*ludensis* Biozone) to earliest Ludlow (*nilssoni–scanicus* biozones). The Arcow Formation passes upwards through a 2 m transition into the dark-grey laminated siltstone at the base of the Horton Formation.

Interpretation

The laminated siltstone intervals in the Brathay and Austwick formations represent the background deep-marine sedimentation in the absence of coarse elastic input. Their precise origin has been much debated, particularly whether they were deposited lamina by lamina as a hemipelagic sediment, or by low-concentration turbidity flows that produced internal parallel lamination. This debate is outlined for the typical Brathay Formation deposits in the interpretation section of the River Rawthey network site. On either hypothesis, the lack of bioturbation in the laminated siltstone implies a sparse or absent benthic fauna, and probable dysaerobic to anaerobic bottom waters.

The graded sandstones in the Austwick Formation are the products of intermediate- to high-concentration turbidity flows (McCabe and Waugh, 1973; Arthurton *et al.,* 1988). These flows entered the region moving WNW and cut erosional sole structures. However, by the time that the waning flows were generating ripple cross-lamination, they were moving ENE, perpendicular to their original flow direction. The possible reasons for this palaeoflow divergence in the Windermere Supergroup have been discussed by Kneller *et al.* (1991), and include adjustment of along-slope flowing currents to the local basin slope and reflection of internal waves off a bounding lateral slope to the turbidite basin.

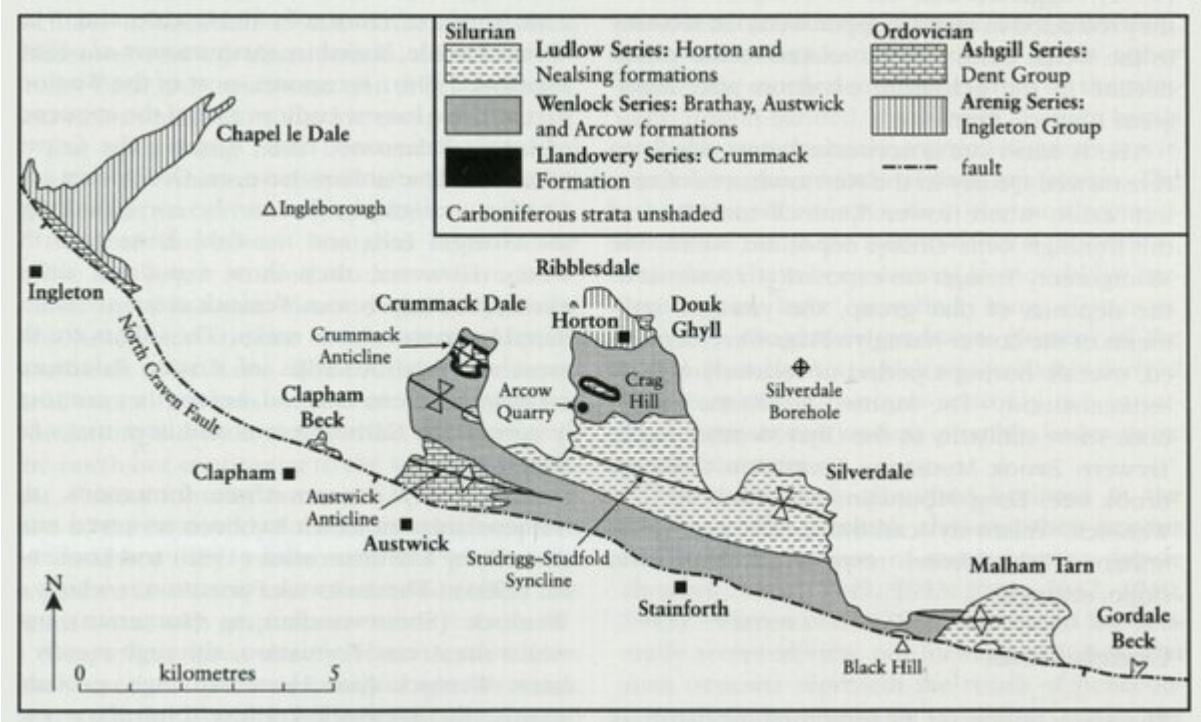
The Arcow Formation contrasts with the Brathay and Austwick Formations in recording a period of oxygenated marine bottom waters. Preservation of organic carbon 'was inhibited, deposition of carbonate was enhanced, and burrowing organisms and a shelly benthos colonized the sea floor. The onset of the oxic environment was due to basin ventilation, probably triggered by the eustatic marine lowstand during the *nassa* and *ludensis* biozones of the late Wenlock (Kemp, 1991; Johnson *et al,* 1991). The rise in sea level at the beginning of Ludlow time (*nilssoni* Biozone) re-introduced anoxia to the basin bottom waters, now recorded in laminated siltstones in the Horton Formation.

The Arcow site displays the first sand turbidites to enter the Lake District Basin, and contracts with the fine-grained deposits more typical of Wenlock sections in the basin, these finer sediments being well exposed in the Rawthey, Brathay and Torver–Ashgill GCR sites. Only in the central and western Lake District do comparable sandstones occur, in the Birk Riggs Formation (Kneller *et al.,* 1994; see Torver–Ashgill and Brathay site reports). These sandstones represent the start of more rapid infilling of the Lake Distict Basin, exemplified by the Ludlow turbidites at the Tebay GCR site.

Conclusions

Arcow Quarry provides a continuous section through much of the Wenlock and lowest Ludlow succession in the Craven inliers. The site is an important display of the anoxic hemipelagic facies that characterizes this time interval, and of the sandstone turbidites and anoxic mudstones that punctuate this background sedimentation. The succession in the Craven inliers also offers instructive comparisons with the Lake District and Howgill Fells sections farther west, particularly in the early incoming of turbidite sandstones. The inliers are the easternmost outcrop of Lower Palaeozoic rocks in northern England, before they are covered by Carboniferous and younger rocks.

References



(Figure 4.56) Location of Arcow Quarry, near Horton-in-Ribblesdale, and geology of the Craven inliers (after Arthurton et al., 1988).

(Figure 4.57) Arcow Quarry, near Horton-in-Ribbles-dale. Sandstone beds of the Austwick Formation. (Photo: David J. Siveter.)