Cadeby Quarry

[SE 52 00]

Highlights

Cadeby Quarry (box 7 in (Figure 4.2)) is the type locality of the Cadeby Formation and provides by far the largest and most comprehensive exposure in Yorkshire of both the Wetherby and Sprotbrough members and their mutual contact; the Wetherby Member here is of open shelf facies and contains more than 20 patch-reefs (at least some of a type found only at Cadeby) and the Sprotbrough Member is of offshore sandwave (shoal) facies with exceptionally large-scale cross-bedding. The intervening Hampole Beds are thicker here than anywhere else and atypically have yielded plant remains, and the erosion surface of the Hampole Discontinuity has a uniquely high relief of up to 3 m.

Introduction

The great working quarry at Cadeby lies on the north side of the River Don, south and east of the hamlet of Cadeby; most of the quarry is scheduled for filling, but the 18–23 m high north face is to be preserved when working ceases. Strata worked in Cadeby Quarry make up most of the Cadeby Formation, and comprise the Wetherby Member (13 m+) and the overlying Sprotbrough Member (10 m+); the latter is typical of this unit in the offshore sandwave or shoal belt of the English Zechstein marginal shelf, but the Wetherby Member is a uniquely spectacular mosaic of large byozoan-algal patch-reefs and surrounding skeletal grainstones. The Hampole Beds (?1–4 m) are atypical in containing abundant siliciclastic mudstones.

There are no comprehensive published accounts of Cadeby Quarry though summaries of strata have been given (Smith, 1969b, 1981b; Smith *et al.,* 1986). Reefs and associated strata exposed in nearby railway cuttings and on the opposite bank of the Don were mentioned by Mitchell (1932a) and Mitchell *et al.* (1947) and a typical Cadeby Quarry reef was discussed and illustrated by Smith (1981b, fig. 5). The presence of plants in the mudstones of the Hampole Beds was mentioned by Downie (1967) and a comprehensive account of the geochemistry of the Hampole Beds exposed in an abandoned railway cutting a short distance east of the quarry was given by Moss (1986).

Description

The position of Cadeby Quarry and its extent in 1990 is shown in (Figure 4.22), which also shows the position of the retreating north face where the GCR site is concentrated. This face is about 1823 m high (according to position) and 300–400 m long.

The quarry is cut through most of the Cadeby Formation, an estimated 7 m of which (proved by boreholes) underlies the quarry floor and a small thickness (probably less than 5 m) has been eroded from the top. The general geological sequence in the quarry is shown diagrammatically in (Figure 4.23).

Wetherby Member, including most of the Hampole Beds

The Wetherby Member at Cadeby Quarry comprises three main rock types, all dolomite; peloid grainstones (with some packstones), bryozoan-rich boundstone (in patch-reefs) and domed stromatolitic laminites. In general the reefs are scattered unevenly in an otherwise continuous sheet of grainstones and grade upwards into stromatolite mantles that progressively extend to form much of the upper part of the member.

Grainstones in the Wetherby Member at Cadeby Quarry are similar to those surrounding the patch-reefs at South Elmsall Quarry and Newsome Bridge Quarry and comprise a varied mixture of pale buff, poorly-sorted ooids (predominant), pellets, compound grains, botryoidal grains, lumps, pisoids, stromatolite flakes, scattered tabular clasts up to 0.1 m across of ooid grainstone, and bioclasts. Some or all of the pisoids may be oncoidal (algal) in origin but no undoubted

algal filaments have been recognized. The bioclasts are mainly represented by casts of largely unworn bivalves (*Bakevellia, Liebea, Permophorus* and *Schizodus*) and small gastropods, and they occur in profusion at some levels. Cavities after secondary anhydrite abound.

Patch-reefs in the Wetherby Member at Cadeby Quarry occur at intervals of 100–200 m in the north and west faces and similarly-spaced low eminences on the quarry floor show where others have been almost quarried away; more than 20 reefs are, or have been, present. Most of the reefs are roughly circular in plan and 15–50 m across at the level of the quarry floor; they have a buff and grey-buff, hard bryozoan boundstone (framestone) core at least 8 m high (bases not seen) and most are steep-sided mounds (Figure 4.23). In detail, the reef-cores are dense masses of dolomite mudstone and siltstone with a varied 5–50% framework of straggling and pinnate bryozoans, including species of *Fenestella* which have not been recorded from other patch-reefs in this member; a photomicrograph of typical reef dolomite from a patch-reef near to Cadeby Quarry was published by Smith (1981b, fig. 11B). At least one of the reefs features striking arrays of finger-sized stromatolite columns, also not reported from other patch-reefs in the Wetherby Member.

Upper parts of the bryozoan patch-reefs at Cadeby Quarry are thickly draped with complexly-domed, cream to pale buff, finely saccharoidal laminites which extend part of the way down the reef sides and either merge with mantles draping adjacent reefs or pass into peloid grainstones. Details are difficult to determine because of the inaccessibility of most of the exposures, but it appears that much or most of the upper part of the Wetherby Member, up to the Hampole Discontinuity, is composed of complexes of stromatolite domes that mainly overlie bryozoan reef-cores and are separated by relatively flat-lying stromatolites and/or grainstones in which domes are present only locally. Fallen blocks from these strata show that lamination is faint, fine and commonly mammilar, and that at least some of the stromatolite domes are composed of stacked minor domes each 0.10–0.30 m across and a few centimetres high. It is possible that the draping effect of stromatolitic dolomite over the reefs is partly compactional, but some primary relief and early cementation is indicated by the evident differential resistance of the reef mantles to erosion when the Hampole Discontinuity was cut.

The Hampole Discontinuity in Cadeby Quarry is unusually uneven, having a local relief of 2.5–3 m and, in places, sub-vertical cliffs up to about 1.5 m high (Smith, 1981b, fig. 5). High points on the discontinuity coincide with upstanding reefs in the main part of the Wetherby Member, against which lower parts of the Hampole Beds display marked onlap; higher parts of the Hampole Beds appear to thin only slightly over these eminences.

The Hampole Beds at Cadeby Quarry are not readily accessible but their position, thickness and relationship to the main part of the Wetherby Member are relatively clear (Figure 4.23) when viewed from the quarry floor. From this vantage it is difficult to recognize the typical Hampole Beds sequence (Smith, 1968, fig. 2) but it seems likely that the usual members of this sequence form the upper (more uniform, Sprotbrough Member) part of the Hampole Beds at Cadeby Quarry and are augmented by a discontinuous lowest unit (up to 1.8 m thick, part of the Wetherby Formation) which occupies hollows in the discontinuity surface. Fallen blocks from this lowest unit reveal it to be mainly of thin- to thick-bedded, buff to grey-green, slightly argillaceous dolomite mudstone with thin beds and lenses of grey, green and red siliciclastic mudstone from which Downie (1967) recorded remains of a land conifer.

Sprotbrough Member, including the upper part of the Hampole Beds

This forms the upper part of the faces all round the quarry and is about 7–10 m thick in the north face; it is not readily accessible, but can be seen from the quarry floor to be mainly coarsely cross-stratified in wedge-shaped sets individually up to about 8 m high. Fallen blocks from this unit show that the rock is typical of the Sprotbrough Member throughout the belt of sandwaves, being composed of pale cream, well-graded, fine ooid grainstones with only a few compound grains and less than 1% of siliciclastic grains (mainly subangular quartz); no fossils have been found in this member at Cadeby Quarry. The rock is of almost pure dolomite, but a little calcite thinly lines some of the many cavities that mark the sites of former patches of secondary anhydrite; the ooids average about 0.10–0.15 mm across (Kaldi, 1980) and many have leached cores. Large-scale cross-stratification is less prevalent in lower parts of the member than in middle and higher parts, and the lowest beds are mainly thick and sub-parallel with the slight rolling relief (?1 m) of the base of the member. The upper dolomite of the Hampole Beds at the base of the member cannot be distinguished with certainty, but is presumed to be present and 0.1–0.3 m thick.

Interpretation

Cadeby Quarry is unique in Yorkshire in providing a large and almost complete section through the Cadeby Formation (hence its choice by Smith *et al.,* 1986, as the type locality) and also in furnishing exceptionally clear information on the distribution pattern of patch-reefs in the lower (Wetherby) member of the formation. The patch-reefs themselves differ in a number of respects from those found elsewhere in the Wetherby Member, and the Hampole Beds are atypically thick and more diverse than in most other places.

Wetherby Member

The main interest in Cadeby Quarry, and its main asset as a GCR site, lies in (a) the many spectacular patch-reefs and enclosing strata and (b) the unusually high relief of the Hampole Discontinuity and the atypically great thickness of the Hampole Beds.

Patch-reefs and enclosing strata

The distribution and character of patch-reefs in the Wetherby Member in Yorkshire were described by Smith (1974b, 1981b, 1989) and are summarized here in the accounts of the Newsome Bridge, South Elmsall and Wood Lee Common sites; they occur in a roughly north to south belt a few kilometres wide that is parallel with the depositional strike and present outcrop, and lie at a range of levels between the Bakevellia Bed and the Hampole Discontinuity. Despite the relatively large number of exposures of patch-reefs, their spacing and relationship to enclosing strata is nowhere as clearly seen as in Cadeby Quarry.

Reefs are particularly abundant in parts of the area west of Doncaster and were first identified as such by Mitchell (1932a); the presence here of beds packed with bryozoans was however, recognized by Kirkby (1861) who inferred that they were the remains of prolific sessile benthic communities that would probably now be termed reefs. Mitchell *et al.* (1947) noted the presence of reefs in a railway cutting [SK 513 996]–[SK 519 995] (Figure 4.22) and Smith (1981b, figs 10 and 11B) illustrated bryozoan boundstone from there. In general, however, few of the reefs in the Don Valley between Cadeby and Conisbrough are fully exposed and their detailed composition and relationships are less clear than at Cadeby Quarry.

Most large patch-reefs in the Wetherby Member in the Yorkshire Province have a bryozoan boundstone (framestone) core and a mantle of coarsely domed algal stromatolites, and in these characteristics the Cadeby Quarry reefs are no exception. They differ from most reefs in the member, however, in being narrower in relation to their height, in not being constructed of obvious saccoliths based on ramose bryozoans such as *Acanthocladia* (though this fossil is very abundant), in containing fenestrate bryozoans such as *Fenestella,* and also in containing narrow ('finger') columnar stromatolites and sinuous stromatolite sheets. The significance of these differences from the general range of patch-reefs in the Yorkshire Province is unclear and merits further study; slightly greater initial water depth and slightly lower salinity are two possible causes.

Grainstones and packstones enclosing the Cadeby Quarry patch-reefs are normal for the reef belt, and require little special comment. They are well seen in the railway cutting a short distance to the south where many weathered faces show the constituent grains more clearly than in the fresh quarry sections. The grainstones there and nearby are exceptional only in their local content of scattered reworked grainstone clasts up to 0.13 m across and of even larger clasts of rock described by Mitchell *et al.* (1947, p. 120) as 'close-grained dolomite'; the presence of these implies contemporaneous (?submarine) cementation and occasional considerable energy levels.

Algal-stromatolite (cyanophyte) mantles widely characterize patch-reefs that extend into the upper part of the Wetherby Member, and were discussed in the accounts of Newsome Bridge Quarry and South Elmsall Quarry; those at Cadeby Quarry are, however, exceptionally thick and extensive and it appears (but is difficult to prove in the available vertical faces) that most of the uppermost 6 m of the member here may be stromatolitic. Only the section at the former Alverley Grange Quarry ([SK 554 992], near Doncaster) was comparable in this respect. As with the differences between the patch-reefs at Cadeby Quarry and those elsewhere, the reasons for the atypical thickness and extent of the stromatolites

is unclear.

The Hampole Discontinuity and the Hampole Beds

Almost throughout its range from near Ripon to near Nottingham, the Hampole Discontinuity has a gentle rolling relief of only a few centimetres, that at the exposure at Micklefield Quarry being typical (see (Figure 4.17)); the relief of up to 3 m at Cadeby Quarry and of 2.5 m at a nearby abandoned railway cutting (Moss, 1986) is therefore exceptional, as are the buried cliff notches surrounding reefs high in the quarry faces at Cadeby. The thickness of strata removed during the erosion of the discontinuity and, by implication, the sea-level decline that caused the erosion, cannot be estimated elsewhere in the Yorkshire Province but is shown at Cadeby to have been at least 3 m. The more normal relief was seen in former exposures of the Hampole Discontinuity at Boat Lane Quarry [SE 533 013] at Sprotbrough, a little over 1 km to the north-east.

The atypically large thickness of much of the Hampole Beds at Cadeby Quarry is clearly a response to the abnormal relief of the discontinuity, the additional beds filling a local hollow and surrounding the more resistant reef-top mounds. Smith (1969b, p. 177) and Moss (1986) suggest that the beds filling these hollows may be estuarine. For further discussion of the Hampole Beds near Cadeby Quarry see Moss (1986) and for discussion of the Hampole Beds in general see Smith (1968) and the account here of Micklefield Quarry.

Sprotbrough Member

Difficulty of safe access to the high faces in which the Sprotbrough Member is seen in Cadeby Quarry limits the value of these for teaching and research purposes, but they nevertheless provide an excellent section through an assemblage of large ooid sandwaves and show their spatial relationship to the underlying Hampole Beds. Other, thicker, sections of these strata may be seen and are more readily accessible at many other places, however, including the nearby Warmsworth Cliff [SE 538 009]. The distribution and environmental significance of the sandwave facies of the Sprotbrough Member of the Cadeby Formation are discussed in more detail in the account of Micklefield Quarry.

Future research

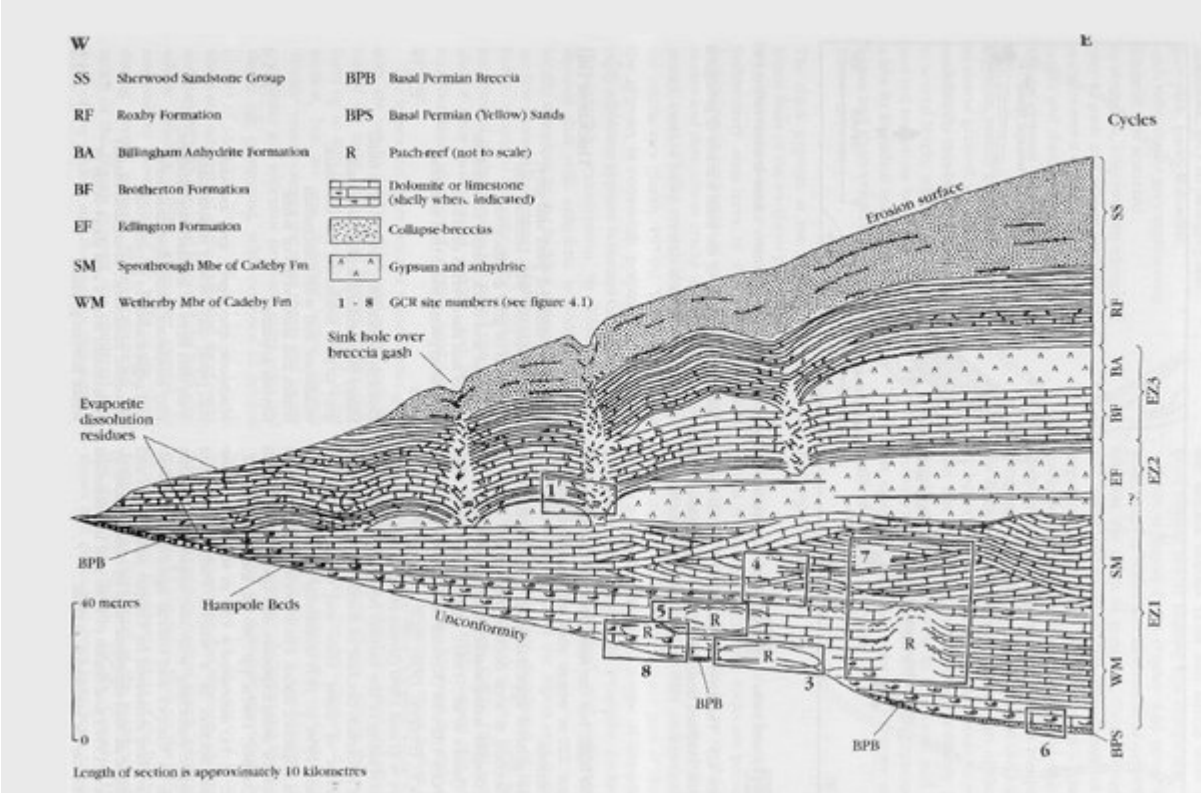
The present inaccessibility of much of the main face at Cadeby Quarry has resulted in much uncertainty and has left ample scope for future research. In particular the biota, ecology and petrography of the patch-reefs is in need of careful study in view of the apparent differences between the Cadeby Quarry reefs and those elsewhere, and the character and flora of the multi-coloured beds between the Hampole Discontinuity and the lower dolomite of the Hampole Beds would amply repay further research.

Conclusions

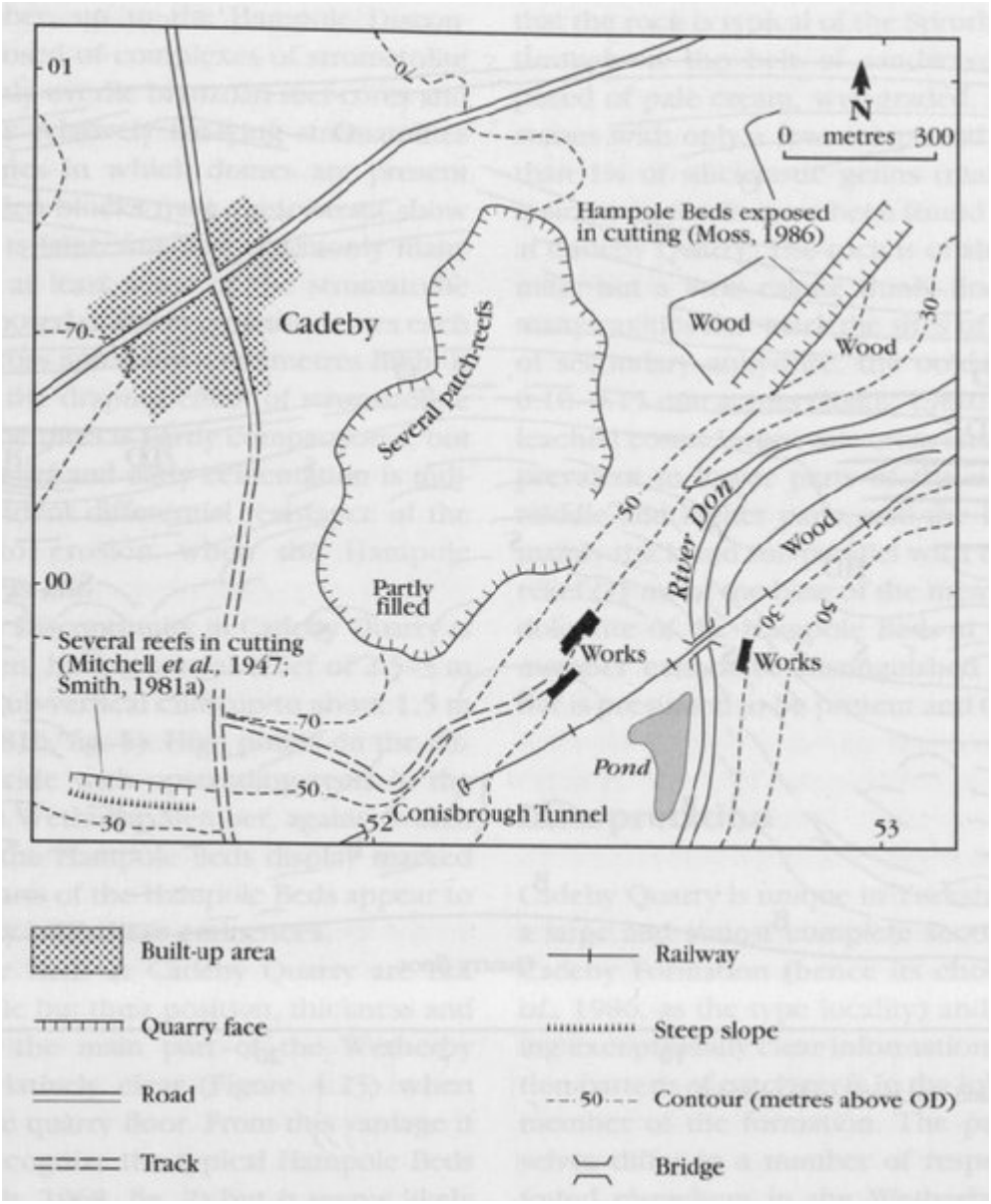
This exceptionally large quarry is the type locality of the Cadeby Formation, although the lowest beds lie below the floor of the quarry and the highest beds have been eroded off. The most complete sequence is in the north face of the quarry, where the Wetherby (lower) Member comprises cross-bedded oolitic dolomite and algal-laminated dolomite, and contains a number of patch-reefs that are taller and steeper sided than patch-reefs found in the Wetherby Member elsewhere in Yorkshire. The overlying Sprotbrough Member mainly comprises finely-oolitic dolomite and features spectacularly large-scale cross-bedding of a type thought to indicate deposition in offshore oolite shoals. The Hampole Beds at the contact of the two members are unusually thick here, and the underlying Hampole Discontinuity has an erosional relief of 2.5–3 m. This unusually steep relief is thought to have been caused when sea level fell by a few metres, exposing the Wetherby Member to a phase of weathering and intertidal conditions before the sea returned and the Sprotbrough Member was formed.

The site is extremely important for the study of reef development, and is more extensive than others in Yorkshire. This should afford opportunities for the closer study of fauna, palaeoecology and petrography of the reefs and the surrounding strata, as well as the changes in depositional environment indicated by the character of the overlying Hampole Beds.

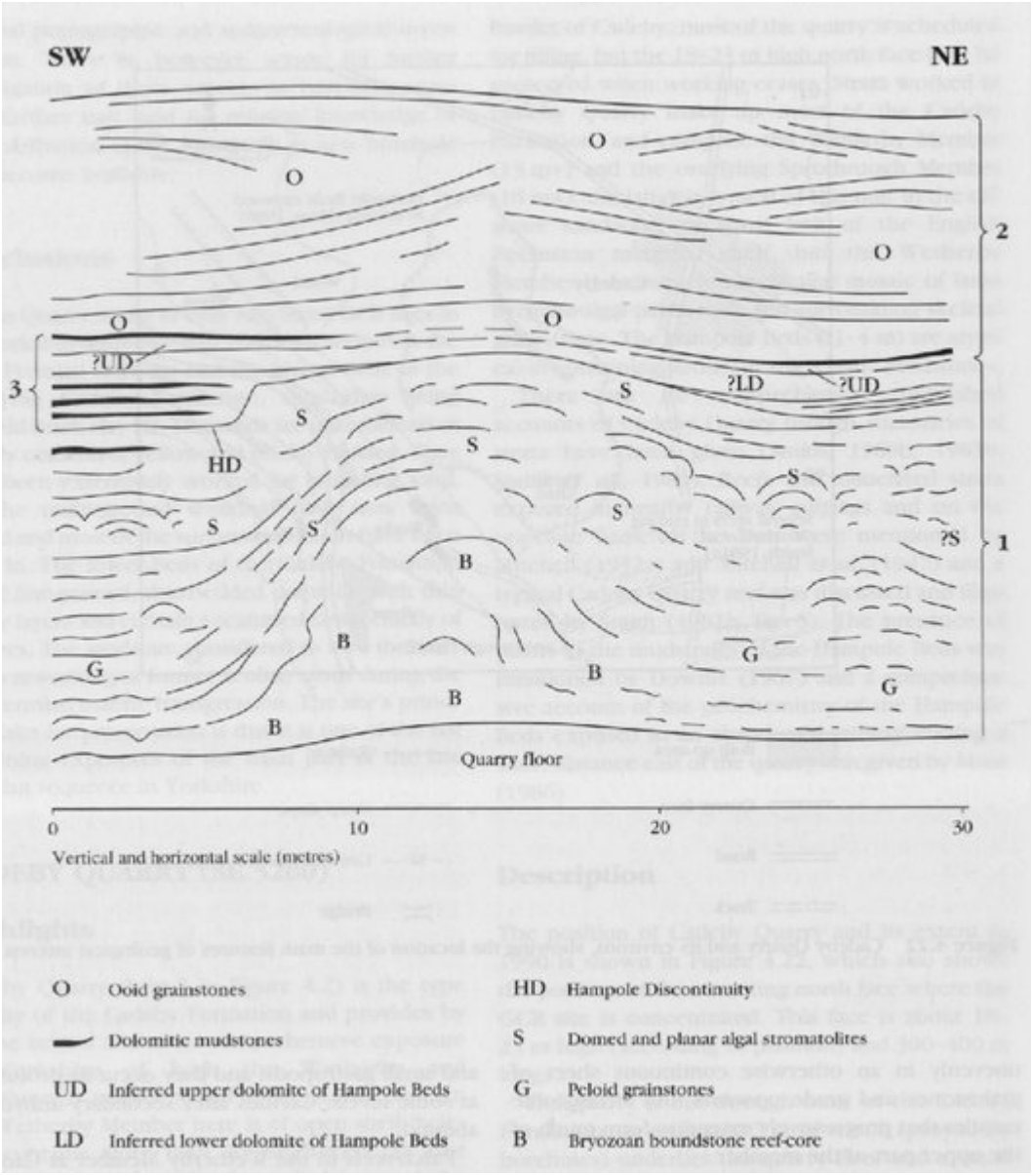
References



(Figure 4.2) Approximate stratigraphical position of marine Permian GCR sites in the Yorkshire Province of north-east England (diagrammatic). Some sites cannot be shown on this line of section and have been omitted.



(Figure 4.22) Cadeby Quarry and its environs, showing the location of the main features of geological interest.



(Figure 4.23) Diagrammatic sketch showing the relationships of the stratigraphical units and main rock types in the north-west face of Cadeby Quarry. The face is about 22 m high. 1, Wetherby Member; 2, Sprotbrough Member; 3, Hampole Beds, resting on the Hampole Discontinuity.

(Figure 4.17) The Hampole Discontinuity (arrowed) and adjoining strata, as seen in 1967 before filling of the lower part of Micklefield Quarry. The white layer is the lower dolomite of the Hampole Beds and the grassy cleft conceals the less resistant upper parts of the Hampole Beds. (Photo: D.B. Smith.)