Hawthorn Quarry

[NZ 43 46]

Highlights

Hawthorn Quarry (box 13 in (Figure 3.2)) is one of the largest exposures of late Permian reef-rocks in north-east England and the only exposure in which their contact with overlying strata is seen; unique exposures fonnerly recorded, but no longer available, revealed the overall profile of the basinward crest of the reef :rnd its juxtaposition with downfaulted or foundered younger stratato the east.

Introduction

Hawthorn Quarry, which ceased working in 1985, exposes the basal beds of the Roker Dolomite Formation (15 m+), the whole of the Hesleden Dene Stromatolite Biostrome (22–26 m, including a basal 0–4 m boulder conglomerate) and the uppermost 15 m of the shelf-edge reef of the Ford Formation. Exposures available up to mid-1958, but now quarried away or covered, showed that the eastern (basinward) crest of the reef crossed the eastern end of the quarry (Smith, 1962), and boreholes drilled in about 1974 proved reef-rock to a depth of at least 44 m below the then quarry floor at about +49 m O.D.

The strata exposed in Hawthorn Quarry dip generally southwards at less than 5° and there are no major folds or faults in any of the strata now visible. The pre-1958 exposures, however, revealed a complex 80° reverse shatter belt abutting and trending parallel with the reef crest, which brought down brecciated, ooidal dolomite on the basinward side.

The rocks at Hawthorn Quarry have been discussed and illustrated by Smith and Francis (1967), Smith (1973b, 1981a), Kitson (1982, petrography), Aplin (1985, petrography of the reef) and Hollingworth (1987, palaeontology of the reef); their interpretation has changed little during the period covered, the main development being the revealing of the boulder conglomerate between the reef and biostromal laminites in about 1980 as the quarry extended gradually westwards. A provisional faunal list for the reef-rock was given by Pattison (in Smith and Francis, 1967, p. 134) and the fauna was analysed in detail by Hollingworth (1987, pp. 258–266).

Description

Hawthorn Quarry [NZ 43 46] is cut into an eastfacing slope near the Durham coast, about 3 km south of Seaham; the boundaries of the quarry are shown in (Figure 3.46), together with the geological boundaries and the position of the main features of geological interest.

The general geological sequence in and around the quarry is given below.

	Thickness (m)
Soil on Durham Lower Boulder Clay	0–5
Gravel, partly calcreted, present only near entrance in east of quarry and in minor rockhead depressions	0–4
———— unconformity ————	
Roker Dolomite Formation	up to 15
Hesleden Dene Stromatolite Biostrome, with boulder conglomerate at base in8 west of quarry	c. 22–26
———— erosion surface ————	
Ford Formation, reef-facies, in floor of quarry c. 15+	

The disposition of the various lithological units within the quarry site is shown in (Figure 3.47).

Ford Formation, reef-facies

Dolomite rocks of this unit are exposed in the lowest levels of the quarry, where they are up to 15 m thick; a borehole in the quarry floor proved an additional 29 m of reef dolomite (Figure 3.47), but its total thickness here may exceed l 00 m. The reef comprises a complex assemblage of autochthonous masses of bryozoan and algal boundstone separated and surrounded by sheets and pockets of shelly detritus (Smith, 1981a, pp. 169–174); laminar (at least partly algal) encrustations and ramifying laminar sheets abound and locally form most of the rock, and a few rolled blocks (some coated) also occur. The reef-rock has a general roughly horizontal thick bedding, with primary dips of up to 30° traceable for a few metres. Pattison (in Smith and Francis, 1967, p. 134) gave a provisional faunal list for reef-rock from Hawthorn Quarry and this has been supplemented by a full faunal analysis by Hollingworth (1987), who distinguished between assemblages in the boundstone masses and surrounding ?algal laminites., Aplin (1985) gave details of the petrography and diagenesis of the rock.

Unique exposures formerly visible (Figure 3.46) and (Figure 3.47) near the quarry entrance revealed the reef crest, where successive reef-flat beds bent sharply over to dip east-northeastwards at up to 90° down the reef front (Smith and Francis, 1967, plate 9; Smith, 1973b, 1981a); similarly steep dips were encountered in a nearby borehole, proving that the reef front maintained a high angle to a depth of at least 35 m below the crest. In inaccessible parts of the former exposures, the reef crest appeared to decline eastwards in a flight of 1–2 m steps (Figure 3.47).

The erosion surface

This is exposed mainly in the south-west and west of the quarry, but is not well seen because it generally coincides with a quarry bench. In the few places where it is exposed clearly, especially in the middle of the south and west faces of the quarry, the surface is sub-horizontal with an average relief of 0.05–0.10 m. In detail, the surface is diversified by scattered slopes of up to 45° and minor depressions up to 0.15 m deep. Even where well exposed, however, the contact has commonly been blurred by diagenetic changes.

Hesleden Dene Stromatolite Biostrome

This member at Hawthorn Quarry comprises a basal boulder conglomerate up to 4 m thick that is present only in the west and south of the quarry, and a thick (*c.* 22 m) unit of algal-laminated dolomite bindstone which is (or was) recognizable all round the quarry except near the entrance.

The boulder conglomerate at the base of the biostrome is 2–4 m thick in the west and south faces of the quarry, but appears to die out eastwards (or to pass into non-conglomeratic bedded rock) in the inaccessible north face. Generally the conglomerate forms a single bed, but in a number of places boulders are only thinly scattered in the uppermost 1–2 m of the unit which is composed mainly of chaotic, finely laminated dolomite with a wide variety of ?algal growth forms. Below this the conglomerate is clast-supported and is composed of subangular to rounded small boulders (mostly 0.1–0.3 m across, but exceptionally 0.6 m) and subordinate cobbles of dolomite boundstone derived from the underlying reef. Most of the clasts are uncoated and a few bear signs of contemporaneous fracturing and re-cementation. The rock is generally poorly-graded and lacks clear imbrication or cross-bedding; possible crude east-dipping foresets, however, are present where the bed thins out in the north face. Interstices between the cobbles and boulders are filled or partly filled with white to pale cream, unfossiliferous, saccharoidal dolomite or calcite (according to location), and calcite-lined irregular voids are common. The filling comprises an estimated 20–30% of the conglomerate and is mainly faintly finely laminar, the laminae being parallel with the cavity walls; similar material also lines the walls of scattered steeply-inclined cracks, some of which are now more than 1 m deep and may have been contemporaneous.

The algal-laminated dolomite is of cream, pale buff and pale grey, silt- to sand-grade saccharoidal dolomite and calcitic dolomite with abundant calcite-lined, irregular cavities after secondary anhydrite; scattered patches of grey and brown saccharoidal dedolomite occur. Bedding is thin to thick, partly according to the state of diagenesis, but is mainly thin where the rock is least altered. At several levels the beds are disposed in rounded to fiat-topped domes up to 20 m across and 3 m high, though most are 3–10 m across and 1–2 m high, and some are quite small (Figure 3.48); dips on the flanks of domes range to almost vertical, and extend down to the basal surface on which the domes lie. In detail the dolomite of the domes, where least diagenetically altered, is finely and slightly w1evenJy laminated, the laminae feat11ring widespread delicate crenulation and commonly being domed on a millimetre-centimetre scale. The basal 1.5 m of the algal laminates is generally an almost pure dolomite rock and is composed of distinctively crenulated dolomite (Smith, 1981 a, fig. 27) that readily distinguishes it from the remainder of the biostrome; the lamination in this, the informally designated 'Crinkly Bed', is accentuated by slight concentrations of manganese dioxide (Figure 3.49).

Hawthorn Quarry

Loose fragments of pisoidal dolomite are mixed on the quarry floor with debris from the 'Crinkly Bed' and from the boulder conglomerate, but the pisoidal rock has not been found *in situ;* similar pisoidal rock at Blackhalls Rocks appears to be an uncommon local variant of the 'Crinkly Bed', filling deep pockets between atypically tall algal domes. The pisoids are up to 18 mm across, flattened, simple or compound, with smooth fine concentric coatings; Kitson (1982, fig. 62) illustratel.i partly silicified pisoids from this bed at Hawthorn Quarry.

Roker Dolomite Formation

Rocks doubtfully referred to this formation form the upper part of the faces of most of the quarry, including those of the narrow entrance where they have been lowered to present ground level by faulting or foundering (or both); they also underlie most of the surrounding fields, where they are known from small quarries and soil brash.

The base of the formation is taken at a thin, but varied bed of brown clayey dolomite or dolomitic clay which is generally inaccessible, although it is well exposed near the south-west corner of the quarry; here it is 0.15–0.25 m thick and has been partly contorted by plastic flow. The basal grainstone at this exposure displays slight onlap, perhaps indicative of a depositional hiatus, but there is no unequivocal evidence of truncation or of a hiatus at the top of the underlying biostrome, and no evidence of the former presence of evaporites.

The Roker Dolomite at Hawthorn Quarry comprises pale buff and cream, mainly ooidal dolomite grainstone in which abundant irregular calcite-lined cavities up to 0. 10 cm across mark the site of former secondary (replacive) anhydrite. According to Kitson (1982), rock in the basal 2 m of the formation is of relatively pure dolomite, but higher beds have a sparry calcite cement; local dedolomitization (by surface water) has occurred near the base of the drift, where travertine and calcite veins are abundant and the rock has been brecciated in places. Component ooids are of coarse to very coarse sand-grade and have leached centres (Kitson, 1982, fig. 44); roost are simple and subspherical, but a few irregular compound grains are present in most hand specimens and compound pisoids up to 5 mm across are locally common. Most of the rock is thin- to medium-bedded, with much of the bedding poorly defined. Preservation of sedimentary strnctures is similarly generally poor, although traces of ripple lanlination, cut-and-fill structures and small-scale planar cross-lamination occur locaJly, especially in ooidal grainstones exposed near the quarry entrance [NZ 4383 4631].

Interpretation

The exposures at Hawthorn Quarry are of special importance because they furnish a complete sequence from the reef of the Ford Formation well up into the inferred Roker Dolomite Formation. They are unique in being the only place where the contact of the reef with overlying strata may be studied; the record of the former position of the reef crest, now covered, enables the sequence to be precisely located relative to the main late Pennian facies belts in the area.

Ford Formation, reef facies

Hawthorn Quarry contains one of only three remaining substantial exposures of the reef-flat sub-facies of the reef of the Ford Formation, the other being the much smaller Townfield Quarry [NZ 4343 4380] at Easington Colliery and Stony Cut GCR site. Several small quarries in this facies in the Easington–Hawthorn area have been filled in recent years, but were described by Smith and Francis (1967). The reef-rocks at Hawthorn Quarry (then much smaller than now) and Townfield

Quarry were discussed briefly by Smith (in Smith and Francis, 1967) and later by Kitson (1982), Aplin (1985) and Hollingworth (1987); Smith (1981a) gave a general review of the characteristics of rocks of the reef-flat based mainly on the two quarries, and Hollingworth (1987) gave detailed analyses of the fauna from them.

Much of the importance of the exposures of reef-rocks at Hawthorn Quarry stems from their large size, which alone allows a comprehensive overview of the general lithology, faunal distribution and great lateral variability of the reef-flat sub-facies. This sub-facies is shown by a combination of former and present exposures to have been at least 300 m wide, and boreholes in the quarry floor showed that it overlies reef-core and reef slope rocks; for comparison, the reef transect at Ford Quarry, Sunderland, revealed a total reef width there of at least 200 m.

Exposures [NZ 4415 4666] at the foot of present coastal cliffs, about 450 m north-east of the reef crest in Hawthorn Quarry, throw some light on contemporary reef-front relief here; allowing for a dip not exceeding 2°, a contemporary reef-front relief of 40–50 m is suggested. This is comparable with that inferred at the southern end of Tunstall Hill GCR site, but is appreciably less than the inferred relief of at least 80 m at Beacon Hill, about 1 km south of Hawthorn Quarry. The exposures feature a coarse breccia (?talus) of reef-derived boundstone, overlain by up to 1.4 m of bedded cream ?ooidal dolomite that fills hollows in the surface of the breccia and is, in turn, succeeded by the dissolution residue of the Hartlepool Anhydrite. The breccia has yielded shelly reef fossils (Trechmann, 1954) and appears to include rounded masses up to 4 m across of intensely encrusted dolomite similar to that at the summit of Maiden Paps, Tunstall Hills.

The reef as a whole is known to stretch in a somewhat tortuous belt from West Boldon [NZ 34 64] southwards to Hartlepool (e.g. Trechmann, 1925; Smith, 1981a), and forms the edge of the Cycle EZ1 carbonate shelf-wedge; it plunges gently southwards so that, in general, lower parts are exposed in the north and higher parts in the south. Smith (1980c, 1981a) recognized and defined several main sub-facies of the reef, and Hollingworth (1987) investigated the faunal distribution and ecology of these. Each of the main sub-facies is exposed in one or other of the several GCR sites in the reef, which include Hylton Castle road cutting, Claxheugh Rock and Ford Cutting and Quarry, Humbledon Hill and Tunstall Hills.

The erosion surface

This is readily accessible only at Hawthorn Quarry, its other known surface exposure being in a gorge [NZ 471 370] in Crimdon Dene where the reef is in a different facies; a possible additional exposure at the northern end of Blackhalls Rocks awaits the removal of about 1.5 m of recent colliery waste from the beach there so as to reveal the reef top (suspected from a borehole [NZ 4716 3991]) drilled in 1984 by the University of Durham.

The importance of the erosion surface lies in its bearing on interpretation of the local and regional sedimentary history and on some aspects of the stratigraphy. In particular, it must record an episode of erosion and redeposition of the rocks of the underlying reef-flat, and, by inference, a sea-level fall of at least a few metres. The extent and duration of the sea level bears on the problematical age of the biostrome (Cycle EZ1 or Cycle EZ2?) and the choice of the EZ1/EZ2 boundary.

Hesleden Dene Stromatolite Biostrome

Hawthorn Quarry is one of the three main exposures of this unit, the others being the eponymous type locality (not a GCR site) and Blackhalls Rocks. Most of the features of the main part of the biostrome are common to the three main exposures, except that broad algal domes such as occur here and at Blackhalls Rocks have not been recorded at the type locality. Algal domes of this exceptionally large size (up to 20 m) were first reported from Hawthorn Quarry and Blackhalls Rocks (Smith and Francis, 1967), but have since been recorded by Eriksson (1977) from Precambrian dolomites in South Africa and from Precambrian limestones in north Africa. Nothing comparable has been recorded in rocks of any age in the British Isles or elsewhere in rock of Zechstein age. The striking 'crinkly' algal laminite at the base of the main part of the biostrome is similar in both thickness and lithology at each of the three main exposures and was illustrated by Smith (1981a, fig. 27).

The environmental interpretation of the algal laminites of the biostrome was considered by Smith (1981a, p. 15), who concluded from modern partial analogues that the rocks were formed on the broad reef-flat of the Ford Formation under a few metres of hypersaline water; this view was accepted by Kitson (1982).

The areal extent of the biostrome is poorly documented, with only a few exposures and borehole provings other than those cited. It has not been proved north of Hawthorn Quarry and known surface exposures farther south are restricted to a working quarry [NZ 475 345] near Hart and to two small old quarries [NZ 448 340] near Whelly Hill Fann (Smith and Francis, 1967, p. 144); in the subsurface, the biostrome was proved above reef dolomite in two boreholes [NZ 465 337] at aisberry Waterworks and, judging from the brief records by Trechmann (1932, p. 170 and 1942, pp. 321–322), possibly also above reef-rocks in boreholes [NZ 507 333] at Hartlepools Water Works. It may also have been present in the Mill Hill Borehole [NZ 4122 4248], Easington. With only one exception the biostrome has not been proved east of the main shelf-edge reef and its apparent absence from areas north of Hawthorn Quarry may result from poor exposure and erosion.

The boulder conglomerate at Hawthorn Quarry, like the overlying laminites, is exposed also in Crimdon Dene [NZ 4715 3705] (a downstream continuation of Hesleden Dene) and at Blackhalls Rocks, but is thinner and less diverse at Hawthorn. Here, too, it differs uniquely in having only a partial matrix, the laminar fill in many of the larger interstices having a central void up to severaJ centimetres across. Other, poorer, exposures of the conglomerate are at the base of coastal cliffs between Hive Point [NZ 443 458] and Beacon Point [NZ 444 454], near Hawthorn, where they appear to form part of the collapse-breccia.

The conglomerate at Hawthorn was first described by Kitson (1982). It is an accumulation of clasts of boundstonc derived from the underlying Ford Formation reef; the angularity of many of the clasts shows clearly that they were eroded and transported from an already lithified reef surface, indicating a high-energy environment similar to that of a modern boulder storm beach. The origin of the laminar matrix is problematical, but it much resembles travertine and deposition from marine or partly vadose waters passing through the interstices seems likely; the incompleteness of the filling may indicate early constriction of the 'throats' by fine detritus and contemporaneous cements, but could also have resulted from inadequate time before burial; close proximity to sea level is probably indicated. The period of conglomerate formation was completed by a phase of apparently chaotic ?algal-stromatolite growth before the more uniform subaqueous regime of the succeeding crenulated algal laminites became established.

Roker Dolomite Formation

The Roker Dolomite Formation exposed in the quarry is normal for the region and requires no special comment except on the uncertainty of its attribution; this doubt results from its apparent lack of diagnostic fossils and its unknown relationship with younger strata, but lithologically similar ooid grainstones at Seaham and Blackhalls Rocks are probably of the same age as those at Hawthorn Quarry and are assigned to the Roker Dolomite Formation with reasonable confidence. The fonnation as a whole is interpreted as the shelf facies of the marginal carbonate wedge of Cycle EZ2 (Smith, 1971a, 1980a, b); its outcrop is restricted to north-east coastal districts from Whitburn southwards (Smith, 1980b, fig. 9), where its main exposures are in coastal cliffs at Whitburn [NZ 41 61], Roker (the type locality, [NZ 40 59] and Seaham [NZ 42 50], and in coastal rock platfom1s at Hartlepool [NZ 52 34].

Structure

The geological structure requires no comment except for the narrow reverse shatter-belt formerly seen between the reef and younger ooid grainstones (Roker Dolomite Formation) near the quarry entrance. The shatter-belt is roughly parallel with the strike of the reef crest and also with a normal NNW/SSE trending fault of 5–6 m displacement (downthrow to the east) in the underlying coal workings; it may be a surface expression of this fault, but it could also have resulted from differential compaction between the reef and the grainstones or from subsidence caused by dissolution of the Hartlepool Anhydrite that formerly lay against the steep reef-face. A combination of any of these causes is also possible, but the third suggested mechanism seems more likely than the others because it most readily accounts for the vertical displacement of 30 m+ in the Magnesian Limestone. Further evidence favouring this third mechanism comes from the partial (?collapse) brecciation of the ooid grainstone near the quarry entrance, and from the presence of fragments of red mudstone (from previously overlying strata) in some of the breccias there.

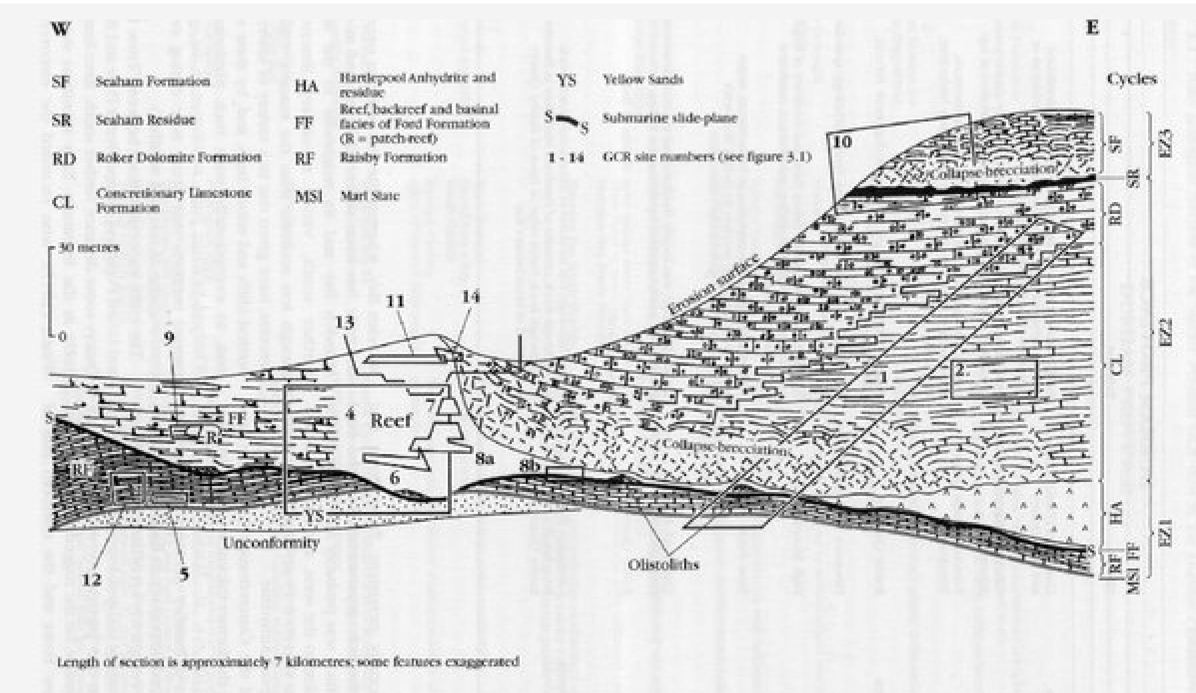
Future research

There are many unresolved geological problems in the rocks of Hawthorn Quarry, and correspondingly good opportunities for future research; some of these are currently being addressed. The ecology and biota of the reef, having been investigated by Hollingworth (1987), is now reasonably well understood, but the precise depositional conditions of the reef, its petrology and the nature and mode of origin of reef encrustations and laminar sheets still require further study. Other problems requiring further research include the nature, extent and origin of the erosion surface and overlying boulder conglomerate, the age, origin and diagenesis of the pisoids and algal laminites of the biostrome, and the age and diagenetic history of the Roker Dolomite Formation.

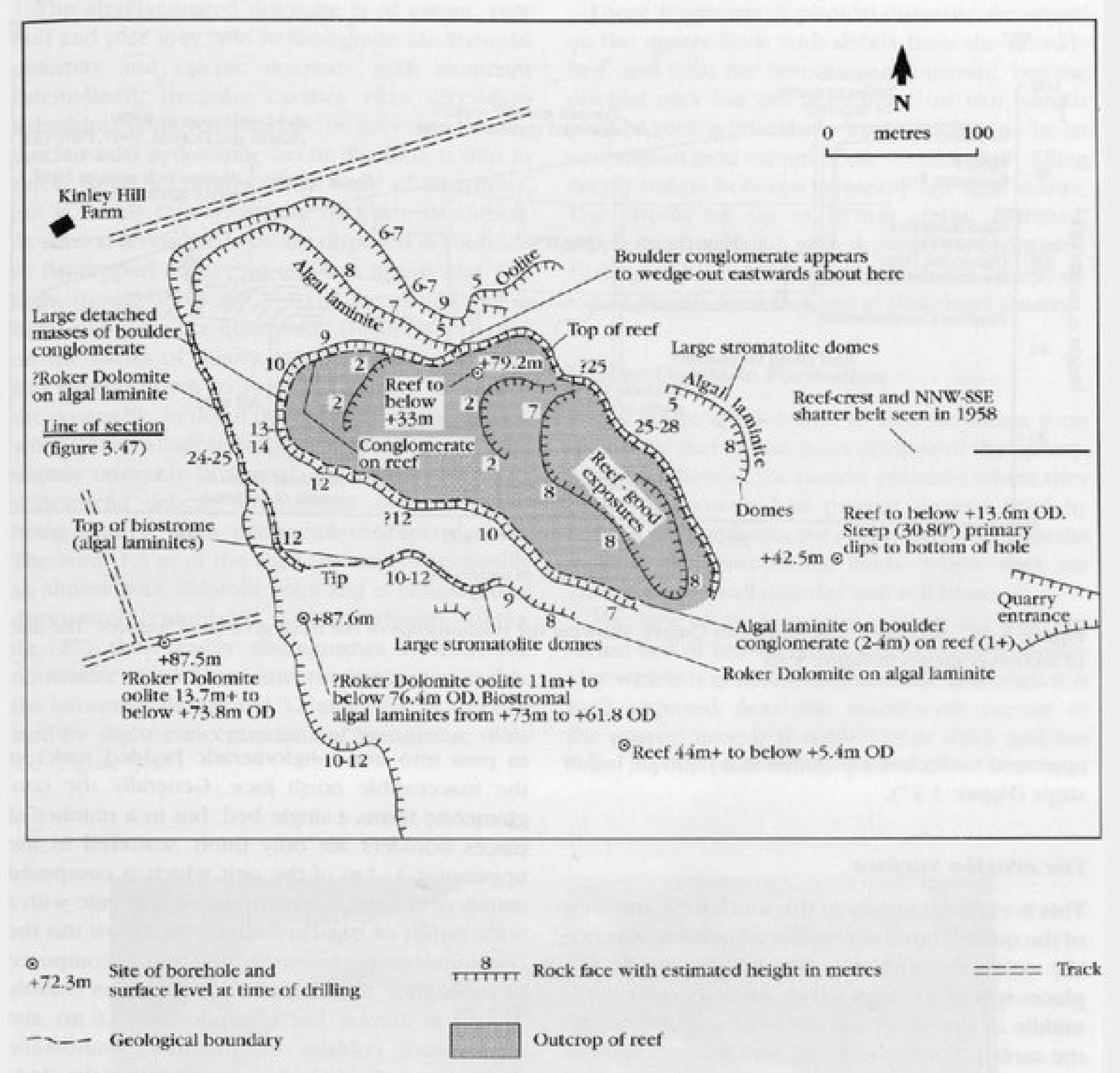
Conclusions

Hawthorn Quarry is an extremely important GCR site in that firstly, it is the largest exposure of late Permian (Ford Formation) reef-flat rocks in northeast England, and secondly, is the only exposure where their disconformable contact with the overlying Hesleden Dene Stromatolite Biostrome can be seen. The boulder conglomerate at the base of the Biostrome is seen elsewhere only in Crin1do11 Dene and at Blackhalls Rocks, whilst the contact between the biostrome and the overlying ?Roker Dolomite Formation is well-exposed only here. The site is ideal for further study and research into reef-rock characteristics, the age and diagenetic history of the Hesleden Dene Stromatolite Biostrome and the overlying Roker Dolomite Formation.

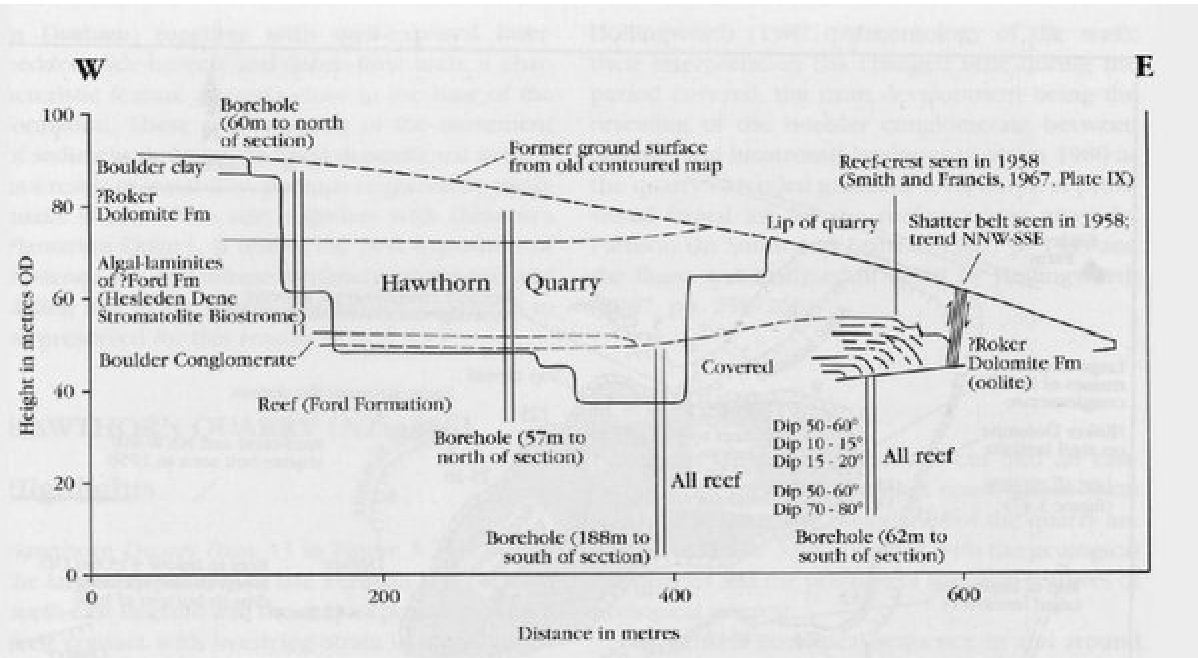
References



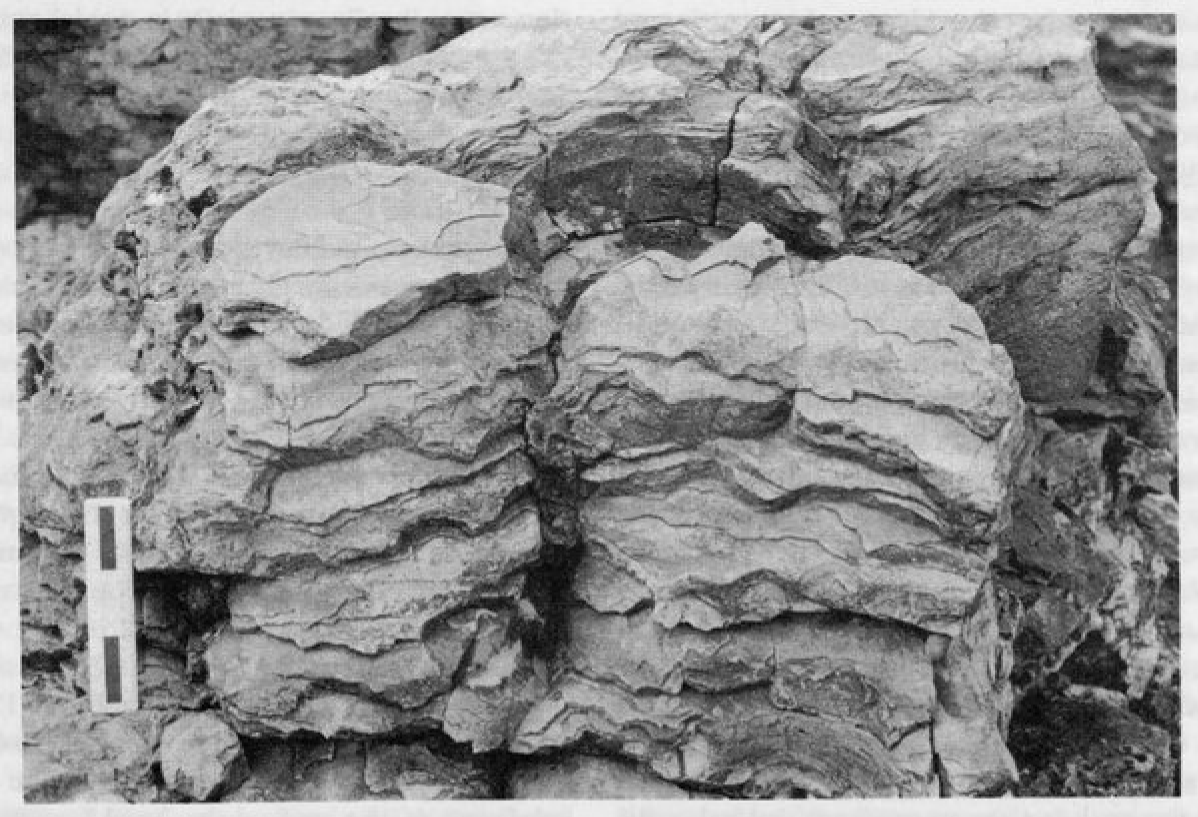
(Figure 3.2) Approximate stratigraphical position of GCR marine Permian sites in the northern part of the Durham Province of north-east England (diagrammatic). Some sites in the southern part of the Durham Province cannot be accommodated on this line of section and have been omitted. The Hartlepool Anhydrite would not normally be present so close to the present coastline but is included for the sake of completeness.



(Figure 3.46) Hawthorn Quarry, showing the location of the main features of geological interest.



(Figure 3.47) Section across Hawthorn Quarry, showing the relationships of the main geological features. The line of section is shown in Figure 3.46.



(Figure 3.48) Small columnar stromatolites just above the boulder conglomerate of the Hesleden Dene Stromatolite 13iostrome near the middle of the south face of Hawthorn Quarry. Bar: 0.32 m. (Photo: D.B. Smith.)

(Figure 3.49) Slight concentrations of manganese dioxide coating a bedding plane in the 'Crinkly Beel' near tl!e base of the Hesleclen Dene Stromatolite Biostrome near the miclclle of the south face of Hawthorn Quarry. Note the asymmetry of the ?algal growth-forms, indicating water flow from the right. Coin: 20 mm across. (Photo: D.B. Smith.)