BLACKHALLS ROCKS

OS Grid Reference: NZ46833948–NZ47633826

Highlights

The coastal cliffs and shore platforms at Blackhalls Rocks (not shown in Figure3.2) constitute the largest and best exposure of the Hesleden Dene Stromatolite Biostrome. The biostrome is almost entirely of dolomite rock and comprises a thick and highly varied boulder conglomerate overlain by a thicker unit of algal laminites ("stromatolites'). The conglomerate is formed mainly of rolled cobbles and boulders derived by erosion of the underlying (but unexposed) reef-flat rocks of the Ford Formation and the algal laminites include a strikingly complexly finely laminated basal layer and several generations of spectacular domes individually up to 1.5 m high and 18 m across. The sequence is capped by ooidal dolomite of the Roker Dolomite Formation and the overlying Seaham Residue.

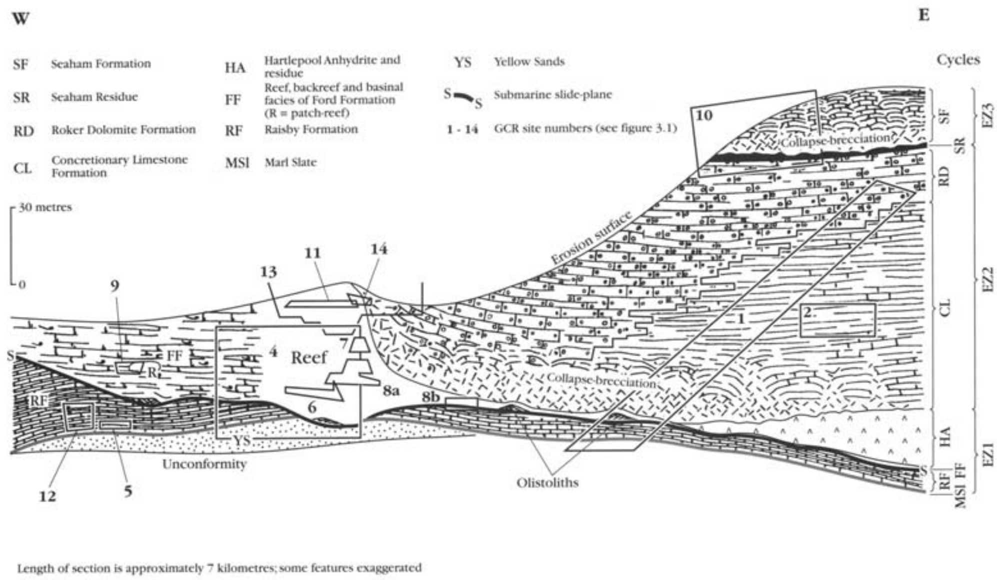

Figure 3.2: Approximate stratigraphical position of GCR marine Permian sites in the northern part of the Durham Province of north-east England (diagrammatic). Some sites in the southern part of the Durham Province cannot be accommodated on this line of section and have been omitted. The Hartlepool Anhydrite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

Introduction

Blackhalls Rocks is a coastal site that exposes almost the full thickness of the Hesleden Dene Stromatolite Biostrome (?45 m) together with the whole of the overlying Cycle EZ2 Roker Dolomite Formation (?16 m) and much of the Seaham Formation. The sequence is gently anticlinal and a borehole near the core of the anticline is thought to have entered reef dolomite of the Cycle EZ1 Ford Formation almost immediately below the lowest beds currently exposed. The anticline is bounded to the north by the mineralized Blackhall Fault (Smith, 1964), which has a northwards downthrow of perhaps 12 m, and to the south by the steeply-dipping Seaham Residue of the Cycle EZ2 Fordon Evaporites. The age of the biostrome is uncertain, with delicately balanced arguments allowing either EZ1 or EZ2 affinities.

The boulder conglomerate at Blackhalls Rocks was first mentioned and scenically illustrated by Sedgwick (1829) and was termed a 'Shell-Limestone conglomerate' by Howse (1858) in recognition of its faunal similarity to the shelf-edge reef of what is now termed the Ford Formation. The section received little further attention until Trechmann (1913) published a brief summary of strata exposed there, and added a list of 24 invertebrate species from clasts in the conglomerate; later, Trechmann (1914) published chemical analyses of the conglomerate and of a thin 'large-grained pea-oolite' (= pisolite) from the top of it (also illustrated in thin-section), and subsequently (1925) gave an augmented fossil list of 29 species and a further five doubtfully identified forms. Woolacott (1918, 1919a) referred to the conglomerate at Blackhalls Rocks as a fossiliferous breccia composed of blocks that had rolled down the eastern edge of the reef, ie. a 'Vorreef', and illustrated it in 1919(a); Trechmann (1925) similarly referred to the conglomerate as a 'Vor-riff' of reef talus.

Apart from a brief mention by Trechmann (1931), the section at Blackhalls Rocks received no further attention until it was described and illustrated by Smith and Francis (1967). Pattison compiled a faunal list (in Smith, 1970a, repeated in Pattison *et al*., 1973) comprising 28 species with an additional four doubtful identifications. Logan (1967) cited the locality as a host to seven species of bivalves, two of which were illustrated and designated as hypotypes. Further description by Smith (1981a) was within a proposed new lithostratigraphical framework in which most of the sequence at Blackhalls Rocks was ascribed to the newly-defined stromatolite biostrome. Finally a full investigation of the sedimentology of the whole of the sequence at Blackhalls Rocks was reported by Kitson (1982). The site also features in several field guides, excursion reports and popular articles (e.g. Smith, 1984).

Description

This site lies on the Durham coast about 8 km north-west of Hartlepool and comprises about 1.1 km of cliffs and shore-platforms (Figure 3.54); the cliffs are about 15–32 m high and comprise up to 24 m of southwards-thickening Quaternary (late Devensian) glacial drift deposits overlying up to 10 m of Magnesian Limestone. The drift deposits form a layered sequence of two stony clays separated by a sand and gravel layer from which perennial seepages cause instability; this level of the cliffs is well known for its unusual plant communities and part of the cliffs is scheduled as a botanical SSSI. The northern section of the cliffs, extending to Blue House Gill, is managed as a local nature reserve by the Durham Wildlife Trust.

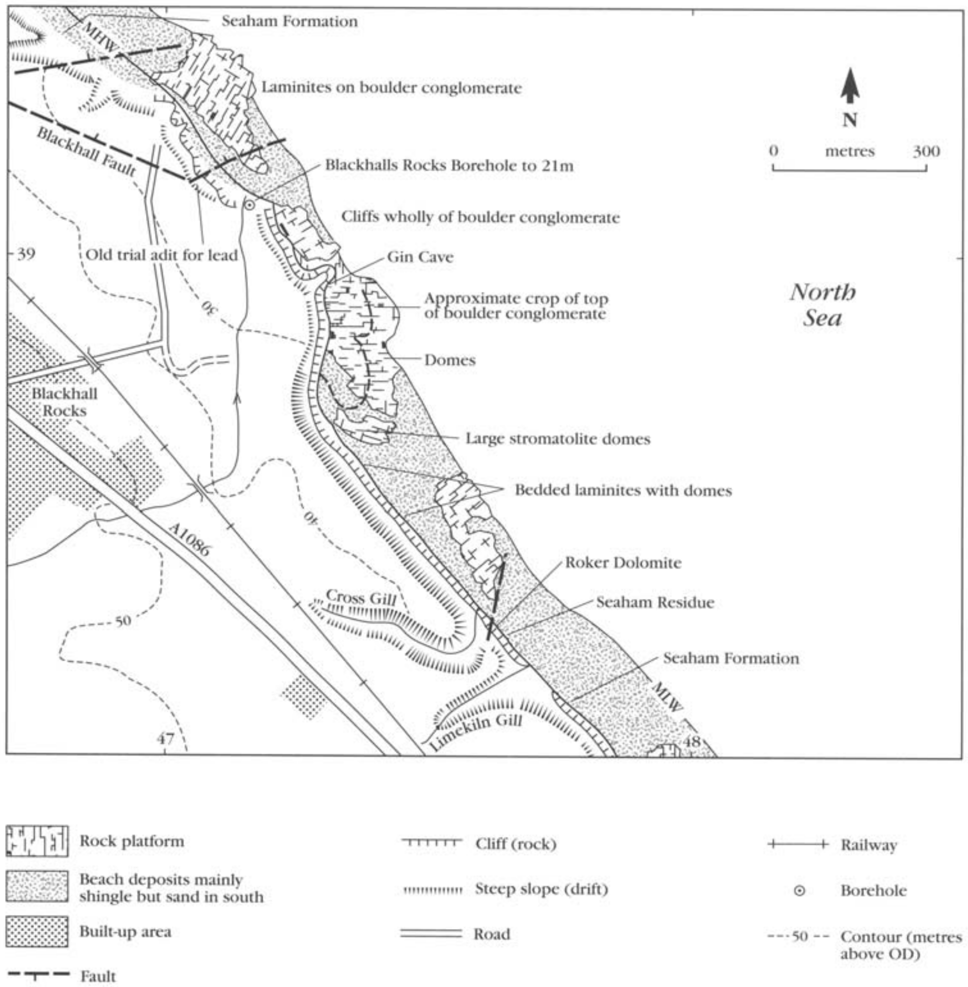

Figure 3.54: Blackhalls Rocks GCR site and its environs, showing the location of the main geological features.

The general geological sequence in and adjoining the designated area isgiven below.

	Thickness (m)
Soil on Durham Upper Boulder Clay	up to 8
Sand and gravelly sand with lenses of red silt in lower part	up to ?7
Durham Lower Boulder Clay	up to 8
Gravel, in scattered hollows	up to 4
——— unconformity ———	
Seaham Formation, mainly south of the site	14.5+
Seaham Residue, mainly near the southern margin of the site	?5
Roker Dolomite Formation	?16
Hesleden Dene Stromatolite Biostrome, including conglomerate *c.* 18 m at base (1.5 m not seen)	?45
Ford Formation, reef-facies (doubtfully identified in borehole)	19.5+

The approximate positions of the main features of geological interest are shown in Figure3.54 and their relationships are shown in Figure 3.55.

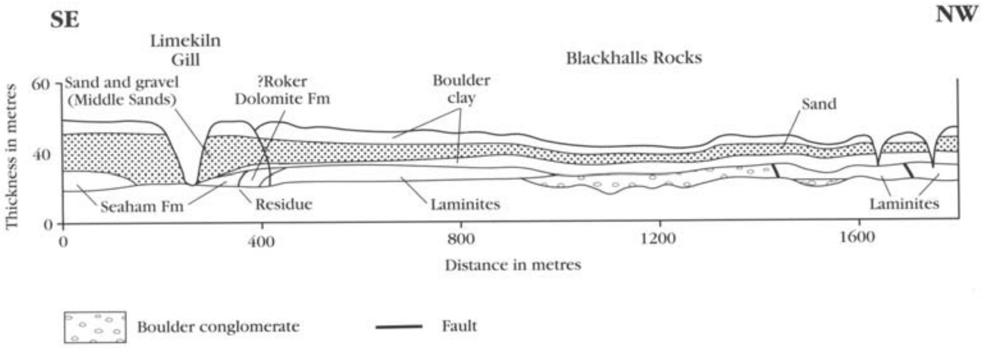

Figure 3.55: Geological strata in the cliffs of the Blackhalls Rocks GCR site (diagrammatic). The laminites and conglomerate together comprise the Hesleden Dene Stromatolite Biostrome. Slightly modified from Smith (1984, p. 24).

Ford Formation reef

This unit is thought to have been penetrated beneath the conglomerate of the biostrome in the 1984 Durham University borehole (NZ 4716 3911) near the axis of the Blackhalls Rocks anticline. Limited core recovered was of cream to buff dolomitized algal–bryozoan boundstone, with subordinate laminar sheets of bindstone or flowstone dipping at up to 70ø. The lithology and structure of the inferred reef-rock here is very similar to that in Hawthorn Quarry and a comparable position in the reef-flat facies seems probable; because of the poor recovery however, the conglomerate-reef contact is difficult to distinguish in the core and may be lower than suggested here. The contact will probably be exposed in the future, when the present beach cover of colliery waste has finally been swept away.

Hesleden Dene Stromatolite Biostrome

This member, as at the Hawthorn Quarry site, comprises a complex and spectacular coarse conglomerate that crops out in the core of the anticline and is the main component of the northern cliffs, and a thick upper unit of algal-laminated dolomite that forms most of the cliffs and shore platforms in the southern half of the site.

The conglomerate at the base of the biostrome is a complex and extraordinarily varied, poorly-sorted accumulation of cobbles and boulders of buff, algal–bryozoan boundstone (predominant) and algal bindstone in a 20–40% matrix of finely laminar clast-encrustations and fine debris (including bioclasts); it is divided almost chaotically into crude commonly eastwards-dipping beds, lenses and wedges by discontinuous, but locally extensive sinuous sheets up to 0.5 m thick of finely crystalline buff laminite and by local probable erosion surfaces. The clasts, matrix and laminar sheets are almost wholly of dolomite, but contain small amounts of pore-filling and cavity-lining late calcite.

The conglomerate is clast-supported and component clasts (commonly 0.15–0.4 m across, but exceptionally 0.9 m) are mainly subangular to rounded and roughly equidimensional (Figure 3.56); imbrication and cross-bedding are rare. Some clasts bear thin finely laminar coatings, but it remains to be established whether these coatings were formed before or after final deposition of the clasts. Non-laminar matrix generally post-dates any laminar coatings and is most abundant in middle and lower parts of the conglomerate; it comprises widely varied proportions of angular to subrounded sand- to pebble-grade debris of boundstone and bindstone (as in the major clasts) together with abraded (?derived) bioclasts, reworked fragments of laminar coatings and a few pisoids. Many of the smaller clasts have finely laminar concentric coatings and some bear evidence of several episodes of fracturing, recementation and recoating (Kitson, 1982). Similar debris forms scattered lenses up to 1 m thick, especially towards the northern end of the site, and probably accumulated in irregular hollows on the contemporary surface of the conglomerate.

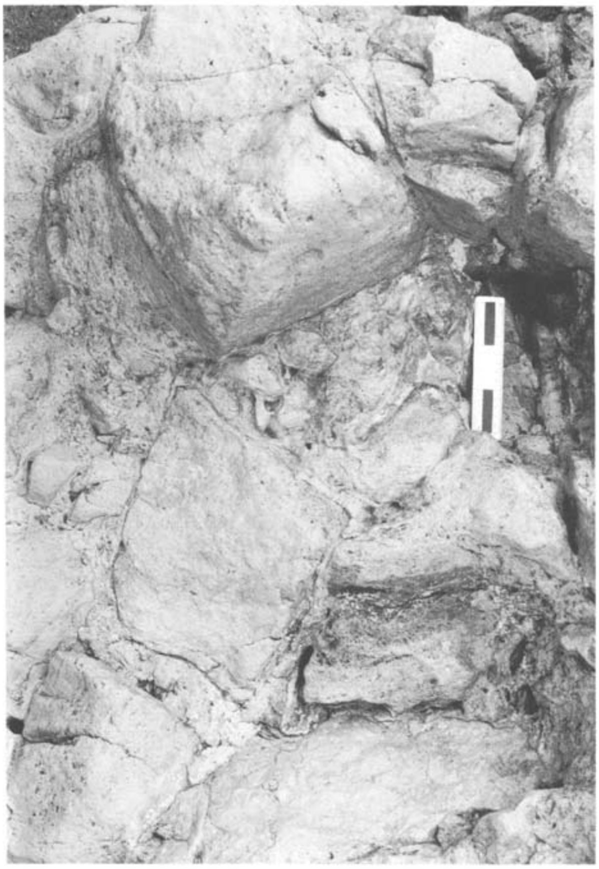

Figure 3.56: Typical example of the boulder conglomerate at the base of the biostrome, comprising clasts mainly of dolomite boundstone from the reef of the Ford Formation, in a matrix of smaller, but otherwise similar, fragments (many of which are coated), algal debris, scarce bioclasts and some laminar cavity-fill and lining. Coastal cliffs near north end of Blackhalls Rocks, c. 200 m north-west of Gin Cave. Bar: 0.16 m. (Photo: D.B. Smith.)

The cobbles, boulders, matrix and debris lenses appear to have been the source of most or all of the fossils listed from Blackhalls Rocks by Trechmann (1913, 1925) and Pattison (in Smith and Francis, 1967, p. 143 and in Smith, 1970a, pp. 85–88). Smith (1981a), however, recorded *Peripetoceras* and Kitson (1982) reported *Bakevellia* and *Permophorus* from laminite sheets in the conglomerate, although it is not clear whether these fossils were part of an indigenous biota or are reworked bioclasts.

The laminar sheets that divide the conglomerate form 30–40% of its bulk in higher parts and generally somewhat less lower down; the thicker sheets are mainly low-dipping (5ø–25ø), but locally steepen to 50ø or more. They divide and reunite grotesquely, and in places appear to surround trapezoidal to rectilinear conglomerate masses (Kitson, 1982) and to line both sides of subvertical fissures up to 1.5 m deep; some sheets are clearly bilateral, with a median void, void-fill or mutual contact. The laminae are fine and relatively even and, in the thicker sheets, are mainly gently undulate and flowing. Most of the thinner laminar sheets, however, clearly coat boulders forming the walls of primary cavities and display a wide range of simple or multistage 20–50 mm diameter botryoidal or laterally-linked hemispherical to columnar stromatolite-like structures with axes disposed at all angles. Kitson (1982, fig. 25b) illustrated probable algal relics in laminar sheets near the site of the 1984 borehole. Late-stage partly botryoidal laminites also line cracks penetrating or crossing some of the larger clasts.

The uppermost bed (0.5–0.8 m) of the conglomerate is a highly complex buff laminar bindstone with relatively fewer boulders than most of the remainder. Lamination in this bed is strikingly tortuous and includes both obvious cavity-lining and a wide range of steep-sided stromatolite-like domes individually up to 0.5 m tall and 1.5 m across, but mostly much smaller; scattered inter-dome hollows in this bed contain much multi-coated laminar debris and also rare clusters of subspherical ?oncoids up to 40 mm across and with more than 30 concentric layers.

The algal-laminated unit is at least 28 m thick and comprises unfossiliferous cream to pale buff silt- to fine sand-grade saccharoidal dolomite with abundant empty or calcite-lined small cavities after dissolved secondary anhydrite; interstitial calcite is widespread. Much of the rock has been finely brecciated by diagenetic processes and Liesegang-type colour banding is widespread. The primary lamination is generally faint and in hand specimens is commonly almost invisible; it is, however, generally distinct on weathered surfaces and is particularly clear and spectacularly crinkly in a widespread 1.3–1.8 m bed (the 'Crinkly Bed', Figure 3.57) at the base where laminae average 45 per centimetre (Smith and Francis, 1967; see also Al-Rekabi, 1982, fig. 3.4). In at least one place this unique lowest bed passes into or includes ooid grainstone and it also contains steep-sided pockets up to 1.2 m deep filled with smoothly thinly multi-coated dolomite pisoids individually up to 50 mm across, but mainly 5–15 mm (Figure 3.58). First noted by Trechmann (1913), and later (1914) illustrated and analysed by the same author, these pisoids commonly have an abraded nucleus of fine dolomite laminite and many bear clear evidence of early lithification in the form of fractures, re-cementation and re-coating (Smith, 1981b, fig. 29; Al-Rekabi, 1982, fig. 3.2B; Kitson, 1982, fig. 30b).

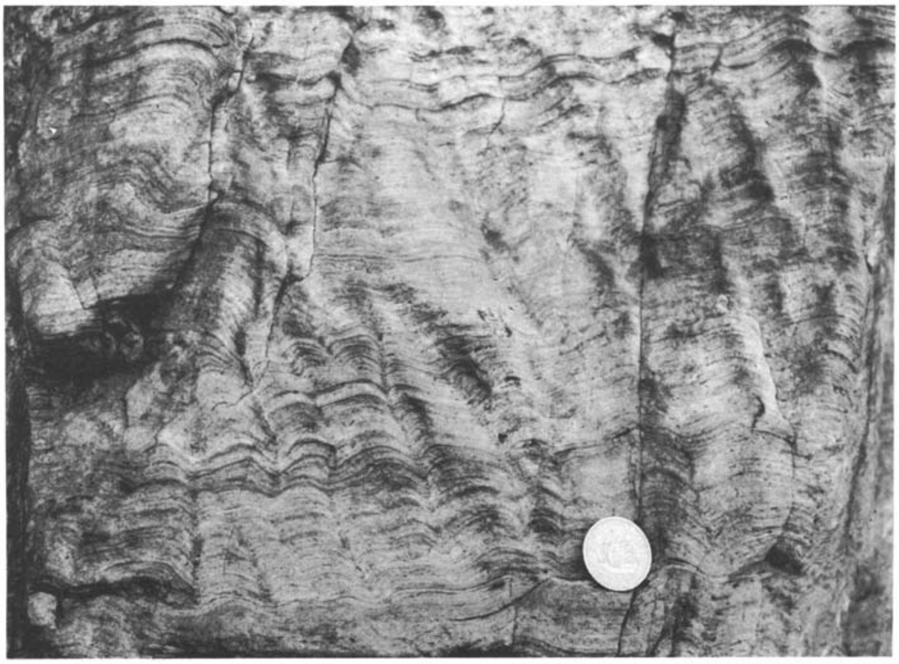

Figure 3.57: Laminar algal bindstone of the 'Crinkly Bed' at the base of the Hesleden Dene Stromatolite Biostrome. Coastal cliffs c. 60 m south of Gin Cave (see Figure 3.54). Coin: 26 mm across. (Photo: D.B. Smith.)

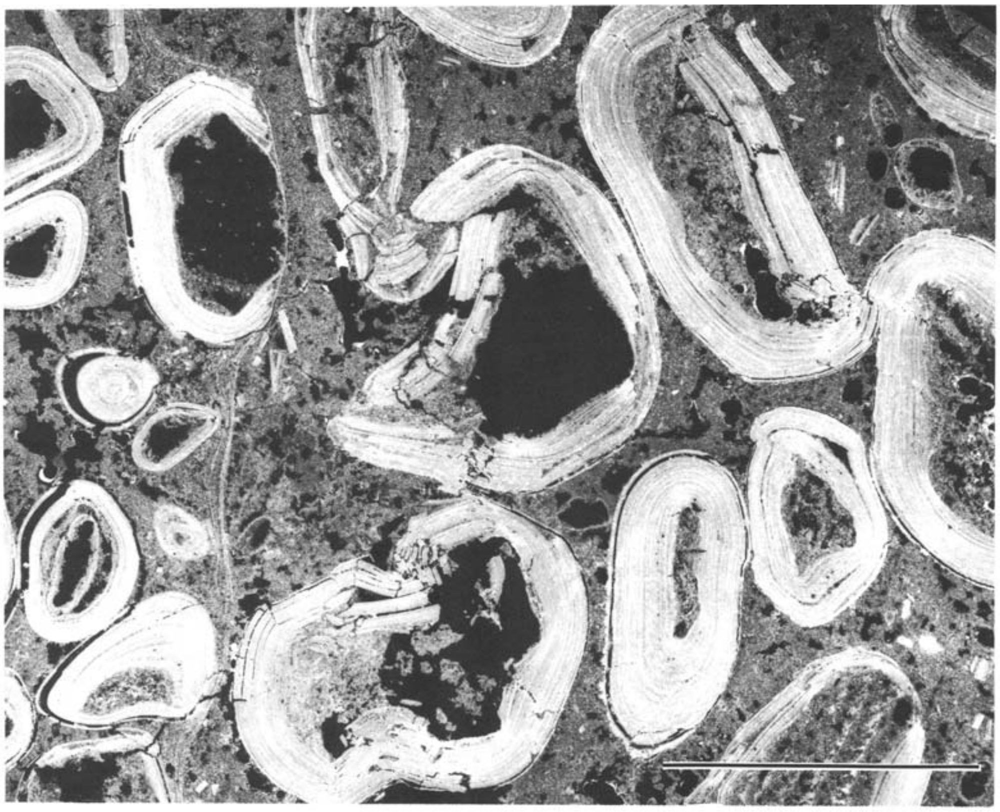

Figure 3.58: Thin section of multi-coated pisoids from steep-sided pockets in the upper part of the 'Crinkly Bed' in coastal cliffs near Gin Cave, Blackhalls Rocks. Interstices and the core of some formerly leached pisoids are occupied by equant dolomite microspar, but many of the pisoids are nucleated on to abraded dolomite clasts including portions of earlier fractured pisoids. Bar: 2 mm. (Photo: D. Kitson.)

Bedding in the algal laminites is generally even and parallel, but is widely diversified by minor domes and gentle undulations with a relief of up to 0.3 m. At several levels, however, continuous layers of large steep-sided rounded to flat-topped domes are present (McKay, in Trechmann, 1913; Smith and Francis, 1967; Kitson, 1982). These domes are formed entirely of crinkly or rippled finely laminated dolomite and exceptionally are up to 1.5 m tall and 18 m across; they are best seen on the foreshore rock platform (Figure 3.59), but mutual relationships are clearer in the cliffs where the domes are locally seen to be separated by gently onlapping dolomite and limited fine contemporaneous debris.

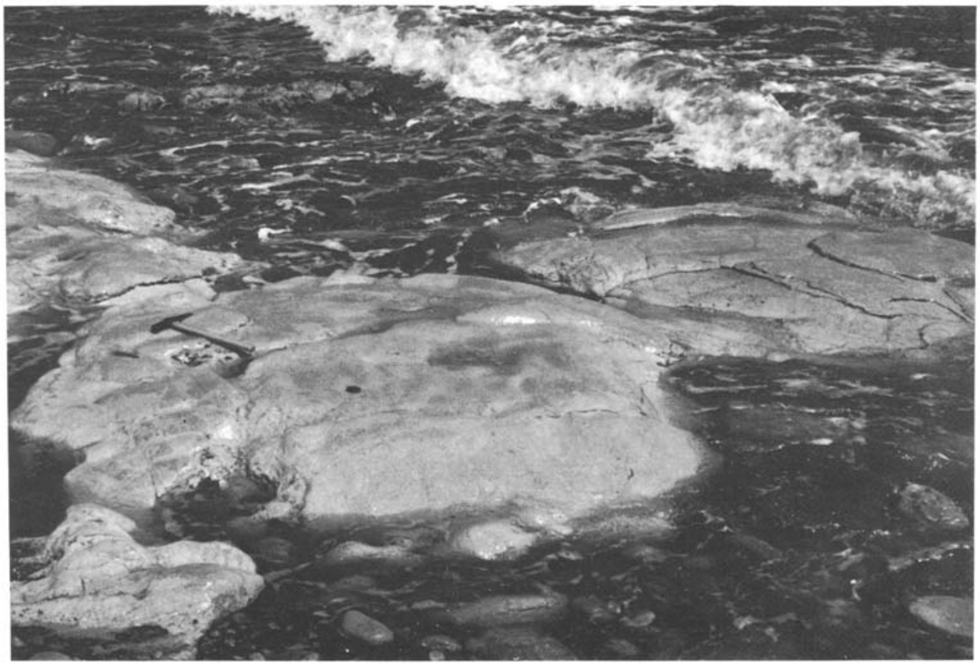

Figure 3.59: Broad dolomite stromatolite domes in about the middle of the Hesleden Dene Stromatolite Biostrome, on the foreshore near Green Stairs, Blackhalls Rocks. Hammer: 0.33 m. (Photo: D.B. Smith.)

Roker Dolomite Formation

This eastward-dipping formation forms much of the rock section in the cliff at the southern end of the site, its base rising north-westwards to reach rockhead near Cross Gill; it reappears patchily on the north side of the anticline, north of the Blackhall Fault. The uppermost 5–6 m of the formation comprise a markedly streaky and partly finely brecciated body of white to cream dolomite ooid grainstone and it is possible that this unit should be regarded as part of the Seaham Residue. Most of the formation, however, is of undisturbed cream dolomite ooid grainstone with strong tabular and trough cross-stratification at several levels;Kitson (1982) reported foresets dipping north-west and north-east at 10ø–15ø. Thin sections show that the ooids have been leached, and that some compound ooids and stromatolite flakes are present; Trechmann (1913, p. 201) reported cores of secondary fluorite in ooids of this formation in the north of the designated area. Trechmann also records *Schizodus* here, the only positive faunal identification in this formation at Blackhalls Rocks, though scattered bivalve-shaped cavities are present in the southern exposures.

The base of the Roker Dolomite Formation is generally difficult to distinguish in the cliff sections, where it is widely obscured by surface wash, but it is partly exposed in the lower ravine (NZ 4759 3825) of Cross Gill where it is interbedded with laminites and includes a 1.35 m ooidal dolomite bed that contains many coarse compound grains, pisoids and lumps. An interbedded basal passage was also recorded on the northern limb of the anticline (Smith and Francis, 1967, p. 150).

Seaham Residue

These insoluble clayey remains of the Fordon Evaporites lie in a gully near the southern boundary of the site; they are perhaps 5 m thick (depending on where the base is taken; see Interpretation). They comprise a lower 2.9–4 m layer mainly of cream ooid grainstone, but with many thin streaks, lenses and layers of brown and buff-brown argillaceous dolomite or dolomitic clay, a median 1.2–1.6 m layer of soft off-white dolomite ooid grainstone (partly brecciated) and an upper layer (maximum 1 m) of complexly interlayered multicoloured streaky clay or clayey dolomite. All the units of the residue are locally contorted and brecciated and the formation as a whole dips eastwards at 35ø–50ø.

Seaham Formation

Carbonate rocks of this formation occupy synclines both north and south of the designated area. They are best exposed in the south where they comprise a foundered and partly collapse-brecciated sequence similar to that at the type locality at the Seaham site; a detailed section here (Smith in Smith and Francis, 1967, pp. 157–160; see also plate XIIIC) shows thinly-layered basal shelly dolomite with *Calcinema* overlain by crystalline limestones patchily rich in spherulitic and globular calcite concretions. Red-stained and ochreous fine-grained carbonate or clay is a feature of the abundant infiltrated fill between disarticulated collapse-breccia fragments here.

Interpretation

The cliffs and rock-platforms at Blackhalls Rocks are doubly important in affording by far the best and most spectacular exposures of the Heselden Dene Stromatolite Biostrome, including most of the boulder conglomerate at its base, and also in furnishing a complete sequence from the reef of the Ford Formation up to (and including) the Seaham Formation. In this latter respect, the section at Blackhalls Rocks parallels and supplements that at the Hawthorn Quarry site, supporting the inferred identification of Roker Dolomite at the top of the sequence there.

The drift at Blackhalls Rocks epitomizes that of much of the Durham coast and requires no special comment; similarly, the Seaham Formation there has much in common with that at its type locality at the Seaham site, and the account (under 'Concretionary Limestone') by Smith and Francis (1967, pp. 157–160) will suffice. The Roker Dolomite Formation and the reef of the Ford Formation are normal for the area and also need no further discussion.

Hesleden Dene Stromatolite Biostrome

Blackhalls Rocks exposes almost the full thickness of this remarkable unit, a feature it shares with Hesleden Dene (and its downstream continuation) and the Hawthorn Quarry site; the boulder conglomerate at its base, however, is much thicker here than at the other localities.

The distribution of the conglomerate at the base of the biostrome is poorly known, but it is more variable in thickness and lithology and much less extensive than the overlying laminites, and in the Hawthorn Quarry site dies out sharply on its basinward side; the nature of its landward margin is unknown, though abutment against a basin-facing cliff notch may be speculated.

The origin of the conglomerate has been the subject of much discussion, but authors from Trechmann (1913) onwards agree that the major clasts were mainly derived from the shelf-edge reef of the Ford Formation. Woolacott (1918, 1919a) regarded it as an offshore (i.e. deep-water) equivalent of the reef and Trechmann (1925) interpreted it as reef talus with the clasts rounded by wave action on the eastern slope of the reef (ie. shallow water). Current research by the writer and Mr D. Kitson suggests that the conglomerate is a storm beach deposit that was formed on the reef-flat when a sea-level fall resulted in erosion of the Ford Formation reef, and that it was subject to phases of exposure, erosion, reworking and burial by conformable sheets of laminar carbonate. The angularity of some of the clasts indicates that the reef-rock was fully lithified before dislodgement and transport.

The origin of the laminar coatings on clasts in the conglomerate at Blackhalls Rocks and of the ramifying laminar sheets remains uncertain and is subject to continuing research. Field relationships and the abundance of laminar debris show that at least some of the laminar coatings and/or sheets must have been formed and lithified whilst the conglomerate was accumulating, and the localized fracturing of the conglomerate itself and of some of its large component clasts indicates that it too was cemented penecontemporaneously. The striking morphological similarity of many structures in the clast coatings and laminar sheets to algal stromatolites previously led the writer to infer deposition through the agency of blue-green (cyanophytic) algae, but the presence of (and lateral passage into) otherwise apparently identical linings of narrow fissures and of sheets of totally inverted laterally-linked hemispherical structures casts doubt on a wholly algal origin and deposition through other microbial or inorganic agencies may have been involved; in this connection the absence of the remains of a browsing fauna may be significant, possibly implying unusual salinity levels (either continental or marine). Final filling of fissures and inter-boulder voids by contemporaneous debris (including much fragmented laminite) distinguishes the Blackhalls Rocks conglomerate from that at Hawthorn Quarry in which much void space remained unfilled.

The general character, distribution and depositional environment of the main (upper) part of the biostrome are discussed in the account of the Hawthorn Quarry site, where it is noted that the biostrome is roughly co-extensive with the shelf-edge reef of the Ford Formation from Hawthorn Quarry southwards, but is not known farther north and only in fragmentary (brecciated) form at one exposure a short distance to the east. The main features of interest and importance in these upper strata at Blackhalls Rocks are exceptionally good exposures of large stromatolite domes on the foreshore rock platforms in the southern part of the designated area; although exposure varies greatly with the movement of sand and shingle, a selection of ripple-topped domes is almost always visible at about mid-tide levels. The basal 'Crinkly Bed' of this upper (stromatolitic) part of the biostrome is superbly exposed in the cliffs near the middle of the site (Figure 3.54), where it closely resembles its equivalent in Hawthorn Quarry site and in Hesleden Dene. This thick bed forms the roof of several of the main caves in the central headlands of the site.

The origin of the pisoids in the 'Crinkly Bed' at the base of the laminates is similarly uncertain. Originally described by Trechmann (1913) as 'pea-stone', Smith (1981b) reinterpreted them as oncoids (algal pisoids); provisional current thinking is that whilst derived algal debris may indeed form the core of many of these bodies, their smooth cortices have more in common with those of cave pearls and their travertine equivalents and they may, therefore, have formed at least partly inorganically in splash pools or other agitated areas. Other pisoids, especially those in pockets near the top of the conglomerate, have finely mammilar coats and resemble those at the Gilleylaw Plantation Quarry site from which F.W. Anderson (in Smith, 1958) recognized the algal growth-forms *Bevocastria conglobata* Garwood.

The considerable significance of the biostrome and the assumed underlying erosion surface in terms of the local and regional evolution of the Zechstein Sea is discussed in the account of the Hawthorn Quarry site.

Seaham Residue

This formation, where exposed near the southern boundary of the Blackhalls Rocks site, is somewhat thinner than at its type locality at Seaham, but this may be a result of attenuation on the dipping limb of a fold. Strict similarity between the two sections is not to be expected, but a broadly similar tripartite lithological subdivision is recognizable at both exposures, with ooid grainstone separating two more plastic clayey layers; a major difference lies in the apparent lack of dedolomite at the Blackhalls Rocks exposure, possibly indicating that the dissolved Fordon Evaporites here were halite-rich rather than sulphate-rich. The uncertainty regarding the thickness of the residue at Blackhalls Rocks arises from doubts on the determination of its base; a case could be argued for taking this at the top of the median dolomite unit and a less plausible case could be made for taking it 5–6 m below that chosen here, at the base of the brecciated ooid grainstone.

The relatively steep easterly dip of the Seaham Residue and adjacent strata at the southern end of Blackhalls Rocks is atypical of the local Magnesian Limestone sequence and may indicate that it overlies the crest of the shelf-edge reef of the underlying Ford Formation and its associated belt of differential dissolutional foundering (Figure3.47).

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.

Future research

The complexity of the different rock types and their mutual relationships at Blackhalls Rocks poses many problems, most of which have been addressed but few wholly solved. In particular, the mode and environment of origin of the laminar coatings of clasts in the boulder conglomerate and of related laminar sheets and void-fill needs to be established, and resolution of the doubt regarding the age of the sparse biota (derived or indigenous?) is crucial.

Solution of these problems would throw much light on the local and regional depositional history including the key questions of the age of the biostrome and possible major sea-level fluctuations. Higher in the sequence, the uncertainty regarding the nature of the contact between the biostrome and the Roker Dolomite Formation prevents definition and full understanding of the Cycle EZ1 – Cycle EZ2 boundary, and, near the top of the sequence, the base of the Seaham Residue needs to be defined satisfactorily.

Conclusion

This coastal site is the largest exposure of the Hesleden Dene Stromatolite Biostrome, including its distinctive coarse basal conglomerate of clasts of boundstone eroded from the Ford Formation reef. At this site, the algal laminates or stromatolites characteristically exhibit spectacular dome structures and a complexly finely-laminated basal bed. Above the biostrome are the Roker Dolomite Formation in the form of cream-coloured oolitic dolomite, and the Seaham Residue (the insoluble remnant of the Fordon Evaporites). The cliffs and shore platforms afford excellent exposures of the above sequence, and detailed evidence of the large variety of depositional and post-depositional structures can be observed along the shoreline. The site requires further study to understand the sedimentological nature and faunal character of the sequence, as well as to define the stratigraphical relationship of its upper part.

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