CLAXHEUGH ROCK, CLAXHEUGH (FORD) CUTTING AND FORD QUARRY

OS Grid Reference: NZ3657

Highlights

This unique complex of large exposures (box 4 in Figure3.2) provides much of the evidence on which the occurrence of massive, late Permian, submarine slumping may be inferred and is the only readily accessible place where the shelf-edge reef of the Ford Formation is seen to pass into equivalent strata on its western (landward) side. Claxheugh Rock was the site of a well-documented major rock-fall in 1905.

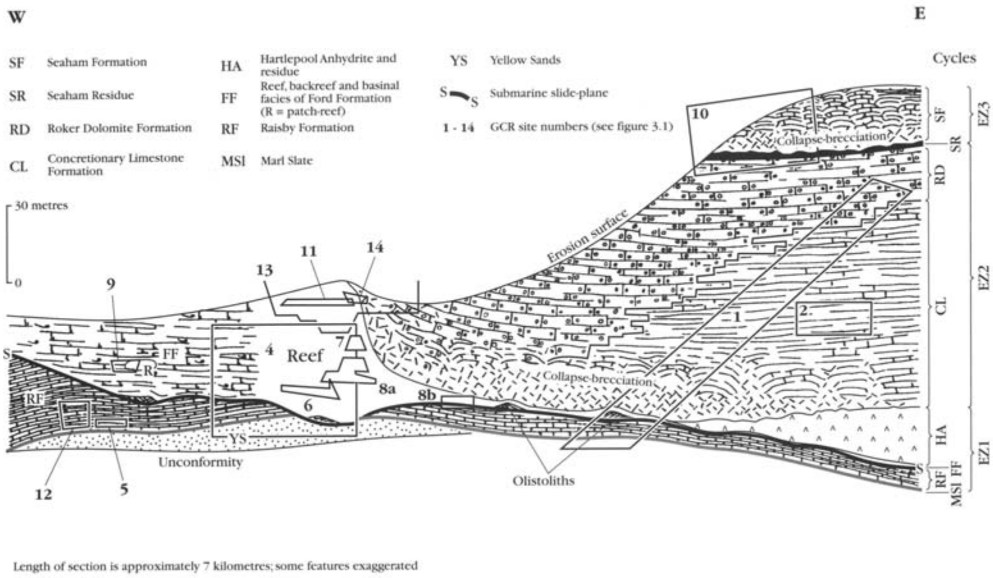

Figure 3.2: Approximate stratigraphical position of GCR marine Permian sites in the northern part of the Durham Province of north-east England (diagrammatic). Some sites in the southern part of the Durham Province cannot be accommodated on this line of section and have been omitted. The Hartlepool Anhydrite 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

Claxheugh Rock (formerly Clack's Heugh = a crag in Mr Clack's property) and the adjoining cutting and quarry lie on the south side of the River Wear in the western outskirts of Sunderland; together the three exposures reveal parts of the Basal Permian (Yellow) Sands, Marl Slate, Raisby Formation and Ford Formation. The sections are the type locality of the Ford Formation, the shelf-edge reef of which was formerly almost completely exposed in cross-section.

The rock faces of the Claxheugh complex of exposures, plus the nearby, but now filled, Claxheugh and Ford (old) quarries, have received more attention in the literature than any other late Permian Marine GCR site. The references range from brief mentions (e.g.Sedgwick, 1829; Howse, 1848, 1858; King, 1850; Howse and Kirkby, 1863; Kirkby, 1866; Lebour, 1884, 1902; Trechmann, 1931) to longer accounts of one or more aspects of the various exposures (e.g. Browell and Kirkby, 1866; Woolacott, 1903, 1905, 1912, 1918; Trechmann, 1925, 1945, 1954; Logan, 1967; Smith, 1969b, 1970a, c, 1981a; Pryor, 1971; Pettigrew, 1980; Hollingworth, 1987; Hollingworth and Pettigrew, 1988). The earlier references were confined to Claxheugh Rock and the railway cutting, but most later workers, were also able to discuss the geology of Ford Quarry which opened in the late 1920s; the south-east and north-east faces of the quarry were specially preserved for geologists by the Sunderland Borough (now City)

Council after quarrying ceased in 1971.

Description

The Claxheugh exposures lie entirely within a fault-bounded trough near the core of the NNW–SSE Boldon Syncline. The position of the site is shown in Figure3.22, together with the locations of the main features of geological interest; the largest rock exposures are Claxheugh Rock and the south-east face of the quarry, but full understanding of the complex facies relationships present stems only from an assessment of all the faces and other available data. The general geological sequence exposed at Claxheugh (including the quarry) is shown below.

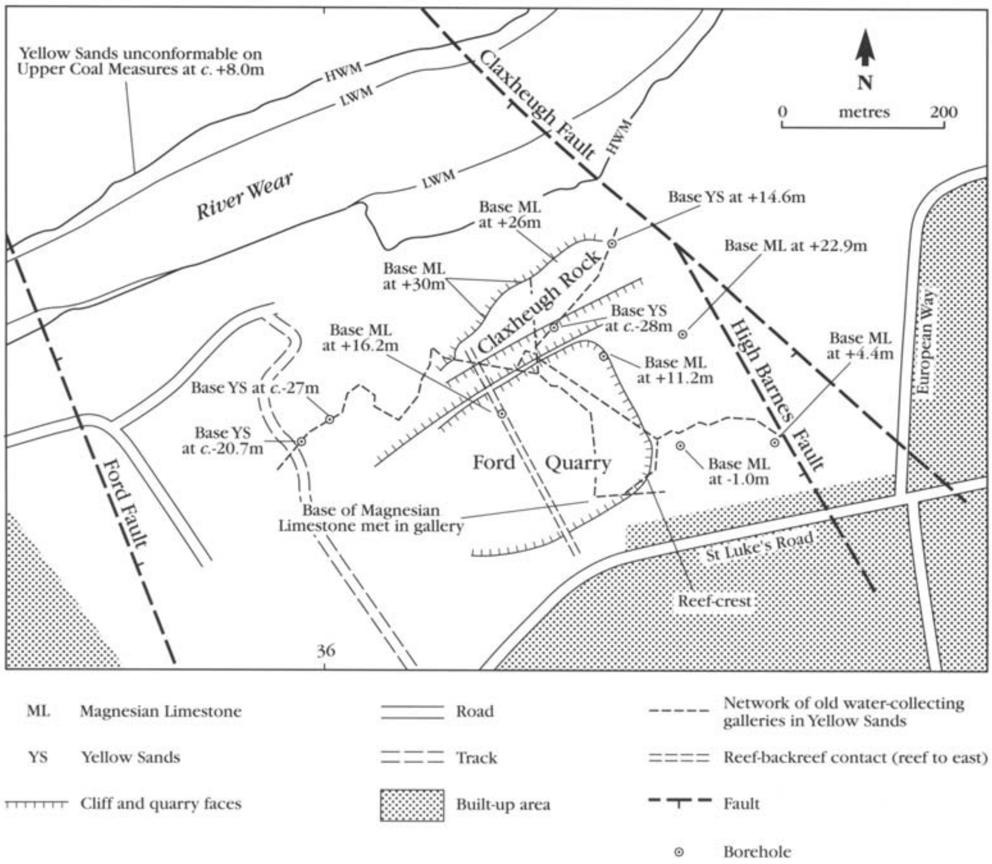

Figure 3.22: Claxheugh Rock, Cutting and Ford Quarry, showing the position of the main features of geological interest.

	Thickness (m)
Drift deposits, mainly boulder clay (thickest in east)	up to 6
——— unconformity ———	
Ford Formation, reef and backreef facies;	at least 55
Raisby Formation, slope facies, with slide-plane and patchy slide-breccia (0–2 m) at top	0–8
Marl Slate	0.77–0.90
Basal Permian (Yellow) Sands (about 18 m seen)	up to ?58
——— unconformity ———	
Upper Coal Measures (Westphalian C)	

The relationships of the several stratigraphical units in the main faces are summarized in Figure 3.23, which was based on drawings made before the partial filling of the quarry. Details of the main Permian units follow.

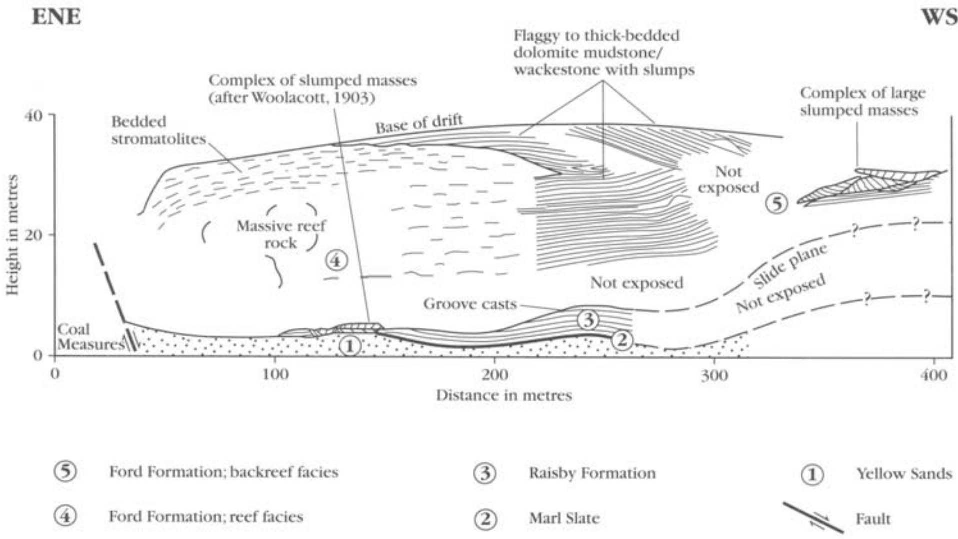

Figure 3.23: Section of strata at Claxheugh Rock, Cutting and Ford Quarry, based on Smith (1970a, fig. 17).

Basal Permian (Yellow) Sands

The ?early Permian aeolian Yellow Sands are almost at their thickest (about 58 m) beneath Claxheugh Rock; upper parts of the formation here were investigated in detail byPryor (1971), who classified the weakly-cemented sand as a fine- to medium-grained subarkose with scattered to abundant coarse grains and large-scale, tangential trough cross-stratification. Pryor noted quartz and potassic feldspar contents of 88% and 8%, respectively, and determined a mixed cement of dolomite and calcite with a little illite.

Boreholes have shown that about half of the Yellow Sands at Claxheugh lie below river level. The formation is of special interest here because it was exploited for water by a local factory from which a complex system of galleries was driven south-eastwards deep into the hill along the local water table (Figure 3.22). Tests by Browell and Kirkby (1866) showed that the sand is remarkably porous, with one cubic foot (0.028 m^3) of the deposit able to hold 10 pints (3.41 litres) of water.

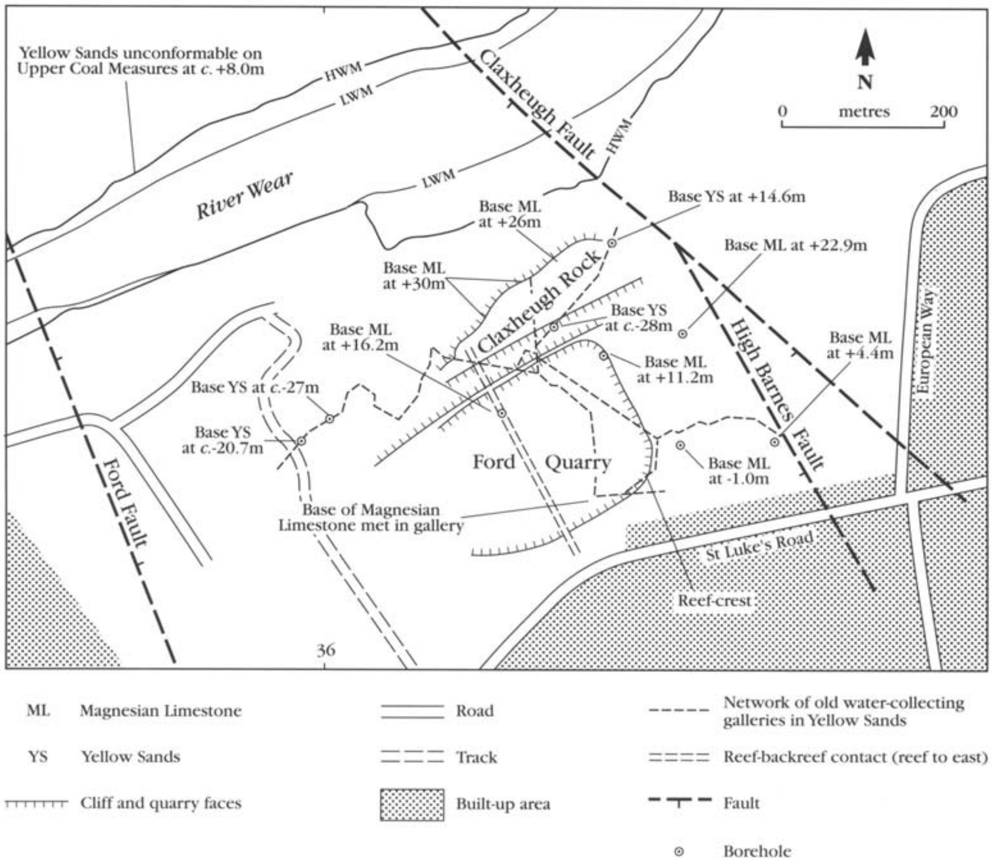

Figure 3.22: Claxheugh Rock, Cutting and Ford Quarry, showing the position of the main features of geological interest.

The top of the Yellow Sands at the north-eastern end of the Claxheugh Rock section slopes steeply south-southeastwards (Trechmann, 1954) and boreholes in the quarry floor show that this slope continues for some distance and takes the reef/sand contact from about +26 m O.D. at outcrop at the north-east end of Claxheugh Rock to about +11 m only 150 m farther south, and to about -3 m O.D. in the south of the quarry (Figure3.24); because of this decline, the base of the limestone was intersected in the most southerly part of the water-gathering gallery.

Figure 3.24: Steeply south-eastwards sloping contact between Basal Permian Sands (pale) and dolomite boundstone of the Ford Formation reef. The slope is interpreted as the northern flank of an east-northeastwards trending submarine slide canyon (Smith, 1971c). The field of view is about 18 m high. (Photo: D.B. Smith.)

Marl Slate

This comprises finely laminated, buff and grey, slightly carbonaceous, dolomitic shale with laminae, lenses and thin beds (some partly contorted) of brown, carbonaceous, plastic clay; scales of palaeoniscid fish are scattered sparingly, but whole fish are very uncommon. The bedding is locally minutely contorted and overfolded at some levels, with an ENE sense of movement, and some of the clay films extend along curved cracks (see below) down into the underlying Yellow Sands. T. Deans (pers. comm., 1959) records a carbonate content of 33% (mainly dolomite) and lead and zinc contents of 330 and 350 ppm, respectively in the Marl Slate here.

Raisby Formation

Flaggy- to medium-bedded (0.05–0.30 m) very finely crystalline dolomite of the Raisby Formation underlies the shelf-edge reef in the western part of the Claxheugh Rock section, and thickens west-southwestwards to more than 8 m (Figure 3.23). The formation was not identified in Ford Quarry, but may have been present and unrecognized in the deep north-west corner (now filled), beneath comparable back-reef strata of the Ford Formation. Some bedding planes bear a thin layer of brown, dolomitic clay and others are slightly stylolitic; a sparse foraminifer–bivalve–brachiopod fauna is present. The truncated top of the formation at the south-western end of the section bears long sub-parallel and divergent WSW/ENE grooves up to several metres long (Woolacott, 1912, fig. 11; Trechmann, 1945), which are interpreted by Smith (1970c) as score marks (groove-casts). Angular fragments and blocks of the formation are complexly intermixed in a coarse breccia lying between the reef and the Yellow Sands in the centre of the section (Woolacott, 1903, section 2, reproduced by Smith, 1970c, fig. 6). Woolacott (1903, section 3) also recorded a system of intersecting curved cracks and minor movement planes that cut the Raisby Formation and underlying beds at the south-western end of the Claxheugh Rock section, but do not extend into the overlying reef.

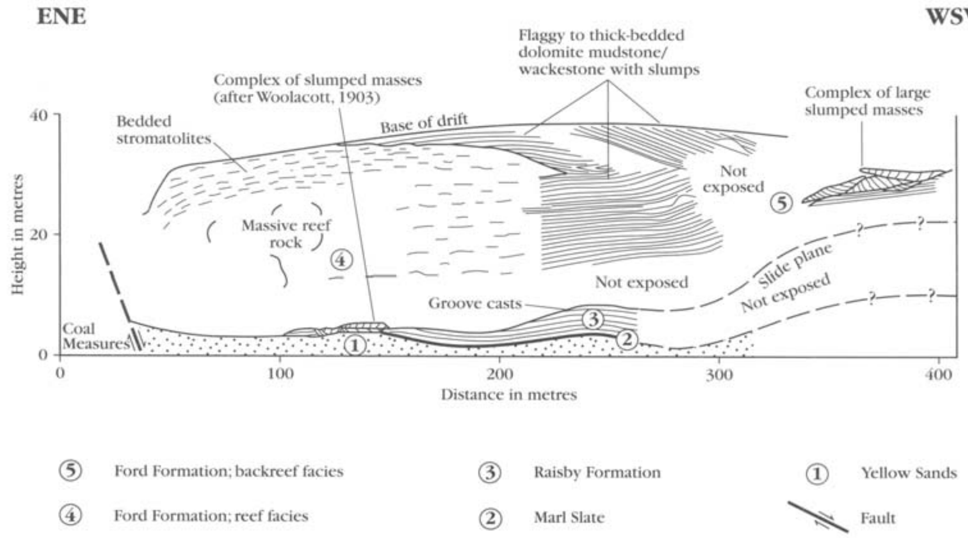

Figure 3.23: Section of strata at Claxheugh Rock, Cutting and Ford Quarry, based on Smith (1970a, fig. 17).

Ford Formation

This is the main marine stratigraphical unit in the Claxheugh–Ford Quarry complex, and comprises reef and backreef facies; the reef is slightly more than 200 m wide and comprises several sub-facies.

The backreef facies is exposed in the south-western part of the quarry and of the adjacent cutting and comprises at least 55 m of buff, very finely crystalline dolomite in relatively even beds commonly 0.1–0.25 m thick. Only the uppermost 18–20 m of these beds are now visible, and dip gently towards the reef, but lower beds in the western parts of the north-west and south-east walls of the quarry were formerly seen dipping reefwards at up to 30ø and to diverge in the same direction. All these backreef-rocks are diversified by the presence of large masses of discordant or crumpled strata (Trechmann, 1945, fig. 2; 1954, fig. 3; Smith, 1970a, fig. 17) interpreted by the writer as the product of submarine slumps. Kirkby (1866, p. 197) and Trechmann (1945, table 1 and plate XV) reported substantial lists of fossils (mainly brachiopods and bivalves) from the backreef strata in the cutting and quarry respectively, both workers believing that these beds formed part of the Lower Magnesian Limestone (=Raisby Formation); Pattison (in Smith, 1970a) recorded 14 species from these beds in the quarry, and Logan (1967) also cited the cutting as a collection locality. Trechmann's list included several forms that he then claimed to be new to the English Zechstein, but the number of 'new' species has declined with more recent studies by Logan (1967), Pattison (unpublished Geological Survey reports, 1969) and Hollingworth (1987). Hollingworth recorded a patch of crinoid debris in the cutting and remarked that the quarry fauna listed by Trechmann indicated an unlithified soft substrate (see also Hollingworth and Pettigrew, 1988, p. 46). Trechmann (1954) noted that the 'Lower Limestone' (= the Ford Formation backreef strata of this account) in Ford Quarry contained nodules and layers of chert that are 'full of Foraminifera and fragments of bryozoa that are not seen in the enclosing dolomite'. Logan (1967), using specimens of shelly 'Lower Magnesian Limestone' (probably the Ford Formation of this account) from the Trechmann collection from Ford Quarry, described and figured hypotypes of *Streblochondria*? *sericea* (de Verneuil) and *Cleidophorus*? *hollebeni* (Geinitz).

The reef facies of the Ford Formation forms the bulk of Claxheugh Rock and the easternmost two-thirds of the cutting and quarry; the contact between the reef and backreef beds is only slightly gradational (Smith, 1981a, figs 5, 6) and was formerly seen to be almost vertical for the whole original height (about 35 m) of the south-east face of the quarry (Figure 3.23). Almost all of the reef-rock in the quarry is of reef-core sub-facies, with a passage into reef crest and uppermost reef slope sub-facies along the north-eastern fringe; a few metres of roughly bedded rock at the top of the main faces may be of reef-flat sub-facies.

The reef-core sub-facies comprises a great mass of buff and brown dolomitic bryozoan boundstone (framestone); it is essentially unbedded, but the reef in the 20 m high cliff of Claxheugh Rock features a number of major sub-concordant partings (Woolacott, 1914, fig. 1; Pettigrew, 1980, fig. 7). Most of the rock is finely crystalline, turbid dolomite in which, because of complex diagenesis, fossils are generally poorly preserved (Trechmann, 1945; Aplin, 1985; Hollingworth, 1987). Despite this, Pattison (unpublished Geological Survey report, 1969, and in Harwood *et al.*, 1982, p. 21) recognized some 16 invertebrate species including several species each of bryozoans, brachiopods and bivalves. Trechmann (1931, 1954) commented that the earliest part of the usual reef sequence is missing at Claxheugh Rock, where the reef rests on a deeply scoured surface of Raisby Formation, Marl Slate and Yellow Sands and no coquina is present. Hollingworth (1987) and Hollingworth and Pettigrew (1988) considered that the abundance of epifaunal genera in the reef is consistent with a lithified substrate and reported that bryozoans such as *Acanthocladia* were stiffened and given extra bulk by laminar algal encrustations. A faunal transect of the upper part of the reef-core in the cutting was given by Hollingworth (1987, fig. 6.35) and Hollingworth and Pettigrew (1988, fig. 9).

The reef-core and ?reef-flat dolomite boundstone in the cutting contains a number of vertical tension fissures up to 0.5 m across and 3 m deep (Aplin, 1985, pp. 90–94), that have not been recognized in the nearby quarry. Aplin reports that the fissures are lined with laminated dolomite of possible algal origin, and that some have cores filled with bioclastic debris; he infers from this fill that the fissures were opened whilst the reef was growing.

In the easternmost part of the cutting and quarry, the crudely bedded uppermost part of the reef-core is seen to increase in dip from almost horizontal to up to 50ø (Smith, 1981a) as it passes through the reef crest into the uppermost part of the reef slope. The rock here is a crumbly, saccharoidal dolomite boundstone and comprises a highly varied mixture of *in situ* and detached masses of bryozoan boundstone (framestone), complexly anastomosing laminar ?algal sheets and cavity-fill, and pockets of shelly rubble that are locally rich in gastropods, the brachiopod *Dielasma* and the nautiloid *Peripetoceras*; most organisms in the rock are algal-encrusted, and encrustations probably comprise more than 70% of the whole. Many of the laminar sheets bear laterally-linked stromatolite hemispheres, and outward and upward-elongated columnar algal stromatolites up to 0.15 m high and 00.5 m across occur in places at least 5 m downslope from the reef crest (Smith, 1981a, fig. 18).

Ford Formation

Although advanced diagenesis has obscured many primary details of the shelf-edge reef of the Ford Formation, and made it an indifferent locality for the study of its biota, the south-east face of Ford Quarry is the only place where a fairly complete cross-section of the reef may be seen and is the only place where the reef–backreef transition is readily accessible. The reef is seen to be at least 200 m wide at this point, but the seaward margin is not exposed.

The shelf-edge reef is also a feature of the GCR site at Hylton Castle to the north, and, to the south, of the sites at Humbledon Hill, Tunstall Hills (north and south), Stony Cut (Cold Hesledon), Hawthorn Quarry and Horden Quarry. Aspects of reef distribution, structure, fabric, biotas and diagenesis at these localities are discussed in the relevant accounts. The aspect for which the reef at Ford Quarry is especially noteworthy is that the north-east face is the best exposure of algal-dominated, nautiloid-rich reef crest and high reef slope dolomite and is the only reef exposure containing columnar stromatolites. The presence of large, rolled, detached blocks here is indicative of phases of high energy.

The exposure of the reef–backreef contact is important for a number of reasons. Firstly, it shows that the landward edge of the reef was sharp, with very little relief, proving that the reef surface was barely higher than the backreef sea floor and that backreef carbonates accumulated at the same rate as the reef grew upwards. Secondly, the virtual absence of reef debris in backreef beds implies little erosion and sediment transport landwards across the top of this part of the reef. Thirdly, the general verticality of the contact shows that the landward edge of the reef remained geographically static whilst the seaward margin prograded; the reef therefore became wider with time.

Finally, the exposed backreef strata themselves are unique in being composed of altered carbonate muds and in containing a fairly varied and abundant invertebrate fauna that includes bryozoans and brachiopods. All the other exposures of backreef strata of this age in north-east England are predominantly of altered oolite grainstones with a sparse bivalve–gastropod fauna. The presence of reefwards-displaced allochthonous slide-blocks in these beds is also unique to Ford Quarry and the cutting, and shows that the backreef sea floor sloped towards the reef and was repeatedly unstable. The reasons for these various differences are not known, butSmith (1994) has speculated that they may have arisen because the reef here grew across the floor of a WSW/ENE submarine slide-canyon at least 30 m deep and the sea here may therefore have been deeper than in most other places.

Future research

Most aspects of the several formations exposed at this complex of exposures have been subject to detailed research in recent years and there seems little scope for further detailed studies in the immediate future; an exception is the backreef facies of the Ford Formation, which presents a number of anomalies noted in the text.

Interpretation

The complex of faces at Claxheugh Rock and in the adjoining cutting and quarry provide vital links in the chain of evidence favouring massive submarine slumping and sliding during Raisby and Ford formation times and also yield key evidence on the structure, shape and composition of the shelf-edge reef of the Ford Formation and equivalent backreef strata. Except for their involvement in submarine slumping, the rocks of the Raisby Formation, Marl Slate and Yellow Sands here are normal for the district and require no special comment.

Evidence bearing on submarine slumping and sliding

The unusual relationships of strata at the base of the Claxheugh Rock section have been commented on by most of the authors listed in the introduction to this account and were formerly the subject of lively debate. Most of the early authors recognized that the absence of the Raisby Formation and the Marl Slate at the north-east end of the section was a secondary feature caused by their removal after deposition and several inferred an erosional unconformity beneath the 'Shell Limestone' (= Ford Formation reef). A briefly-held alternative explanation by Woolacott (1903) invoked the collapse of a large cave, but was superceded byWoolacott (1912) who envisaged massive destructive east-northeastwards thrusting of the reef over and into the underlying strata. Trechmann (1945) accepted the evidence of thrusting, but clearly had reservations and, in 1954, diffidently suggested that the missing 30 m or so of the lower part of the reef might have been represented by anhydrite, since dissolved. None of these explanations fully accounted for all the facts, however, and this shortcoming led to a new interpretation (Smith, 1970c) in which the Raisby Formation, Marl Slate and the uppermost part of the Yellow Sands here were thought to have slid away downslope (east-northeastwards), leaving a deep slide-canyon which was subsequently filled and buried by the Ford Formation. This interpretation accounts for the scoremarks and matching ridges (= groove casts) between the Raisby and Ford formations, the breccia of Raisby Formation, Marl Slate and Yellow Sands debris and the overall relationships, but leaves unexplained the enigmatic later growth of a major shelf-edge reef at right angles to the trend of a large, linear sea-floor hollow. Similar features and abnormal stratigraphical relationships were formerly visible in Downhill Quarry (NZ 348601) 3 km NNW of Claxheugh, and large allochthonous masses of Raisby Formation strata, interpreted as slide-blocks (olistoliths), are present downslope at the coastal site at Trow Point and Frenchman's Bay, South Shields. The whole event and its field expression constitute the Downhill Slide.

Woolacott's (1903, Section 2) faithful recording of a particularly complicated part of the Claxheugh Rock section underlines the importance for geologists of making full records of what they see, even if they cannot interpret or understand it; the exposure was covered by debris from the 1905 landslip, but Woolacott's drawing and description were invaluable in the reinterpretation by Smith (1970c) of the history of the area late during Raisby Formation time. Similarly, Trechmann's (1945, fig. 2; 1954, fig. 3) sketches of the south face of the quarry accurately record discordances that he interpreted as evidence of tectonic thrusting, but which are now regarded as submarine slide-planes overlain by allochthonous slide-blocks. These features are still visible, however, and furnish eloquent evidence of the effect of submarine sliding and slumping on partly-consolidated carbonate muds; the exposures of slumped beds in the Ford Formation in the cutting are even more spectacular and convincing (Smith, 1994, plate 10).

Conclusion

This GCR site is the type section of the Ford Formation and is of international importance in that it shows an almost complete section through the late Permian shelf-edge reef and its passage into equivalent backreef strata to the west. It is particularly important in displaying evidence of penecontemporaneous late Permian submarine sliding and slumping on a large scale. This site has been extensively described in the literature and has been the subject of recent research. It is essential therefore that exposures at the site be preserved for further study and for other educational purposes.

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