TUNSTALL HILLS (SOUTH-EAST END) AND RYHOPE CUTTING

OS Grid Reference: NZ395538–NZ399537

Highlights

The group of exposures (boxes 8a and 8b in Figure 3.2) at the south-eastern end of Tunstall Hills is unique in including a readily accessible large exposure of debris-rich foreslope beds of the shelf-edge reef of the Ford Formation, here overlain by massive *in situ* reef. Slightly east of the reef is an excellent exposure of the younger residue of the Hartlepool Anhydrite Formation, which is in turn overlain by rocks of the Roker Dolomite Formation; the latter were almost totally brecciated (broken up) by foundering for at least 50 m when the anhydrite was dissolved by percolating ground-water.

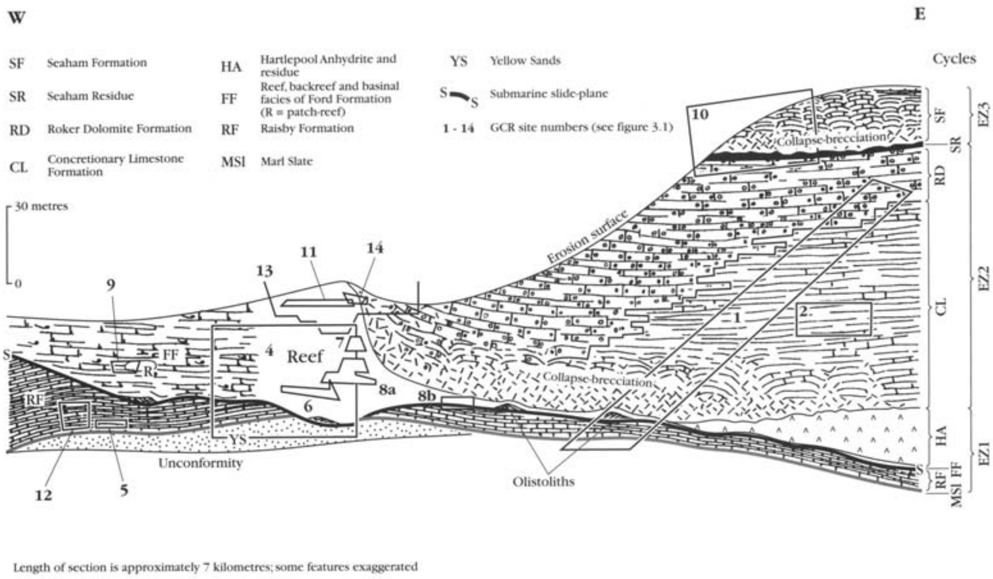

Figure 3.2: Approximate stratigraphical position of GCR marine Permian sites in the northern part of the Durham Province of north-east England (diagrammatic). Some sites in the southern part of the Durham Province cannot be accommodated on this line of section and have been omitted. The Hartlepool Anhydrite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

The exposures of reef-rock here form an integral part of the ridge that extends south-eastwards for almost a kilometre from Maiden Paps; they comprise one large and several small quarries cut into the hill itself and a rock-wall cut into the base of the southern extremity of the hill to accommodate a former railway. The quarries are all in massive reef dolomite and limestone with a relatively varied fauna dominated by bryozoans, brachiopods, gastropods and bivalves, and the rock-wall is in eastward-dipping reef debris and interbedded low reef slope deposits, the latter with their own distinctive assemblage of fossils.

The off-reef exposure is in a former railway cutting some 220–270 m ESE of the easternmost exposures of reef-rock; it comprises 2 m+ of bedded reef-equivalent dolomite overlain by 1–6 m of powdery and brecciated dolomite which, in turn, is succeeded by foundered collapse-brecciated Roker Dolomite. The north-western part of the cutting was preserved and re-excavated by the local council for research and teaching purposes when the remainder of the cutting was filled in 1981.

Early references to the reef-rocks at Tunstall Hills are too imprecise for locations mentioned to be identified now, though it is possible that all the various exposures were grouped together for reporting purposes; if this were so, fossils from the south-eastern end of the hills could have been included in the fossil lists published by, for example, King (1848, 1850), Howse (1850, 1858) and Kirkby (1857, 1858, 1859). Analyses of reef-rock by Trechmann (1914, p. 241) seem likely to be from the large quarry at this end of the hills, however, and brief comments on the reef-rock in this same quarry were made by Trechmann (1945, p. 344). Logan (1967, plate 4) later cited the quarry as the source of a hypotype of *Bakevellia* (*Bakevellia*) *ceratophaga* (Schlotheim) and Smith (1971b) summarized the main features of the geology. Further details were given in a series of excursion guides and reports (e.g. Smith, 1973a, 1981d) and by Smith (1981a, 1994). Finally, the petrology and diagenesis of the reef-rocks here were investigated in depth by Aplin (1985) and the faunal communities in the reef were analysed and discussed by Hollingworth (1987) and Hollingworth and Pettigrew (1988).

The earliest detailed reference to rocks in the railway cutting was by Trechmann (1954, p. 198), who listed the fauna in the lowest beds exposed and interpreted the overlying powdery dolomite breccia as 'a sort of mylonite' associated with a thrust plane; this dolomite was later reinterpreted as the dissolution residue of the Hartlepool Anhydrite by Smith (1971a, 1972) and the overlying breccia was interpreted as the foundered remains of the Cycle EZ2 carbonate unit.

The nomenclature used in this account follows traditional practice except that, to avoid confusion, the term 'Ryhope cutting' is restricted to the former railway cutting at Ryhope and the former half-cutting starting some 220 m farther WNW is referred to as 'the rock-wall'.

Description

The several parts of the site at the south-east end of Tunstall Hills and the Ryhope Cutting are shown in Figure 3.31, which also shows the main features of geological interest.

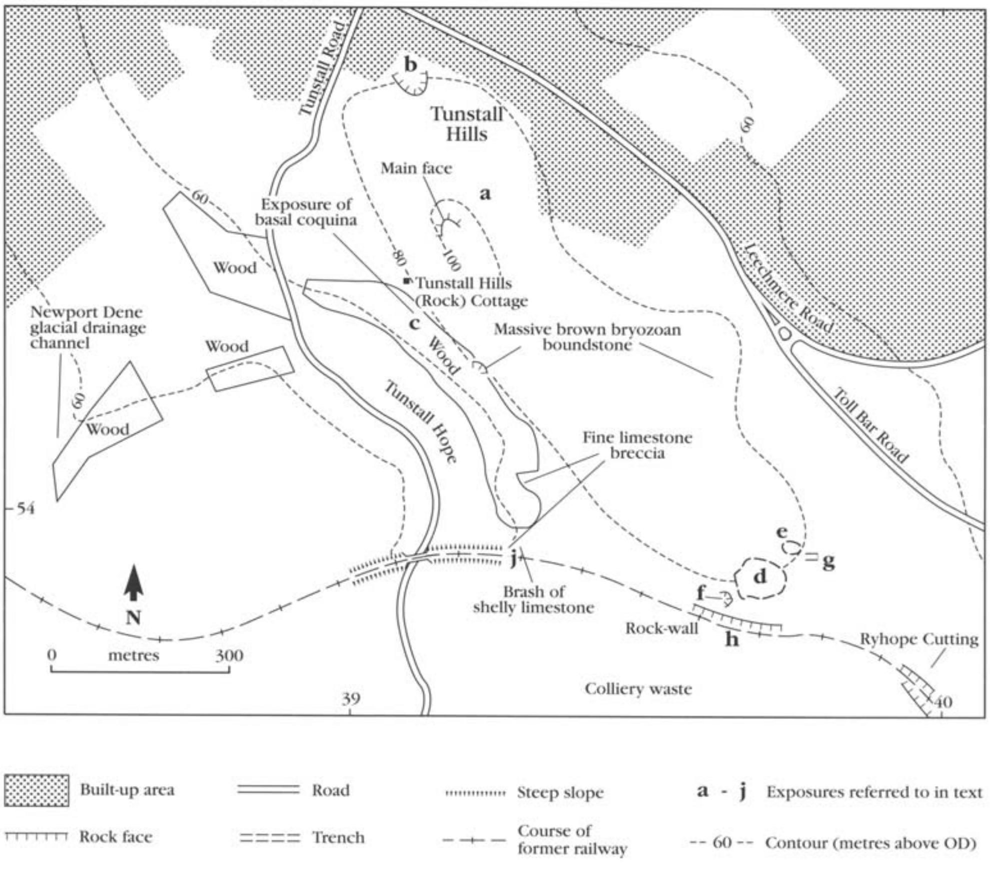

Figure 3.31: Tunstall Hills (north and south), showing the position of the main exposures and features of geological interest.

Exposures of reef-rocks of the Ford Formation

These comprise the main quarry ("d' in Fig 3.31), two smaller quarries (e, f), a trench (g) and a large artificially steepened rock wall (h); the position of a number of minor additional exposures (j) is also shown in Figure 3.31. The mutual relationship of exposures d to h is shown in Figure 3.34.

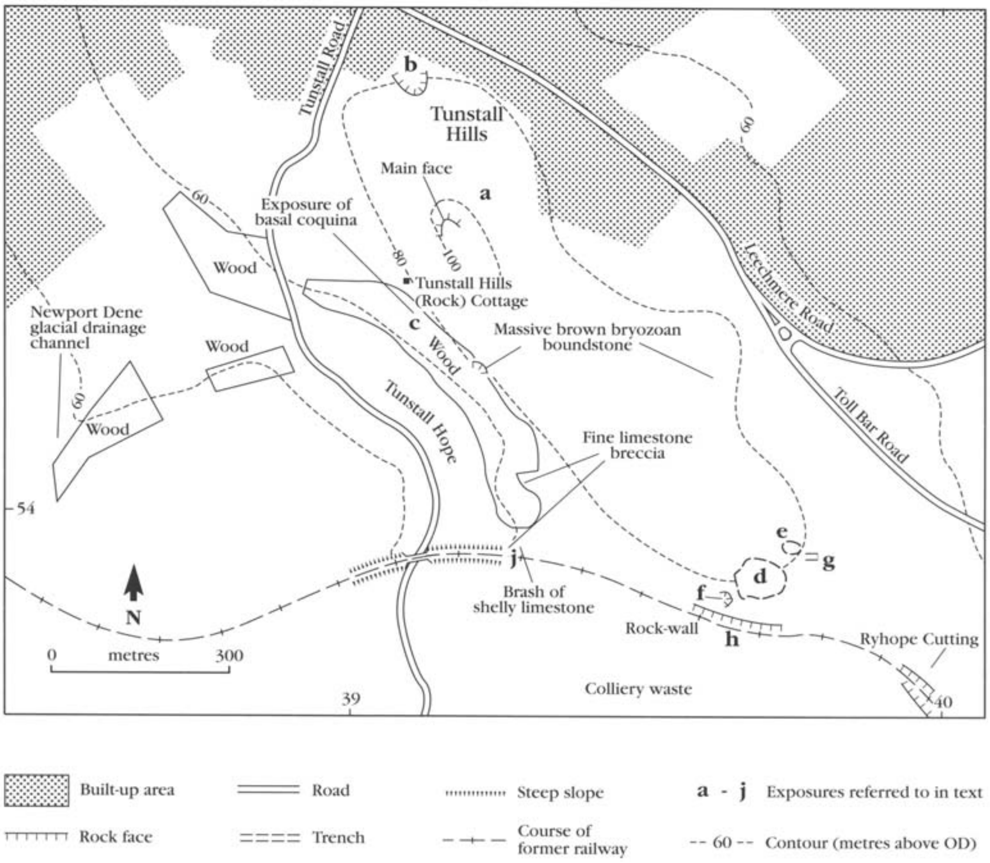

Figure 3.31: Tunstall Hills (north and south), showing the position of the main exposures and features of geological interest.

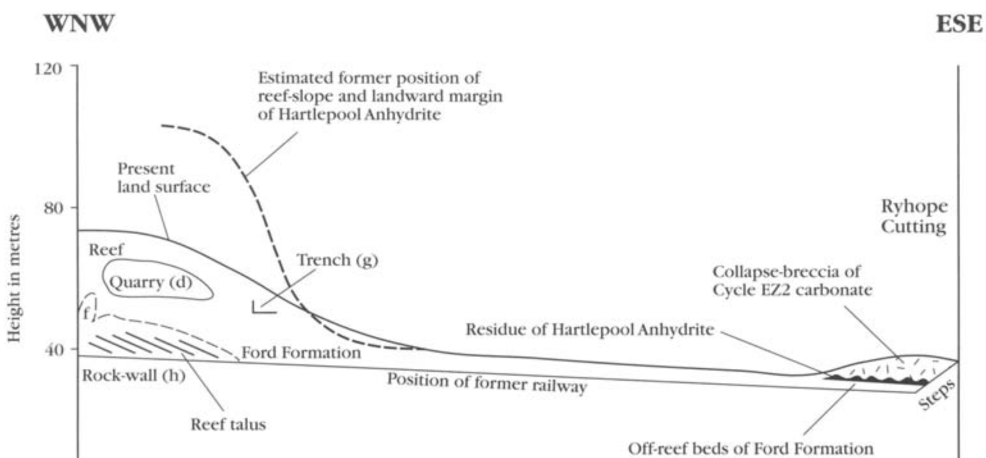

Figure 3.34: Relationships of reef and off-reef (including post-reef) strata at the south-east end of Tunstall Hills and in the Ryhope Cutting (diagrammatic). See Figure 3.31 for the location of the various exposures.

The main quarry (d) is about 90 m across and exposes up to 15 m of massive buff to brown algal–bryozoan boundstone (framestone/bafflestone) with several sinuous anastomosing thin sheets of complexly laminar bindstone that dip eastwards at 15–70ø; western parts of the quarry are interpreted as lying in the reef-core with eastern parts approaching the mid reef slope (Smith, 1981a, fig. 3; Hollingworth, 1987, fig. 1.6; Hollingworth and Pettigrew, 1988, fig. 4). The fauna of the main quarry was listed by Pattison (Geological Survey internal report, 1966) and Hollingworth (1987, table 8), and was discussed by Hollingworth (1987) and Hollingworth and Pettigrew (1988, their locality 7, 'Tunstall Hills East'); Hollingworth showed that the fossil assemblage is broadly typical of the reef-core, with *Dielasma* being numerically dominant (34%) and fenestrate bryozoans totalling 16%. Many of the fossils are unusually well preserved in the limestones (Smith, 1981a; Aplin, 1985; Southwood, 1985; Hollingworth, 1987; Hollingworth and Pettigrew, 1988) and Smith (1981a) and later authors have speculated that the structures in these partly secondary rocks might have been inherited from primary fabrics that are less clear in the intervening dolomite stage.

Most of the rock in the main quarry is of coarsely crystalline, iron-stained limestone with very coarse replacive calcite spherulites concentrated along the western side (Trechmann, 1914, 1945; Aplin, 1985). Trechmann (1914, p. 241) quoted three analyses of limestone from this quarry and one photomicrograph (plate 36.4) and Aplin (1985, table 5.1) presented two analyses and several photomicrographs (figs 5.4, 5.4, 5.6, 5.8, 5.9, 5.17C and 5.18B); calcite was shown to be predominant in all five rocks analysed, with less than 4% of dolomite in each, but extensive petrographic examination by Aplin of these and other rocks from the quarry revealed a complex diagenetic history and at least some calcite replacement of dolomite and gypsum/anhydrite. Preservation of primary fabrics is generally good in much of the limestone and reveals evidence of former marine botryoidal and fibrous ?aragonite cements (Aplin, 1985); complex ?algal encrustations coat many of the bryozoan frame elements (Smith, 1981a, fig. 26; Aplin, 1985, fig. 5.6) and in places form most of the rock (Figure 3.35). Boundstone masses such as characterize the reef-core at Humbledon Hill are fewer here, though an excellent example of a 1.8 m concentric algal–bryozoan subspherical mass lies in the extreme south-east corner of the quarry. The sinuous laminar bindstone sheets are mainly less than 0.2 m thick and some extend for the full height of the quarry face; some appear to be unilateral, having accreted only basinwards, but others appear to be bilateral and presumably coat the walls of fissures in a fully lithified host rock.

Figure 3.35: Dense ?algal encrustations in reef boundstone in the main old quarry (d) at the south-east end of Tunstall Hills. Delicate bryozoan frame elements form less than 5% of the rock. Coin: 26 mm across. (Photo: D.B. Smith.)

The small old quarry ("e' in Figure 3.31; NZ 3975 5394) situated a short distance north-east of the main quarry, is cut mainly into hard, massive, brown, crystalline, slightly dolomitic limestone similar to that in the main quarry and is interpreted as reef-core facies approaching the middle of the reef slope. The rock appears to be formed mainly of hard, crystalline bryozoan boundstone (framestone/bafflestone) with pockets and irregular sheets of shelly rubble; the rubble dips predominantly south-eastwards at 10–25ø, but local westward dips also occur. The fauna of the quarry has not been specially studied, but crinoid debris is abundant locally. Very coarse calcite spherulites form much of the rock near the south-east corner of the quarry.

The small old quarry ("f' in Figure 3.31; NZ 3964 5386) immediately south-west of the main quarry lies at a lower topographical and stratigraphical level and exposes massively rubbly high-foreslope reef talus. The major clasts in the talus are of algal–bryozoan boundstone superficially similar to that in the main quarry, but work by Aplin (1985) shows that the limestone is generally more finely crystalline and that, paradoxically, primary fabrics are less well preserved; the limestone contains abundant dolomite relics. Aplin states (p. 260) that the talus interdigitates westwards into *in situ* reef-rock, here represented by unbedded dolomite algal–bryozoan boundstone in a large face that extends westwards from the small quarry.

The trench ("g' in Figure 3.31; NZ 3978 5392) lies about 40 m north-east of the main quarry and topographically slightly lower. It is about 1.5 m deep and is cut into brown (iron-stained) crystalline bryozoan boundstone (framestone/bafflestone) with hints of a gentle north-easterly dip and much coarsely spherulitic calcite. Hollingworth (1987) and Hollingworth and Pettigrew (1988, their locality 8) fully describe and discuss the brachiopod-dominated fauna and doubtfully assign the trench rocks to the reef crest sub-facies (see Interpretation); some of the bryozoans are especially well preserved and were thought by Hollingworth (1987) to be in life position. A full faunal list was given by Hollingworth (1987, table 9).

The rock wall ("h' in Figure 3.31; NZ 3964 5382–3971 5380) is about 70 m long and up to 8 m high and is cut in dolomitized reef talus deposited on the lower part of the reef-foreslope; the talus comprises a crudely eastward-dipping (20–35ø) accumulation of debris derived from higher parts of the reef slope (including the crest), together with the remains of an indigenous fauna (Smith, 1981a). Tumbled blocks of bryozoan and bryozoan–algal boundstone form more than half the rock (Smith, 1981a, figs 8, 23) and lie in a matrix of finer rubble. The blocks, some more than 3 m across, contain a mid- to high-slope fauna dominated by brachiopods and bryozoans, but the finer rubble contains a much more varied fossil suite; careful collecting by Hollingworth (1987) from a representative pocket of shelly rubble here enabled him to distinguish the allochthonous from the indigenous brachiopod and bivalve fauna, and allowed reconstruction of a reef talus palaeocommunity (Hollingworth, 1987, fig. 6.34, reproduced as Hollingworth and Tucker, 1987, fig. 8 and Hollingworth and Pettigrew, 1988, fig. 17). Faunal lists were given by Pattison (Geological Survey internal report, 1966) and Hollingworth (1987, table 19).

The remaining substantial reef-related exposures ("j' in Figure 3.31, NZ 3926 5395–3929 5394) lie in a separate group some 400 m WNW of the rock wall and are of several different rock types; diagenetic changes and extensive brecciation have obscured much of the primary character of the rocks, but they include both dolomite and limestone. Fragments in the brecciated rocks are mainly less than 0.1 m across, though some exceed 0.3 m, and algal-type lamination is present in some. Extremely fossiliferous calcitic dolomite (possibly basal coquina) is abundant in hillside brash (NZ 3929 5395) at the eastern end of this group of exposures.

Exposures of rocks of the Ford, Hartlepool and Roker formations in Ryhope Cutting

This preserved remnant (NZ 399537) of a former 300 m-long railway cutting reveals the following sequence.

	Thickness (m)
Roker Dolomite Formation (foundered):	
Breccia of subrounded to angular fragments up to 0.30 m across (but mainly less than 0.05 m) of grey and buff calcite- and dolomite-wackstone/?grainstone in a matrix of fine-grained carbonate; much laminar cavity-fill, especially in lower part; base markedly uneven, relief 2–4 m	7+
Inferred residue of Hartlepool Anhydrite Formation:	
Breccia of small, soft, angular fragments of cream finely saccharoidal dolomite in a cream powdery matrix; strong flow-lines in places and several laccolith-type intrusions into overlying breccia (most now covered); sharp rolling base (relief 3 m), partly truncating underlying strata	1–6
Ford Formation, off-reef beds:	
Dolomite brachiopod-bryozoan wackestone, cream-buff, in gently folded thick beds; partly dedolomitized at top at north-west end of cutting (T.H. Pettigrew, pers. comm., 1981)	2+

The bedded dolomite at the base of the section is sparingly to moderately fossiliferous and is notable for containing *Neochonetes davidsoni* which is typical of off-reef Ford Formation strata; faunal lists were given by Trechmann (1954, p. 198) and Hollingworth (1987, table 20), and T.H. Pettigrew (pers. comm., 1981) also records ?*Astartella* and *Permophorus costatus*. No reef-derived debris other than bioclasts has been noted in this dolomite. Judging from the record of strata encountered in Ryhope Colliery shaft nearby (NZ 3989 5353), Cycle EZ1 strata are here about 85 m thick, of which the Raisby Formation is unlikely to exceed 50 m.

The top of the bedded dolomite in the preserved faces has some of the characteristics of an erosion surface, with slopes reaching 70ø (T.H. Pettigrew pers. comm. 1981); in the cutting as a whole, before filling, the surface was generally gently and unevenly rolling and had a total relief of at least 4 m in all directions.

The overlying soft breccia, mainly 1–2 m thick in the preserved exposures, but thickening to 6 m where intruded into the overlying hard breccia (see Smith, 1994, fig. 44), was seen in the former cutting to thin south-eastwards to 0.1–0.3 m; it was probably from here that Trechmann (1954) recorded stellate gypsum clusters. This was the bed regarded by Trechmann as marking a thrust plane, and later reinterpreted (Smith, 1972) as the residue of the Hartlepool Anhydrite. The harder calcitic breccia is interpreted as the foundered remains of the Cycle EZ2 carbonate formation, here probably of Roker Dolomite facies.

Interpretation

The advantage of the exposures at the south-east end of Tunstall Hills and in Ryhope Cutting lies in their close grouping, which provides not only a convenient view of the rocks themselves, but also of their mutual relationships; the reef-rocks furnish unambiguous and unique evidence that the reef-core prograded basinwards (i.e. eastwards) over earlier reef talus and the rocks east of the reef show that the succeeding 50 m + Hartlepool Anhydrite formerly approached to within 200 m of the reef foreslope.

Reef-rocks

The relationship between the reef and the local topography has been discussed in the account of the exposures at the north-western end of Tunstall Hills and the correspondence is particularly close at the south-eastern end; here, notwithstanding the probable erosion of some of the landward margin of the reef, it is clear that the group of quarries lies in the core of the reef, towards its seaward margin; equally clearly, the exposures of bedded reef talus show that bed by rough bed, the front of the reef migrated basinward as it built upwards, so that the reef-core extended out over the former reef foreslope.

Relationships between reef, topography and stratigraphy are less clear on the south-west side of the valley of Tunstall Hope, where the main shelf-edge reef undoubtedly forms much of the high ground at Tunstall village and to the south, but is difficult to delineate. Similarly, the presence of Tunstall Hope makes it impossible to relate the shelf-edge reef directly to the reef-rocks exposed in the nearby old railway cutting (NZ 388538) at High Newport, though these were probably formed as a patch-reef in the Ford Formation lagoon (Smith, 1981a; Hollingworth, 1987).

In greater detail, rocks in the main quarry (d), the small quarry (e) and trench (g), together comprise a partial transect from mid reef-core to near the middle of the reef foreslope, though Hollingworth's tentative identification of reef crest lithofacies in the trench is difficult to reconcile either with some aspects of the biota or with the lithology. The main quarry is doubly important in that, together with the exposures of reef-core at the northern end of Tunstall Hills and at Humbledon Hill, it yielded the fossils upon which Hollingworth (1987, fig. 6.15) was able to reconstruct the reef-core palaeocommunity.

The main quarry is also important in being one of the two main exposures (the other being at the northern end of the hill) where the reef is of coarse-grained limestone, rather than the more usual dolomite, and in which primary fabrics are well preserved; from his detailed studies Aplin (1985, p. 305) concluded that the coarse-grained limestone was produced by the calcitization of partially dolomitized limestone and is thus partly dedolomite. 'Some fabrics' he wrote, 'were regenerated during dedolomitization, but many of the fabrics observed are thought to be secondary replacements of primary aragonite and a high-Mg calcite'.

The small quarry (f) is also important mainly because of Aplin's work; he identified it as one of the main places in the shelf-edge reef where the rock is composed of finely crystalline limestone in which primary fabrics are poorly preserved. Aplin (p. 305) concluded that these limestones are dedolomites and resulted from the reaction of the former dolomite with meteoric fluids during or after Mesozoic/Tertiary uplift.

The rock-wall (h) is important in being the only large surface exposure of the talus aprons of the shelf-edge reef in north-east England. An underground exposure of the reef talus has been recorded in the walls of tunnels through the reef at Easington Colliery 10 km to the SSE (Smith and Francis, 1967, pp. 136–7 and 169). The lithology and biota of the rock at the two exposures is generally similar.

The presence of rocks resembling collapse-breccias at exposure (j) is enigmatic, and the brecciation could be entirely diagenetic in origin; if they are collapse-breccias it implies the former presence here of abundant soluble rocks, presumably secondary anhydrite, which would be difficult to account for by present views of the local palaeogeography.

Off-reef Ford Formation and later rocks

Ryhope Cutting, in addition to providing evidence of the former proximity to the reef of Hartlepool Anhydrite, is important in being one of only four places where the basin-floor bedded equivalent of the reef is known to be exposed. The apparent absence of reef-derived detritus other than bioclasts is particularly noteworthy here in view of the short distance (less than 200 m) between the exposure and the toe of the reef slope. The base of the reef-equivalent strata is not exposed, so that their thickness is not known, but comparable strata proved in the Easington Colliery tunnels are 9–15 m thick (Smith and Francis, 1967, p. 137), indicating a very sharp eastward thinning of the off-reef strata. Farther east, at Frenchman's Bay and Trow Point (South Shields), reef-equivalent strata appear to be absent.

The other exposures of basin-floor rocks of probable reef age are in the floor of Ryhope Dene (NZ 4131 5170) 2.5 km SSE of the cutting and at Dene Holme (NZ 454404), Horden; all are different from each other, both lithologically and faunally, though a link is the common presence of chonetoid brachiopods and nodosariid foraminifera. A number of exposures of sparingly shelly, bedded dolomite in the East Boldon area, 8 km NNW of the cutting, may also be in reef-equivalent strata basinward of the reef, but stratigraphical relationships cannot be proved; if these rocks are of the same age as the reef, the reef foreslope may not be as high in the northern part of its course as the 100 m or so inferred from the spatial relationships of reef and succeeding strata in the Hawthorn–Easington area farther south (Smith, 1981a).

Future research

The structure, palaeontology, ecology and petrology of the reef have recently been investigated in considerable detail, so that there is presently little scope for further broadly based research into these aspects. There remains, however, considerable doubt regarding the relationship of the reef to enclosing and underlying strata, especially in the High Newport and Tunstall areas, and these aspects are worthy of further investigation; delineation of the reef–backreef boundary, for example, and identification of the age of subreef strata (Raisby Formation or Ford Formation?) would help to reduce the present uncertainties, and the possibility that collapse-breccias may be present at exposure (f) deserves investigation in view of its considerable palaeogeographical implications.

East of the reef, scope for further research undoubtedly exists into the sedimentology, distribution and biota of basinal strata of reef age, and determination of the age of bedded, shelly dolomite east of the reef in the East Boldon area would be extremely helpful in reconstructing the contemporary palaeogeography. Further research is also required on the petrography and origin of the supposed residue of the Hartlepool Anhydrite in Ryhope Cutting, and on the overlying inferred collapse-breccias.

Conclusion

The varied rocks in these two readily accessible groups of excavations at the south end of Tunstall Hills include *in situ* reef limestone and dolomite that can be seen to have prograded over its own earlier detritus and, in the cutting, one of the few exposures of fossiliferous basinal rocks equivalent in age to the shelf-edge reef. Detailed study of the reef-rock in the western group of excavations has revealed a complex history of mineralogical changes, and study of the abundant fauna in the reef detritus (talus) has yielded vital clues to the assemblage and lifestyle of the many invertebrate organisms that lived there.

The presence of an inferred residue of Hartlepool Anhydrite directly overlying the reef-equivalent beds in the cutting, is important in showing how close the anhydrite must once have approached to the steep seaward slope of the reef, although the anhydrite was almost certainly wholly younger.

The reef-rocks have been researched in detail but there remains the question of the relationship of the reef to the surrounding strata, the petrography of the residue of Hartlepool Anhydrite, and the origin of the collapse-breccias, presently considered as part of the Roker Dolomite Formation. For these reasons, the site is an important link in the understanding of reef growth and progradation in the late Permian, and the style of sedimentation along the western margin of the Zechstein Sea.

Reference list

Aplin, G. (1985) Diagenesis of the Zechstein main reef complex, NE England. Unpublished Ph.D. Thesis, University of Nottingham.

Hollingworth, N.T.J. (1987) Palaeoecology of the Upper Permian Zechstein Cycle 1 reef of NE England. Unpublished Ph.D. Thesis, University of Durham.

Hollingworth, N.T.J. and Pettigrew, T.H. (1988) *Zechstein Reef Fossils and their Palaeoecology*. Palaeontological Association Field Guide to Fossils No. 3, University Printing House, Oxford, 75 pp.

Hollingworth, N.T.J. and Tucker, M.E. (1987) The Upper Permian (Zechstein) Tunstall Reef of north-east England: palaeoecology and early diagenesis, in *The Zechstein Facies in Europe* (ed. T.M. Peryt), Springer-Verlag, Berlin, pp. 25–51.

Howse, R. (1858) Notes on the Permian System of the counties of Northumberland and Durham. *Annals and Magazine of Natural History*, **19**, 304–12.

King, W. (1848) *A Catalogue of the Organic Remains of the Permian Rocks of Northumberland and Durham*, Newcastle upon Tyne.

King, W. (1850) *A Monograph of the Permian Fossils of England*, Palaeontographical Society, London, 258 pp.

Kirkby, J.W. (1857) On some Permian fossils from Durham. *Quarterly Journal of the Geological Society of London*, **8,** 213–8 and plate 7.

Kirkby, J.W. (1858) On Permian entomostraca from the Shell-Limestone of Durham. *Transactions of the Tyneside Naturalists' Field Club*, **4,** 122–71.

Kirkby, J.W. (1859) On the Permian Chitonidae. *Quarterly Journal of the Geological Society of London*, **15**, 607–26.

Logan, A. (1967) *The Permian Bivalvia of Northern England*. Monograph of the Palaeontographical Society, London, 72 pp + plates.

Smith, D.B. (1971a) *The Stratigraphy of the Upper Magnesian Limestone*: *a revision based on the Institute's Seaham Borehole*, Report 71/3, Institute of Geological Sciences, 12 pp.

Smith, D.B. (1971b) 1:10,560 Geological Map Sheet NZ 35 SE. Institute of Geological Sciences.

Smith, D.B. (1972) Foundered strata, collapse-breccias and subsidence features of the English Zechstein, in *Geology of Saline Deposits* (ed. G. Richter-Bernburg), UNESCO (Earth Sciences 7), pp. 255–69.

Smith, D.B. (1973a) The Permian in north-east Durham, in *The Durham Area* (compiler G.A.L. Johnson), Geologists' Association Guide No. 15, pp. 15–21.

Smith, D.B. (1981a) The Magnesian Limestone (Upper Permian) reef complex of north-eastern England, in *European Fossil Reef Models* (ed. D.F. Toomey), Special Publication No. 30, Society of Economic Paleontologists and Mineralogists, pp. 161–86.

Smith, D.B. (1981d) Account of field excursion to the Permian of Tyne and Wear. *Proceedings of the Yorkshire Geological Society*, **43**, 467–70.

Smith, D.B. (1994) *The Geology of the Sunderland District*, Memoir of the British Geological Survey, Sheet 21.

Smith, D.B. and Francis, E.A. (1967) *The Geology of the Country between Durham and West Hartlepool*, Memoir of the Geological Survey of Great Britain, Sheet 27.

Southwood, D.A. (1985) The taxonomy and palaeoecology of bryozoa from the Upper Permian Zechstein reef of NE England. Unpublished Ph.D. Thesis, University of Durham.

Trechmann, C.T. (1914) On the lithology and composition of Durham Magnesian Limestones. *Quarterly Journal of the Geological Society of London*, **70**, 232–65 + 2 plates.

Trechmann, C.T. (1945) On some new Permian fossils from the Magnesian Limestone near Sunderland. *Quarterly Journal of the Geological Society of London*, **100**, 333–54 + 1 plate.

Trechmann, C.T. (1954) Thrusting and other movements in the Durham Permian. *Geological Magazine*, **91**, 193–208.