Tunstall Hills, Sunderland; Maiden Paps and the Tunstall Hills (Rock Cottage exposure)

[NZ 39 54]

Highlights

The twin mounds of Maiden Paps at the north-west end of Tunstall Hills (box 7 in (Figure 3.2)) are probably the best-known topographical expression of the shelf-edge reef of the Ford Formation and also contain a number of the most important exposures of fossiliferous reef-rock; these include a large exposure of reef-core in the more southerly mound, which also features several steeply-dipping laminar sheets and tension gashes. The nearby 'Rock Cottage' exposure is unique in revealing highly fossiliferous primary limestones at the base of the reef, which bear evidence of contemporary sea-floor cementation. More than 50 type, cited and illustrated fossils are from Tunstall Hills, and at least two species of fossil invertebrates carry the name *tunstallensis.*

Introduction

Maiden Paps are two prominent local landmarks (see Hollingworth, 1987, appendix D, fig. 3) in the southern outer suburbs of Sunderland; they form part of a chain of knolls that mark the position of the shelf-edge reef of the Ford Formation between West Boldon [NZ 34 60] and Horden [NZ 43 41]. The hilltops are excellent vantage points for viewing the close relationship between the local geology and scenery and afford a superb view to the west of the low-lying floor of the former glacial Lake Wear and its associated drainage channels.

Reef-rocks, mainly of limestone, but some of dolomite, make up all the exposures at Maiden Paps and total perhaps 35 m in thickness. The more northerly of the mounds is mainly grass-covered and now bears only a single small quarry exposure of shelly dolomite near its northern extremity; in contrast, the southern mound bears many exposures including a north-facing quarry cliff of reef limestone (8 m+). Slightly farther south is the famous 'Rock Cottage' exposure of reef-base limestone coquina.

The shelly rocks of Tunstall Hills have been known since the writings of Winch (1817) and Sedgwick (1829) and, together with those at Humbledon Hill, were the main collecting ground for Howse (1848, 1858), King (1848, 1850) and Kirkby (1857, 1858, 1859); few additional species have been found here since 1860, though long lists were given by Trechmann (1945), Logan (1967), Pattison (internal Geological Survey report, 1966) and Hollingworth (1987). Hollingworth also gave a faunal list from the 'Rock Cottage' exposure, where some of the gastropods have retained part or all of their original colour (Hollingworth, 1987; Hollingworth and Tucker, 1987; Hollingworth and Pettigrew, 1988).

Analyses of the reef-rocks were given by Aplin (1985), who also illustrated (p. 378) the main face and discussed the complex diagenetic history of the reef. Burton (1911), Woolacott (1912) and Trechmann (1945) noted the presence of coarse, frosted, quartz sand grains in fissures in the main face and the origin and filling of the fissures was discussed by Smith (1981b) and Aplin (1985). The diagenesis of the coquina at the base of the reef in the 'Rock Cottage' section was detailed by Tucker and Hollingworth (1986) and Hollingworth and Tucker (1987), who also drew conclusions on some general aspects of early reef history.

Working of the quarries ceased more than a century ago, but the discovery of the 'Rock Cottage' reef-base limestone by Hollingworth in 1983 was followed by NCC-funded excavation to help in GCR assessment and the exposure has since been enlarged and fenced by the Sunderland Borough (now City) Council.

Description

Rock exposures at and near Maiden Paps include the main face cut into reef-core limestone on the north side of the southern mound, a small quarry [NZ 3910 5472] in reef slope dolomite at the foot of the north slope of the northern mound and the small exposure of basal coquinoid limestone [NZ 3910 5432] high on a wooded slope about 70 m south of 'Rock Cottage' (shown on Ordnance Survey maps as Tunstall Hills Cottage'). The position of the above exposures is shown in (Figure 3.31) which also shows the positions of several minor exposures.

The north face of the main quarry (a) is about 8 m high and 30 m across, but the exposure also extends a short distance south-eastwards on the north-east side of the hill and rather farther southwards on the west side (Figure 3.31). Although at first sight almost unbedded, close inspection reveals hints that parts of the rock, like that at Humbledon Hill and Hylton Castle Cutting, may comprise rounded 1–3 m masses of bryozoan boundstone that are separated and surrounded by vaguely bedded shelly rubble; in places small *Dielasma* shells in life position form dense swarms attached to boundstone masses that were, by inference, already lithified.

The abundance of fossils for which Tunstall Hills was noted in the past is less noteworthy now, though locality citations in the early (and some of the later) works were generally limited to 'Tunstall Hills' or 'Tunstall' and the precise point of origin cannot now be identified. These localities, presumably, though not undoubtedly, referring to Maiden Paps, were a source of more than 50 type, cited and/or illustrated individuals for King (1848, 1850), almost 40 for Howse (1848, 1858) and more than 40 for Trechmann (1945) who gave some precise locality details; Logan cited the hills as a source of almost 30 species of bivalve and illustrated several from here. The main face (a) yielded 16 species to Hollingworth (1987, table 7), with *Dielasma* forming 38% and *Bakevellia* (*Bakevellia*)21% of the fauna; he described the assemblage as of low diversity, with less than 10% of bryozoans, and combined the data from here with that from the main quarry at the south-eastern end of the hills and from Humbledon Hill, to reconstruct a model of a reef-core palaeocommunity (Hollingworth, 1987, fig. 6.15, reproduced as fig. 6 in Hollingworth and Tucker, 1987 and as fig. 16 in Hollingworth and Pettigrew, 1988). Fossil preservation ranges from poor to extremely good, even in single specimens. In several substantial parts of the face, particularly near the centre-top, bryozoan and other frame-building elements are thickly coated with concentric ?algal encrustations that locally form almost all of the rock.

Most of the rock in the main face and adjoining exposures is of hard, crystalline, brown, ferruginous limestone with abundant coarse radial calcite (Trechmann, 1945; Aplin, 1985). Aplin noted that, as in the main quarry at the south-eastern end of the hills, the rock is mainly coarse-grained; he described and illustrated a range of early diagenetic fabrics from here, including botryoidal and radial-fibrous types, and interpreted some of these as replaced, primary aragonite cements possibly of marine origin; many of the botryoidal and radial fibrous cements are nucleated onto calcite-replaced nodular anhydrite or gypsum. An XRD analysis of algal bryozoan bindstone from this face revealed 100% calcite, and high trace contents of manganese and iron were also identified in the same sample (Aplin, 1985, tables 5.1 and 5.2).

Steeply dipping, sinuous, laminated limestone sheets up to 0.6 m thick are concentrated near the middle and western end of the main face (Figure 3.32) and may be traced south-eastwards (i.e. roughly parallel with the reef trend) for a few metres to tens of metres. Some of the sheets appear to be unilateral (Figure 3.33), but others are bilateral and undoubtedly coat the walls of former fissures (Smith, 1981b, p. 174; Aplin, 1985, pp. 233–253, with several illustrations); both types are patchily to extensively replaced by coarsely crystalline radial calcite (see Aplin, 1985, table 5, for XRD analyses from here). Some of the fissures are incompletely filled and retain irregular median voids; others contain frosted, coarse quartz sand grains (Burton, 1911; Woolacott, 1912; Trechmann, 1945), fallen blocks of reef-rock (some now thickly coated; see Smith, 1994, plate 15) and a few bioclasts (Aplin, 1985, fig. 5.12C) that may also have fallen in rather than have been in life position. Hollingworth (1987, p. 220) found no fossils of fissure-dwelling invertebrates in the fissure fill.

The small old quarry (b) at the foot of the more northerly mound exposes a few metres of cream and buff shelly dolomite boundstone with a strong suggestion of very steep (approaching vertical) east-northeasterly?primary dips (Smith, 1981a). Hollingworth (1987, table 13, his 'Electricity Substation' exposure) recorded 14 invertebrate species from here, with *Dielasma* (40%) and *Bakevellia* (18%) greatly exceeding *Acanthocladia* (7%) and *Synocladia* (5.5%); he noted (pp. 279–280) that all the forms present were adapted to life on a steeply-sloping substrate, in keeping with the inferred steep dips of this reef slope palaeoenvironment.

The palaeontology of the coquinoid rocks at the important 'Rock Cottage' exposure (c) was investigated in great detail by Hollingworth (1987) and their petrology was described by Tucker and Hollingworth (1986) and Hollingworth and Tucker (1987). The base of the coquina is not exposed, but the lowest part of the new excavation lies only a few metres up the hill from temporarily exposed, sparsely fossiliferous, well-bedded 'dolomicrite'; the outcrop of the coquina may be traced southeastwards for about 100 m, but then ends abruptly at the High Barnes fault which has an estimated downthrow south of 25 m. According to Hollingworth (1987, pp. 170–173), the coquinoid limestone comprises a crumbly basal unit (0.6 m+) of 'pale cream to buff, well-bedded, calcified coquina overlain by dark brown, iron-rich, partially decalcified coquina' (about 2 m) which, in turn, is succeeded by about 3 m of 'slightly more massive buff-brown, crystalline coquina'. The basal unit has a diverse biota of brachiopods, bivalves, gastropods and bryozoans, but the dark brown limestone is composed almost entirely of the articulated valves of *Dielasma.* The uppermost unit contains an exceptionally varied and abundant fauna dominated by *Dielasma,* and also contains teeth of two genera of fish *Vanessa* and *Wodnika*) ; some of the gastropods retain their original colours. The coquina passes up into 0.4 m+ of bryozoan boundstone (framestone) in which fenestrate bryozoans (mainly *Fenestella*) are dominant, with *Dielasma* persisting in abundance. In total the coquina yielded the remains of 23 invertebrate species, enabling Hollingworth (1987, fig. 6.3) to reconstruct a base-of-reef palaeocommunity; this diagram was reproduced by Hollingworth and Tucker (1987, fig. 4) and Hollingworth and Pettigrew (1988, fig. 15). The coquina/reef-core transitional strata yielded 26 species (Hollingworth, 1987, table 2).

Petrographic examination of reef-base rocks from the Rock Cottage site (Tucker and Hollingworth, 1986; Hollingworth, 1987; Hollingworth and Tucker, 1987) revealed that they had escaped dolomitization and, partly in consequence, retain traces of primary marine cements, now calcite; these include aragonite crusts and botryoids, isopachous layers and fans of acicular calcite, and calcite fans. The cements are interpreted to indicate widespread episodic early cementation of the coquina as it lay on the shallow sea floor, with occasional brief episodes of exposure and cement dissolution.

Interpretation

The shelf-edge reef of the Ford Formation features in, or is the main constituent of, seven GCR sites in north-east England, each exposing different sub-facies; taken together they reveal much of the structure, character and history of the reef. The designated sites are scattered unevenly along the outcrop, and comprise (from the north) Hylton Castle road cutting, Claxheugh Rock and adjoining exposures, Humbledon Hill, Tunstall Hills (both ends), Stony Cut, Hawthorn Quarry and Horden Quarry ((Table 3.1); in general the more northerly sites expose the low and middle parts of the reef and the southern sites expose the higher parts.

Some information on the distribution of the reef is given in the accounts of the other reef sites herein, and was summarized by Trechmann (1925, plate 15) and Smith (1981a, fig. 9). There are, however, still many places where the information is too poor to allow precise delineation and the maps, accordingly, are locally little more than speculative; this is particularly so in low-lying areas, where the ridge or topographic step that normally indicates the position of the reef is missing and thick drift deposits cover the rock. The correspondence between topography and reef is generally good at Tunstall Hills, however, with the north-west to south-east ridge probably closely following the reef slope on its eastern side; some erosion of the western side has undoubtedly reduced the width of the reef there, but the hills as a whole are only a little narrower than the usual 300600 m reef width. The inferred correspondence between the eastern side of the ridge and the reef foreslope is strongly supported by the presence of Cycle EZ2 collapse-breccias in the Ryhope Cutting at the south-eastern end of the hills and by the observed juxtaposition of the reef slope with post-reef collapse-breccia in hill-slope exposures at Easington Colliery [NZ 436 437] and Horden [NZ 435 417].

In greater detail, Tunstall Hills are important as one of the two main source localities of fossils reported on by King, Howse, Kirkby, Trechmann, Logan and Hollingworth, though locality information given by the early authors was generally vague. The exceptionally large collections of well-preserved fossils made by Hollingworth from the precisely located 'Rock Cottage' exposure is especially significant for the light it throws on the palaeocommunity of the reef-base coquina; this exposure is also noteworthy for the evidence of early cementation and the inference of shallow-water deposition of the coquina uniquely preserved here (Tucker and Hollingworth, 1986; Hollingworth and Tucker, 1987). Though lacking a framework and therefore not being a true reef, the cemented coquina nevertheless provided a firm substrate upon which the succeeding reef could be constructed.

The main face (a) of reef-core limestone affords by far the best exposure of steeply-dipping laminar sheets in the Cycle EZ1 reef and is one of the two main exposures investigated by Aplin (1985) in his study of coarsely crystalline partly secondary reef limestones. The origin of the laminar sheets remains somewhat uncertain because, although some are clearly bilateral fissure-fill, others that are lithologically similar lack deposits on a hanging wall and may be primary reef-surface encrustations (Smith, 1981a; Aplin, 1985). The fissures presumably resulted from tension caused by unequal support around the reef crest and the steep (50–90°) upper reef slope, and their presence is an additional indicator of early cementation of the reef; similar fissures occur in comparable parts of many major shelf-edge and barrier reefs, including the famous Capitan Reef of New Mexico and West Texas. Aplin's exhaustive study of the laminar limestone sheets suggested that they were mainly early and of marine origin, but that some could be inorganic subaerial flowstones (speleothems); this latter interpretation, coupled with the presence of ?wind-blown quartz sand grains in at least one fissure, suggests a phase or phases of subaerial exposure of the reef (Trechmann, 1945; Aplin, 1985).

The host limestones at Maiden Paps, like those in the main quarry at the south-east end of Tunstall Hills, were thought by Aplin to have resulted from the calcitization of partly dolomitized limestones and are therefore, in part, dedolomites; many of the fabrics, he commented, are probably neomorphic replacements of primary aragonite and high magnesium-calcite.

The topographically high level of the 'Rock Cottage' exposure (about +78 m O.D.) and the presence of sparingly fossiliferous dolomite a few metres lower provides further evidence of the marked primary relief of the base of the reef (see interpretation of the Humbledon Hill and Gilleylaw Plantation Quarry sites). The base of the 'Rock Cottage' exposure lies an estimated 103 m above the Marl Slate, in an area where the intervening Raisby Formation is unlikely to be more than 50 m thick and the Yellow Sands to be no more than a few metres thick; it follows that at least 50 m of bedded dolomite of the Ford Formation probably underlies the reef-base at 'Rock Cottage'.

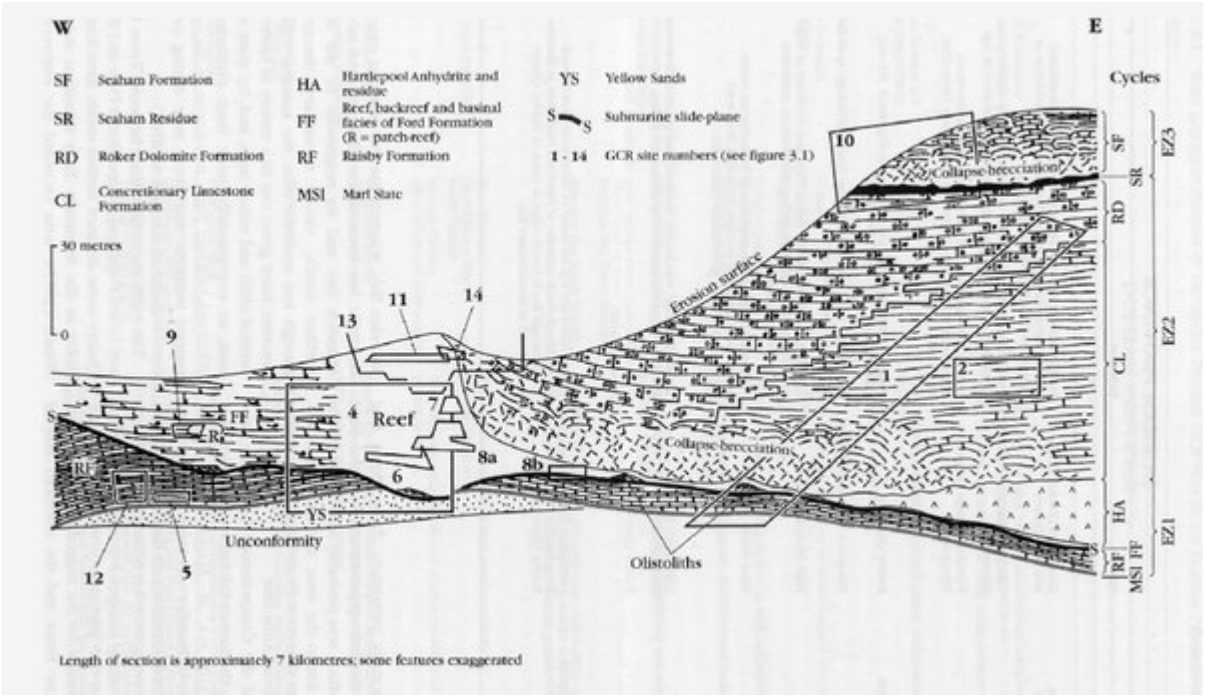
Future research

The overall structure and stratigraphical position of the reef-rocks here are still only poorly understood and require further investigation (though this would probably necessitate drilling or the creation of additional surface exposures), and the age and origin of the fissure-fill and other laminar sheets remains uncertain.

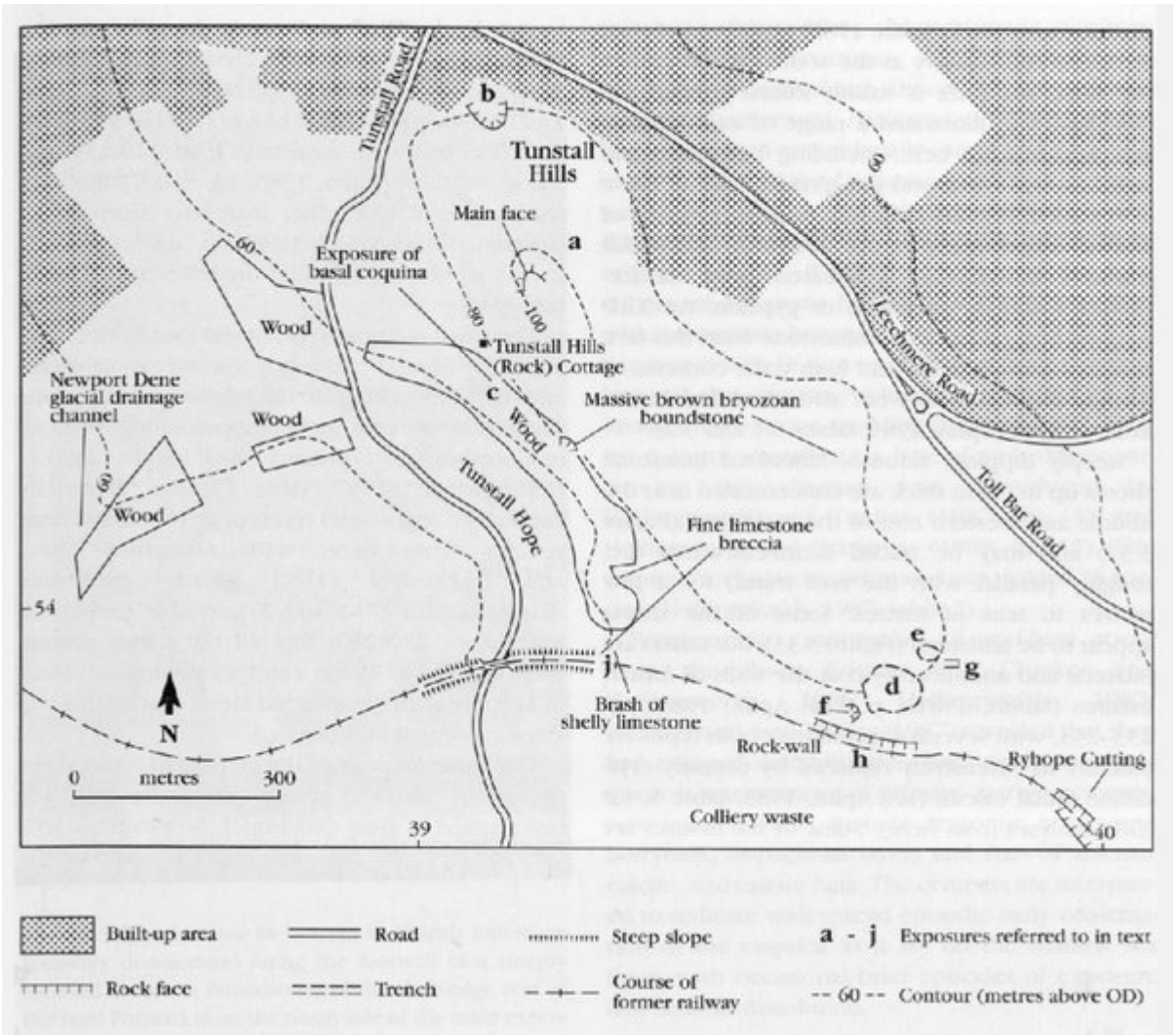
Conclusions

The site is one of a series of GCR sites which highlight the shelf-edge reef of the Ford Formation in north-east England. This series includes a number of important exposures of fossiliferous reef-rock, and one exposure of the underlying reef-base coquina. Both reef-core and reef slope rocks are exposed, the former comprising masses of bryozoan-rich rocks surrounded by shelly rubble, and the latter characterized by very steeply-dipping, sparingly shelly dolomites and limestones. The coquina contains a varied and abundant fauna, which has allowed workers to reconstruct a base-reef community. The former shape of this part of the reef and its relationship to the surrounding rocks is still not well understood, and further study is required. Although exposures are now limited, the preservation of this site is important for the overall understanding of late Permian reef development.

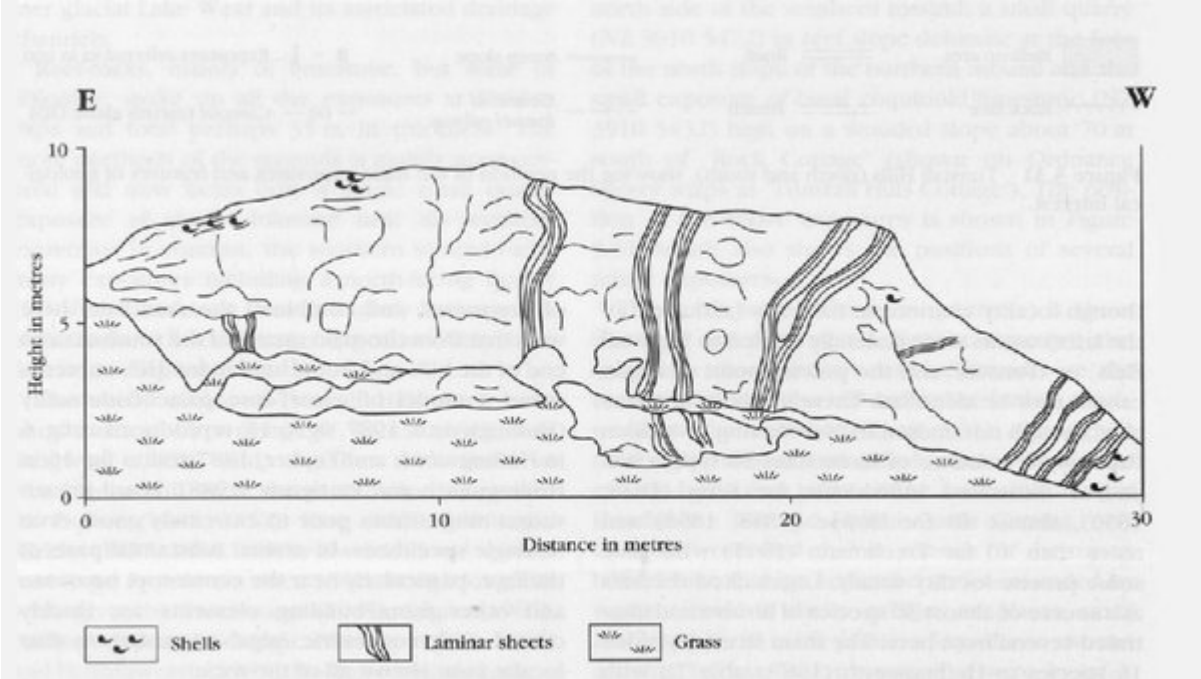
References



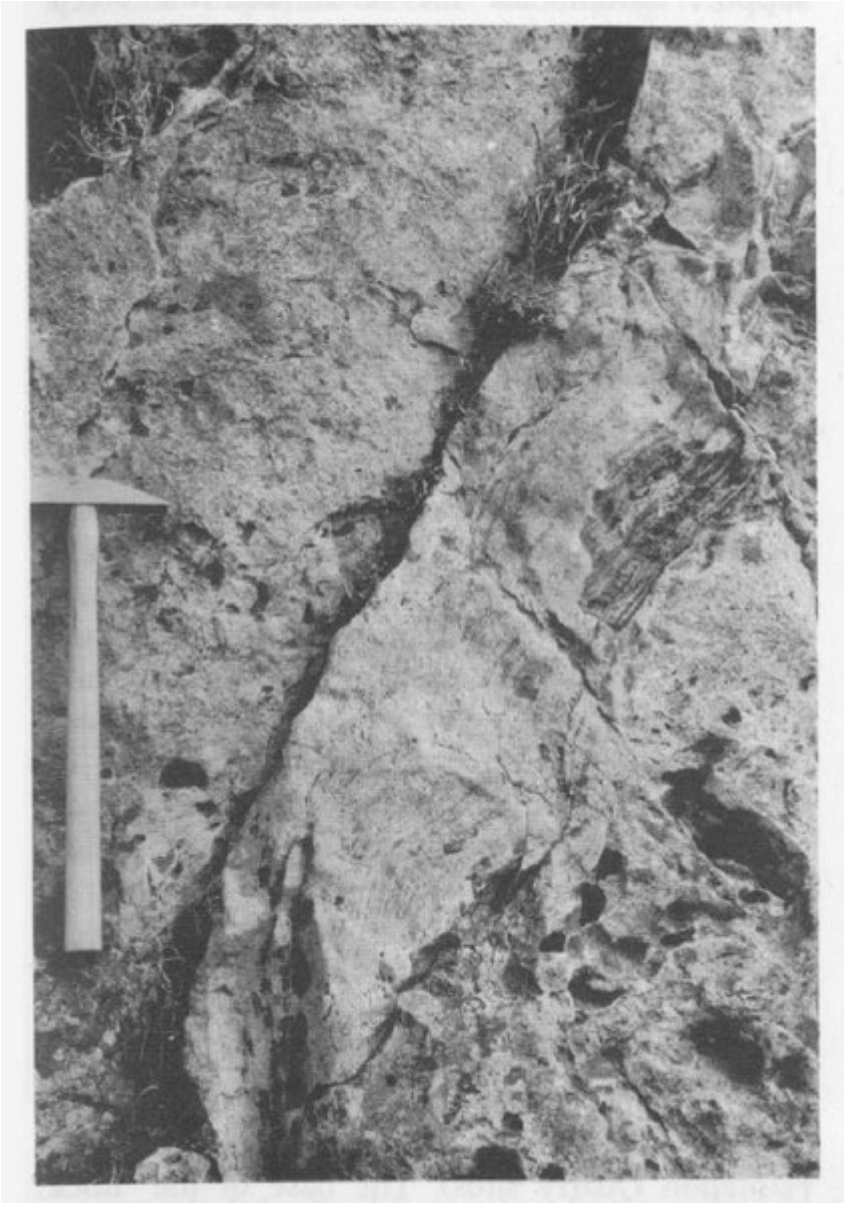
(Figure 3.2) Approximate stratigraphical position of GCR marine Permian sites in the northern part of the Durham Province of north-east England (diagrammatic). Some sites in the southern part of the Durham Province cannot be accommodated on this line of section and have been omitted. The Hartlepool Anhydrite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



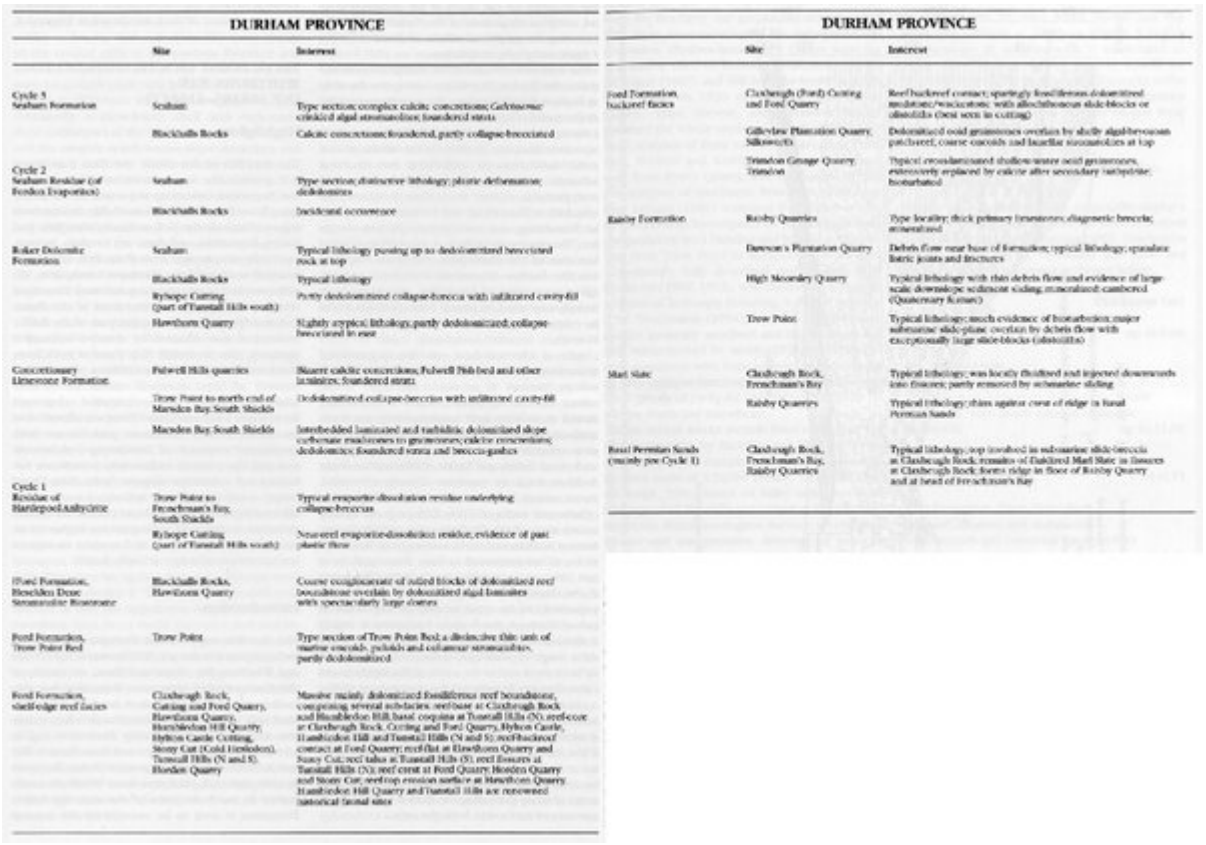
(Figure 3.31) Tunstall Hills (north and south), showing the position of the main exposures and features of geological interest.



(Figure 3.32) The main quarry face on the north side of the more southerly of Maiden Paps, Tunstall Hills. Most of the rock is brown bryozoan boundstone, locally with profuse encrustations. At least two of the tension gashes have partial central voids. Simplified from a sketch by Aplin (1985, p. 378).



(Figure 3.33) Laminar to botryoidal (?algal) limestone (possibly dedolomite) lining the footwall of a steeply inclined fissure in boundstone of the shelf-edge reef of the Ford Formation on the north side of the main exposure at Tunstall Hills (north). Hammer: 0.33 m. (Photo: D.B. Smith.)



DURHAM PROVINCE

	Site	Interest
Cycle 5 Seaham Formation	Seaham	Type section; complex calcitic concretions; *Gebrowia*-crinkled algal stromatolites; foundered strata
	Blackhalls Rocks	Calcitic concretions; foundered, partly collapse-brecciated
Cycle 2 Seaham Residue (of Fordon Evaporites)	Seaham	Type section; distinctive lithology; plastic deformation; dedolomites
	Blackhalls Rocks	Incidental occurrence
Roker Dolomite Formation	Seaham	Typical lithology passing up to dedolomitized brecciated rock at top
	Blackhalls Rocks	Typical lithology
	Rylope Cutting (part of Tunstall Hills south)	Partly dedolomitized collapse-breccia with infiltrated cavity-fill
	Hawthorn Quarry	Slightly atypical lithology, partly dedolomitized; collapse-brecciated in east
Concretionary Limestone Formation	Fulwell Hills quarries	Bizarre calcitic concretions, Fulwell Pisb bed and other laminites; foundered strata
	Trow Point to north end of Marsden Bay, South Shields	Dedolomitized collapse-breccias with infiltrated cavity-fill
	Marsden Bay, South Shields	Interbedded laminated and turbiditic dolomicrites and dolomicritic slope carbonate mudstones to grainstones; calcite concretions; dedolomites; foundered strata and breccia-gashes
Cycle 1 Residue of Hartlepool Anhydrite	Trow Point to Frenchman's Bay, South Shields	Typical evaporite-dissolution residue underlying collapse-breccias
	Rylope Cutting (part of Tunstall Hills south)	Near-reef evaporite-dissolution residue; evidence of past plastic flow
Ford Formation, Hesledon Dene Stromatolite Boundstone	Blackhalls Rocks, Hawthorn Quarry	Coarse conglomerate of rafted blocks of dolomitized reef boundstone overlain by dolomitized algal laminites with spectacularly large domes
Ford Formation, Trow Point Bed	Trow Point	Type section of Trow Point Bed; a distinctive thin unit of marine oncoids, pisolith and columnar stromatolites, partly dedolomitized
Ford Formation, shelf-edge reef facies	Cleadeugh Rock, Cutting and Ford Quarry, Hawthorn Quarry, Hutchinson Hill Quarry, Hylton Castle Cutting, Stony Cut (Cold Hesledon), Tunstall Hills (N and S), Hordon Quarry	Massive mainly dolomitized fossiliferous reef boundstone, comprising several subfacies: reef-base at Cleadeugh Rock and Humbledon Hill, basal coquina at Tunstall Hills (N); reef-core at Cleadeugh Rock, Cutting and Ford Quarry, Hylton Castle, Humbledon Hill and Tunstall Hills (N and S); reef-backreef contact at Ford Quarry; reef-flat at Hawthorn Quarry and Stony Cut; reef talus at Tunstall Hills (S); reef fissures at Tunstall Hills (N); reef crest at Ford Quarry; Hordon Quarry and Stony Cut; reef-top erosion surface at Hawthorn Quarry. Humbledon Hill Quarry and Tunstall Hills are renowned historical fossil sites

DURHAM PROVINCE

	Site	Interest
Ford Formation, backreef facies	Cleadeugh (Ford) Cutting and Ford Quarry	Reef/backreef contact; spectacularly fossiliferous dolomitized mudstone/wackestone with allochthonous slide-blocks or olistoliths (best seen in cutting)
	Gilleview Plantation Quarry, Silksworth	Dolomitized oolid grainstones overlain by shelly algal-bryozoan patchreef; coarse oncoids and bacellar stromatolites at top
	Trimdon Grange Quarry, Trimdon	Typical crossbedded shallow-water oolid grainstones, extensively replaced by calcite after secondary sulphate; bioturbated
Raisby Formation	Raisby Quarries	Type locality; thick primary limestones; diagenetic breccia; mineralized
	Dawson's Plantation Quarry	Debris flow near base of formation; typical lithology; speculaic lintic joints and fractures
	High Moorsley Quarry	Typical lithology with thin debris flow and evidence of large scale downslope sediment sliding; mineralized; cambered (Quaternary Karst)
	Trow Point	Typical lithology; much evidence of bioturbation; major submarine slide-plane overlain by debris flow with exceptionally large slide-blocks (olistoliths)
Marl Slate	Cleadeugh Rock, Frenchman's Bay	Typical lithology; was locally thickened and injected downwards into fissures; partly removed by submarine sliding
	Raisby Quarries	Typical lithology; thins against crest of ridge in basal Permian Sands
Basal Permian Sands (mainly pre-Cycle 1)	Cleadeugh Rock, Frenchman's Bay, Raisby Quarries	Typical lithology, top involved in subsurface slide-breccia at Cleadeugh Rock; remains of fissilized Marl Slate in fissures at Cleadeugh Rock forms ridge in floor of Raisby Quarry and at head of Frenchman's Bay

(Table 3.1) Main geological features of the marine Permian GCR sites in the Durham Province of the English Zechstein