Chapter 3 North-east England (Durham Province)

Introduction

Most of the GCR sites documented and discussed in this chapter lie within perhaps 30 km of the original western shoreline of the late Permian Zechstein Sea and north of the Cleveland High (Figure 1.2). There is no evidence of a connection with the Bakevellia Sea at any time during the first two main sedimentary cycles (EZ1 and EZ2) and only limited evidence of a brief connection with the Vale of Eden inland sedimentary basin during Cycle EZ3 (but see Holliday, 1993 and Smith, in press).

The Cleveland High (Figure 1.2) projected eastwards into the basin a few kilometres south of Darlington and strongly influenced sedimentation during Cycle EZ1 and part of Cycle EZ2. It was a broad, gentle, topographical feature where subsidence may have been relatively slightly slower than that to the north and south, and it remained emergent until eventually buried by onlapping sediments of the Edlington Formation. Following its burial, the Cleveland High appears to have exerted little or no effect on sedimentation and Cycle EZ3, and later English Zechstein strata in the Durham and Yorkshire provinces are similar to each other.

Rather more than half of the designated marine Permian sites are in the Durham Province and several of these are large complex coastal or inland exposures of international importance; amongst these outstanding sites are the Blackhalls Rocks coast section, the Claxheugh Rock — Ford Quarry section, Fulwell Hills Quarries and the unrivalled coastal cliffs between (and including) Trow Point (South Shields) and Whitburn.

The location of all the GCR sites in the Durham Province is shown in (Figure 3.1).

Together the sites in the Durham Province span the whole of the local marine sequence, almost all the major formations and their varied facies being represented at one or more sites. No major carbonate rock unit is unrepresented, but the thick evaporites known in the subsurface farther east and south have been dissolved at outcrop where their place is taken by dissolution residues; this dissolution had the effects firstly of delaying understanding of the stratigraphical and sedimentological relationships of the younger members of the sequence, especially of the Cycle EZ2 carbonate rocks, and secondly of furnishing a wide and instructive range of subsidence features ranging from regional foundering by more than 100 m, to spectacular collapse-breccias and late-stage breccia-gashes. The complexity of the rocks at several of the Durham sites is daunting, and many problems remain to be solved. The sites nevertheless have outstanding qualities as outdoor classrooms for the demonstration of the effects of geological processes and afford abundant material for future research.

Consideration of the early Permian Basal (Yellow) Sands in the Durham Province is inappropriate here, and full discussion will appear in the companion Review volume on the continental Permo-Triassic Red Beds of Britain. Nevertheless, the top of the Formation is exposed at Raisby Quarries, in Frenchman's Bay (South Shields) and at Claxheugh Rock, and is described briefly in the site accounts here for the sake of completeness. The involvement of the top of the desert Yellow Sands at Claxheugh Rock in massive submarine sliding, indeed qualifies the formation there for inclusion in this volume. A product of such a seemingly improbable combination is to be seen at Tynemouth Cliff, 12 km to the north, where a marine debris flow at the top of the Raisby Formation comprises pebbles and cobbles of shelly dolomite in a matrix rich in aeolian sand grains (Smith, 1970c).

No localities specifically listed for their exposures of the Marl Slate have been included in the Marine Permian Review, but are expected to feature in the volumes on palaeobotany and Palaeozoic fish. Nevertheless, normal Marl Slate is exposed at Claxheugh Rock, Frenchman's Bay and Raisby Quarries, and is described in the appropriate accounts. At Frenchman's Bay the top of the Marl Slate has been removed by end-Raisby Formation submarine slumping and sliding, and these processes have removed the whole of the Marl Slate for more than 150 m at the north-eastern end of the Claxheugh Rock section.

Carbonate rocks of the Raisby Formation are the sole subject at the Dawson's Plantation (Penshaw) and High Moorsley sites and are the main subject at the type locality at Raisby Quarries; they also feature at Claxheugh Rock and from Trow Point to Whitburn and are considered briefly in the accounts of those sites. The listing of the Dawson's Plantation and High Moorsley Quarry sites is founded on the evidence of downslope sediment slumping and sliding exposed there superbly, including crumpled strata and atypically fossiliferous debris flows up to 1 m thick; the presence of these features is a link in the chain of evidence favouring a slope origin for these strata in this northern part of the province, though such slumping was not endemic and an external initiating stimulus such as an earth tremor has been inferred (Smith, 1970c). Raisby Quarries afford a complete eponymous sequence through the formation, and have been freely cited in the literature since 1914; they are famous for the unusual presence of thick primary limestone and for an extensive suite of secondary minerals. Fossils (especially some large brachiopods such as *Horridonia*) are locally well-preserved in Raisby Quarries, but evidence of the widespread slumping low and high in the formation has not been recognized here. The thin Raisby Formation at Trow Point is unusual for its evidence of prevalent bioturbation and for the presence, at its top, of a spectacularly complex mass of slide-blocks (olistoliths) of Raisby Formation strata; at Frenchman's Bay most of the formation is inferred to have been removed by the same episode of massive submarine sliding (the Downhill Slide, named after Downhill Quarry, West Boldon) and the largest of the slide-blocks is about 72 m long and 7.5 m thick.

Rocks of the Ford Formation are amongst the most varied of the Magnesian Limestone sequence and feature in more scheduled sites than those of any other late Permian rock-unit in the Durham Province; this is mainly because of the renowned fossil content of the shelf-edge reef which extends from Sunderland to Hartlepool (Figure 3.1) and has attracted attention for almost two centuries. Each of the main sub-facies of the reef is represented at one or more GCR sites and together the several reef sites provide a cross-section through most of the reef and afford full opportunities for further research. The scheduled exposures are reasonably representative of the reef as a whole, but reefs are notoriously variable and surviving unscheduled reef exposures such as those at Dalton-le-dale [NZ 408 476], Easington Colliery [NZ 434 438], Beacon Hill (Hawthorn) [NZ 442 453] and Castle Eden Dene [NZ 44 40] reveal other aspects of the reef not clearly seen at the scheduled sites. Details of the lithology, biota and structure of the reef are given in the individual site accounts, which draw extensively on historical records and on more recent work by Aplin (1985), Hollingworth (1987) and the author (Smith, 1981a; 1994).

Landward (west) of the reef, dolomitized carbonate rocks of the Ford Formation are exposed in three scheduled sites, including Ford Quarry where the reef/backreef contact is uniquely clearly exposed, and Gilleylaw Plantation Quarry (Silksworth) where a lagoonal patch-reef is overlain by shallow-water oncoidal dolomite of a type known at only two other localities in the Magnesian Limestone. The third site, Trimdon Grange Quarry, exposes diagenetically altered backreef or lagoonal oolite several kilometres west of the reef, but this widespread facies is underrepresented in the Durham site network and Trimdon Grange Quarry has to be viewed in conjunction with other exposures such as those in the local nature reserves at Bishop Middleham [NZ 33 32] and Wingate [NZ 37 37] quarries.

Seaward of the reef, the youngest and in some respects the most enigmatic accepted member of the Ford Formation is exposed at and between Trow Point and Frenchman's Bay, South Shields. This, the thin but distinctive Trow Point Bed, is present here in both its peloid/oncoid and columnar-stromatolitic modes, which are also known from cored boreholes immediately offshore, as well as in many North Sea hydrocarbon boreholes and, far to the east, in surface exposures and boreholes in Germany and Poland.

The youngest carbonate rock-unit doubtfully assigned to Cycle EZ1, and therefore to the Ford Formation, is the Hesleden Dene Stromatolite Biostrome, superbly exposed at Blackhalls Rocks and less well seen at Hawthorn Quarry. At the latter the biostrome is seen to rest on an erosion surface cut onto the shelf-edge reef of the Ford

Formation and is overlain by supposed Roker Dolomite. The doubts about the age of the biostrome stem from the local presence of fragments of it in collapse-breccias thought to be related to the dissolution of the Cycle EZ1 Hartlepool Anhydrite, and therefore younger than at least part of the latter. However, the approximate aerial coincidence of the reef and biostrome, plus their faunal affinities, slightly favour a Cycle EZ1 age rather than a Cycle EZ2 age for the biostrome, unless its fauna was derived. The exposures of dolomitized algal stromatolites and cobble–boulder conglomerate at Blackhalls Rocks are particularly impressive and throw much light on contemporary geography and processes.

The carbonate rocks of Cycle EZ2 form almost all the coastal cliffs in the Durham Province and are the main interest in the outstanding site stretching south-eastwards from Trow Point, South Shields to Whitburn Bay; they comprise the predominantly shallow-water shelf and uppermost slope carbonates of the Roker Dolomite Formation and the roughly synchronous slope dolomites and limestones of the Concretionary Limestone Formation. Equivalent strata are unknown in the Yorkshire Province except in boreholes, so that the northern Durham cliffs and quarries are the only large-scale surface exposures available for detailed study of the complex sedimentology and diagenesis of these Cycle EZ2 strata. They are also the only places where the spectacular effects of large-scale foundering may be clearly related to the dissolution of former thick evaporites.

There are no GCR sites in which the Roker Dolomite Formation is the main interest, but it is present incidentally and with its normal lithology and fauna, at Whitburn, Seaham, Hawthorn Quarry, Blackhalls Rocks and in the Ryhope Cutting (as collapse-breccia). At Blackhalls Rocks and Hawthorn Quarry the formation displays no evidence of having foundered onto the underlying biostrome, implying that the Cycle EZ1 anhydrite did not overlap the reef here, but the formation has foundered by perhaps 50–100 m at the Ryhope and Seaham exposures. At Ryhope the collapse-brecciated Roker Dolomite is within 200 m of the reef-front, supporting the evidence from other localities such as West Boldon [NZ 35 61], Easington Colliery and Horden that the Hartlepool Anhydrite once lay against the reef at Ryhope even if it did not overlap it. The Seaham exposure is of interest in that the uppermost few metres of the formation have been much fractured and dedolomitized, probably by the formation and dissolution of a complex network of evaporite veins related to the formerly overlying Fordon Evaporites. Large exposures of gently foundered Roker Dolomite extend northwards from the Seaham site and form the coastal cliffs at Roker [NZ 40 59] and Whitburn [NZ 41 61]; here it overlies the well-known cannon-ball Limestone near the contact with the Concretionary Limestone Formation. The Roker Dolomite lies in its normal stratigraphical position at Hartlepool, where thick Cycle 1 anhydrite has resisted dissolution.

Carbonate rocks of the Concretionary Limestone Formation are the sole interest at the Fulwell Hills Quarries and in the Marsden Bay to Whitburn area of the Trow Point to Whitburn GCR site. Faces preserved in the formerly vast complex of quarries at Fulwell Hills are remarkable for the great range of calcite concretions for which this formation is justly famous, and incidentally display sedimentological evidence favouring a submarine slope origin for these strata; they also include fish-bearing calcite-laminites, a characteristic shared with equivalent beds at Marsden Bay from which fossil fish were first collected from this formation. The Fulwell Hills sections display ample evidence of foundering through dissolution of the former underlying Hartlepool Anhydrite, but the evidence of foundering is especially dramatic and inescapable at Trow Point and Frenchman's Bay where almost completely brecciated dedolomitized Concretionary Limestone overlies the thin dissolution residue of the Hartlepool Anhydrite. Farther south, the effects of the major foundering are spectacularly displayed in Marsden Bay, where late-stage collapse of large dissolution-induced cavities is believed to have been the cause of a number of massive subvertical 'breccia-gashes' or 'breccia-pipes'. The main phase of foundering was Palaeocene or earlier, judging from the mutual relationship of foundered ?Roker Dolomite and the *c.* 58 million-year old Hebburn or Monkton Dyke, the crop of which was discovered recently on the coast at Whitburn by Mr G. Fenwick.

The Marsden Bay section, though extensively calcitized in addition to the brecciation, is still mainly of dolomite and comprises a mid-slope complex of interbedded sapropelic organic-rich fine laminates, graded turbidites and slumped beds (including oolite grainstones translated from the Roker Dolomite shelf). These strata and their associated secondary effects (calcitization and foundering) continue in the coastal cliff south of Lizard Point where they merge gradually with shelly carbonate rocks inferred to have been formed in oxic conditions in the upper part of the basin-margin slope.

The Concretionary Limestone rocks exposed at Fulwell Hills and in the Trow Point to Whitburn GCR site are reasonably representative of this most variable of formations, and include the foraminifer–gastropod–bivalve–ostracod-rich rocks that abound in high-slope facies such as those in coastal cliffs a few hundred metres south of Lizard Point. They are, however, relatively poor in calcite spherulites such as typify rocks of this formation in most inland exposures in the South Shields to Whitburn area. They nevertheless afford unrivalled opportunities for the study of the sedimentology and complex diagenesis of the formation and for observing the profound effects of the dissolution of thick underlying evaporites.

The insoluble remains of the youngest Cycle EZ2 strata — the Fordon Evaporites — comprise the striking Seaham Residue and are the main feature of the northern end of the Seaham site; they also crop out at the south end of the Blackhalls Rocks site. Both exposures illustrate graphically the effects of evaporite dissolution on underlying and overlying carbonate rocks, though the Fordon Evaporites were probably thinner there than the Hartlepool Anhydrite at Trow Point and Frenchman's Bay and the foundering was correspondingly less disruptive. The residue at Seaham is many times thicker than that of the Hartlepool Anhydrite, implying that the Fordon Evaporites contained a much higher proportion of insolubles, and it has been strongly contorted by plastic flow (perhaps whilst the evaporites, probably including salt, were still present).

Light is thrown here on the depositional environment of the Fordon Evaporites by the sedimentary features of an ooidal limestone in the Seaham Residue at Seaham, which was probably formed at or very near contemporary sea level. Undissolved Fordon Evaporites (mainly salt) have been recorded in a borehole 12 km ENE of Sunderland (Smith and Taylor, 1989) and are about 15–30 m thick in northern County Cleveland, approximately 25 km along strike from Seaham.

Carbonate rocks of Cycle EZ3 crop out in only limited areas of the Durham coast, mainly in synclines at Seaham and north and south of Blackhalls Rocks; all are estimated to have foundered by at least 120 m as a combined result of the dissolution of the Hartlepool Anhydrite and the Fordon Evaporites. At its type locality in the walls of Seaham Harbour, the Seaham Formation is mainly of thin-bedded limestone with a restricted biota and a range of shelf-type sedimentary structures, but both there and to the south of Blackhalls Rocks it also features bizarre calcite concretions similar to some of those in the Concretionary Limestone Formation farther north. Foundering is expressed by medium-scale tilting and dislocation of blocks of the Seaham Formation at its main exposures, and at Seaham was accompanied or followed by the creation of breccia gashes that contain fragments of strata (including the Rotten Marl) that are now otherwise eroded from the area.

The main features of the GCR Marine Permian sites in the Durham Province are summarized in ((Table 3.1), and the approximate stratigraphical positions of most of them are shown in (Figure 3.2).

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

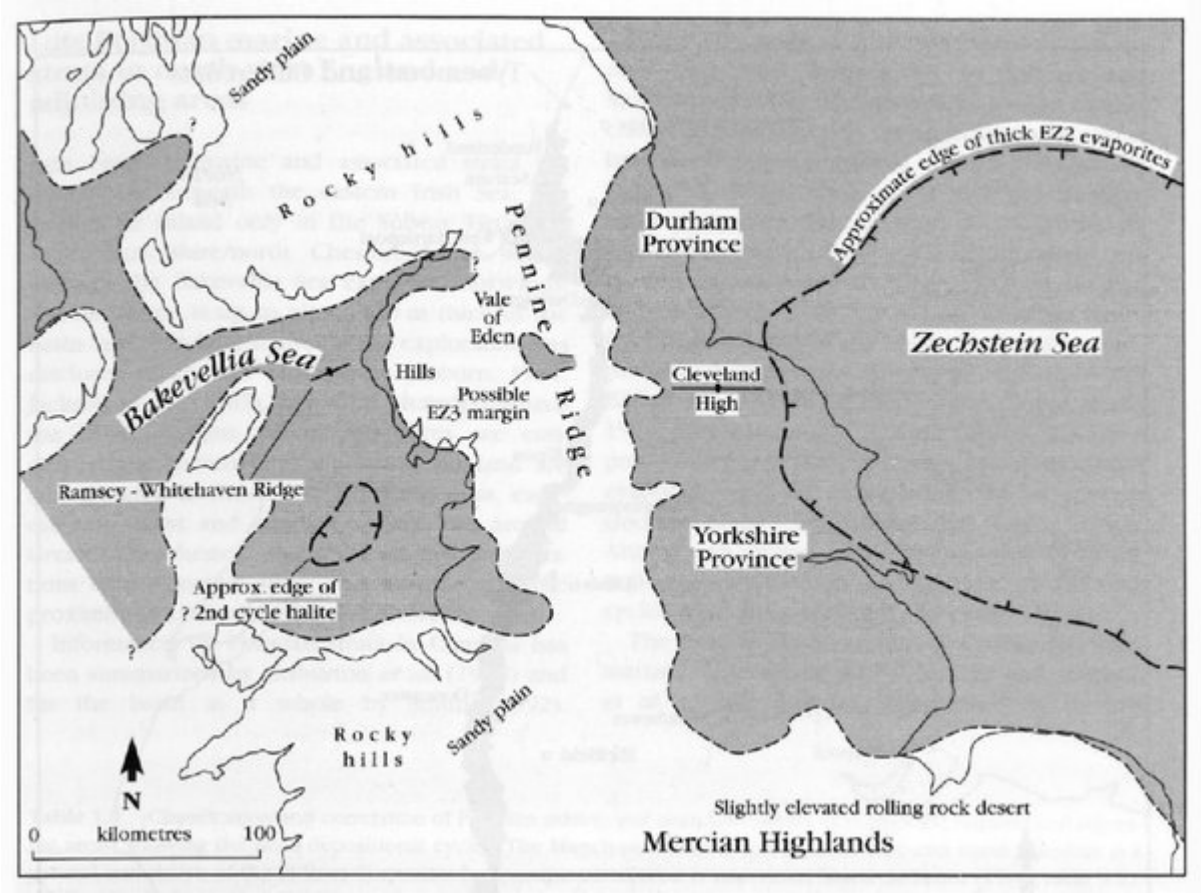
Durham Province

	Site	**Interest**
Cycle 3		
Seaham Formation	Seaham	Type section; complex calcite concretions; *Calcinema;* crinkled algal stromatolites; foundered strata
	Blackhalls Rocks	Calcite 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
	Ryhope 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

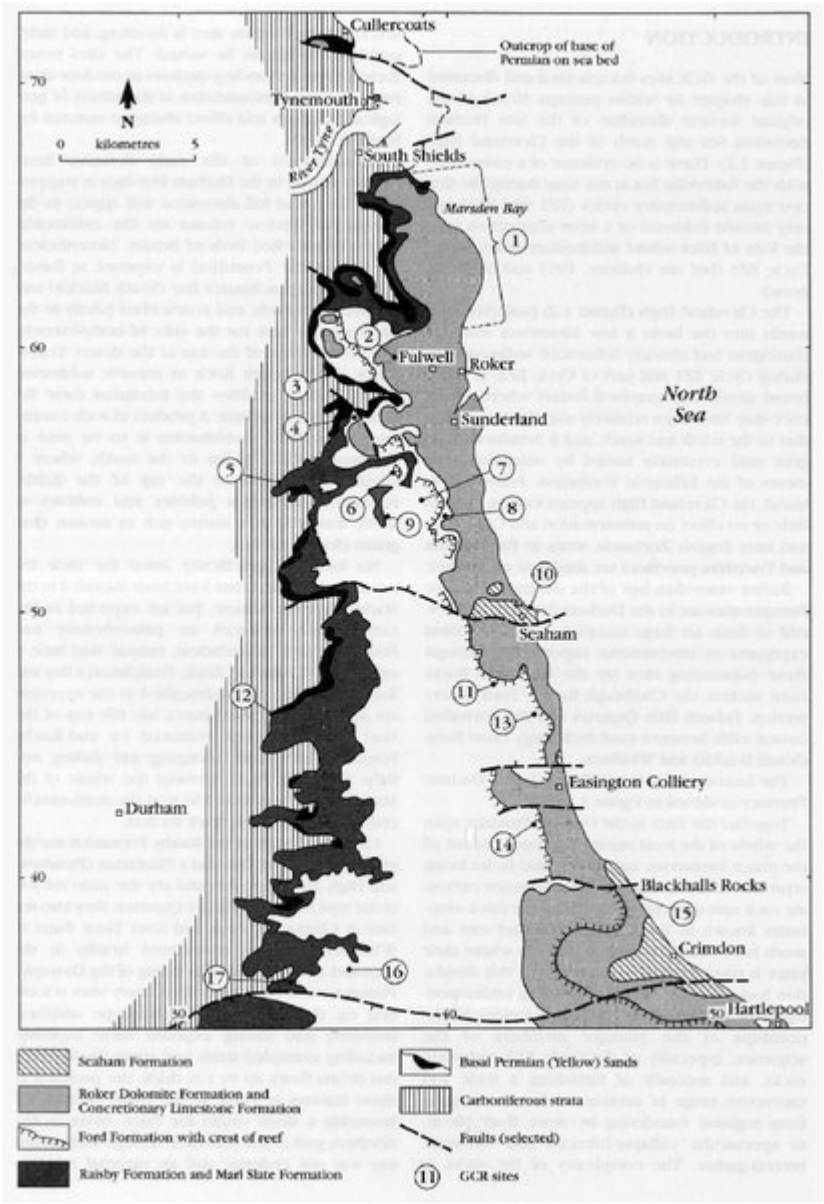
Concretionary Limestone Formation	Fulwell Hills quarries	Bizarre calcite concretions; Fulwell Fish-bed and other laminites; foundered strata
	Trow Point to north end of Marsden Bay, South Shields	Dedolomitized collapse-breccias with infiltrated cavity-fill
	Marsden Bay, South Shields	Interbedded laminated and turbiditic dolomitized 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
	Ryhope Cutting (part of Tunstall Hills south)	Near-reef evaporite-dissolution residue; evidence of past plastic flow
?Ford Formation, Heselden Dene Stromatolite Biostrome	Blackhalls Rocks, Hawthorn Quarry	Coarse conglomerate of rolled 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, peloids and columnar stromatolites, partly dedolomitized
Ford Formation, shelf-edge reef facies	Claxheugh Rock, Cutting and Ford Quarry, Hawthorn Quarry, Humbledon Hill Quarry, Hylton Castle Cutting, Stony Cut (Cold Hesledon), Tunstall Hills (N and S), Horden Quarry	Massive mainly dolomitized fossiliferous reef boundstone, comprising several sub-facies: reef-base at Claxheugh Rock and Humbledon Hill; basal coquina at Tunstall Hills (N); reef-core at Claxheugh 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, Horden Quarry and Stony Cut; reef-top erosion surface at Hawthorn Quarry. Humbledon Hill Quarry and Tunstall Hills are renowned historical faunal sites
Ford Formation, backreef facies	Claxheugh (Ford) Cutting and Ford Quarry	Reef-backreef contact; sparingly fossiliferous dolomitized mudstone/wackestone with allochthonous slide-blocks or olistoliths (best seen in cutting)
	Gilleylaw Plantation Quarry, Silksworth	Dolomitized ooid grainstones overlain by shelly algal–bryozoan patch-reef; coarse oncoids and lamellar stromatolites at top

	Trimdon Grange Quarry, Trimdon	Typical cross-laminated shallow-water ooid grainstones, extensively replaced by calcite after secondary ?anhydrite; 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; spatulate listric joints and fractures
	High Moorsley Quarry	Typical lithology with thin debris flow and evidence of large-scale downslope sediment sliding; mineralized; cambered (Quaternary feature)
	Trow Point	Typical lithology; much evidence of bioturbation; major submarine slide-plane overlain by debris flow with exceptionally large slide-blocks (olistoliths)
Marl Slate	Claxheugh Rock, Frenchman's Bay	Typical lithology; was locally fluidized 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)	Claxheugh Rock, Frenchman's Bay, Raisby Quarries	Typical lithology; top involved in submarine slide-breccia at Claxheugh Rock; remains of fluidized Marl Slate in fissures at Claxheugh Rock; forms ridge in floor of Raisby Quarry and at head of Frenchman's Bay

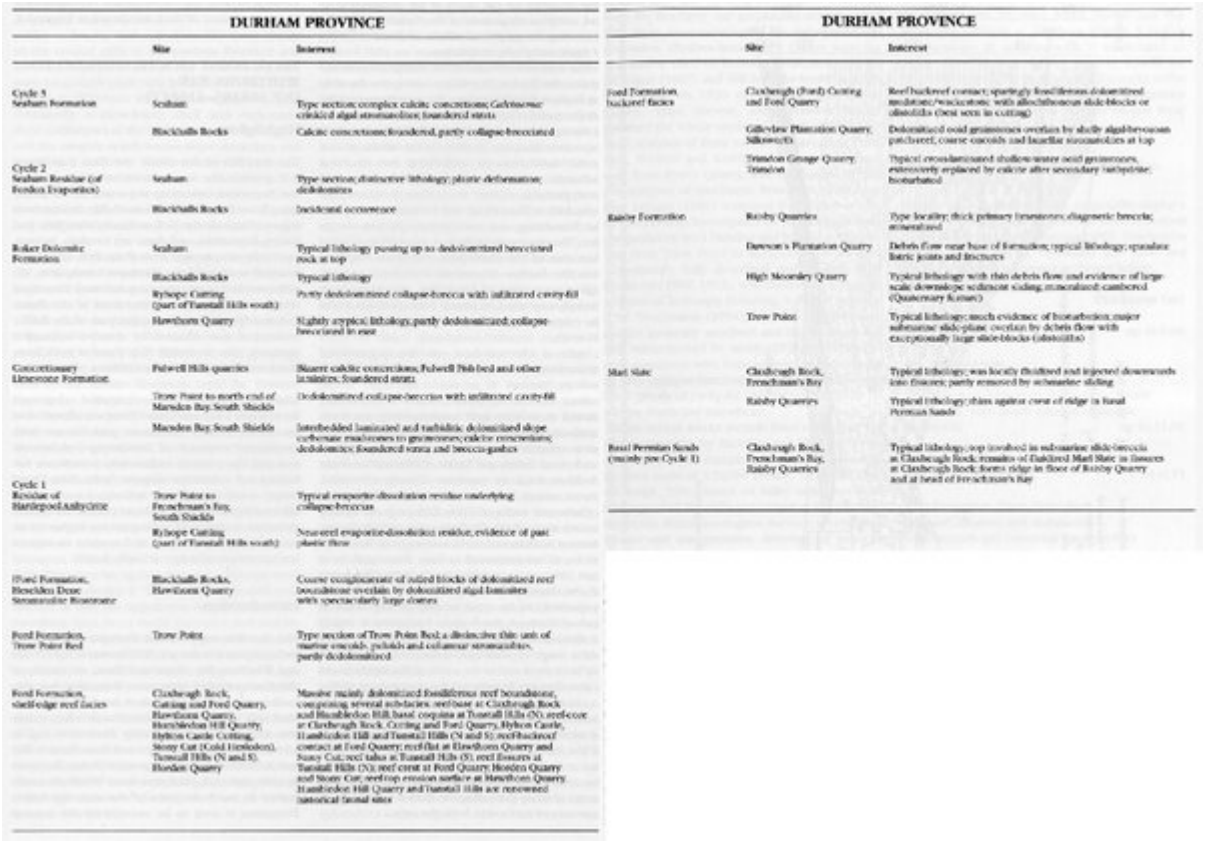
References



(Figure 1.2) Outlines of the late Permian seas of northern England and adjoining areas, showing the persistent Pennine Ridge. After Smith (1992, fig. 9.8).



(Figure 3.1) The distribution of Permian marine rocks in the Durham Province, showing the location of Permian marine GCR sites: 1, Trow Point to Whitburn Bay; 2, Fulwell Hills Quarries; 3, Hylton Castle Cutting; 4, Claxheugh Rock, Cutting and Ford Quarry; 5, Dawson's Plantation Quarry, Penshaw; 6, Humbledon Hill Quarry; 7, Tunstall Hills (north); 8, Tunstall Hills (south) and Ryhope Cutting; 9, Gilleylaw Plantation Quarry; 10, Seaham; 11, Stony Cut, Cold Hesledon; 12, High Moorsley Quarry; 13, Hawthorn Quarry; 14, Horden Quarry; 15, Blackhalls Rocks; 16, Trimdon Grange Quarry; 17, Raisby Quarries. The map is based on Smith (1980b, fig. 9).



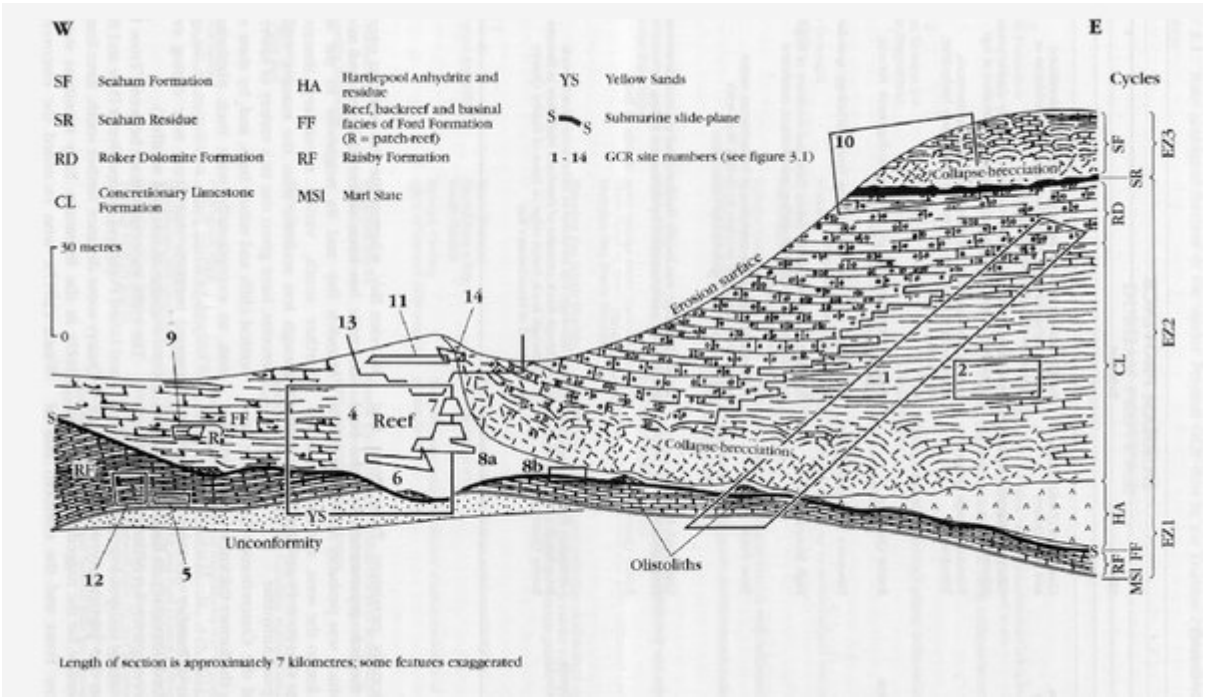
DURHAM PROVINCE

	Site	Interest
Cycle 5 Seaham Formation	Seaham	Type section; complex calcite concretions; Gelyhorse crinkled algal stromatolites; foundered strata
	Blackhalls Rocks	Calcite 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
	Ryhope Cutting (part of Tunstall Hills south)	Partly dedolomitized collapse-breccia with infiltrated cavity-fill
	Hawthorn Quarry	Slightly atypical lithology, partly dedolomitized; collapse-brecciated in part
Concretionary Limestone Formation	Fulwell Hills quarries	Bizarre calcite 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 turbidite dolomicrites, slope carbonate mudstones to grainstones; calcite concretions; dedolomites; foundered vertical and breccia-gashes
Cycle 1 Residue of Hartlepool Anhydrite	Trow Point to Frenchman's Bay, South Shields	Typical evaporite dissolution residue underlying collapse-breccias
	Ryhope Cutting (part of Tunstall Hills south)	Near-reef evaporite-dissolution residue; evidence of past plastic flow
(Ford Formation, Hesledon Dene Stromatolite Biostrome	Blackhalls Rocks, Hawthorn Quarry	Coarse conglomerate of rolled blocks of dolomitized reef boundstone overlain by dolomitized algal laminites with spectacularly large domes
Ford Formation, Trow Point Reef	Trow Point	Type section of Trow Point Reef; a distinctive thin unit of marine encrusts, cylindrs and columnar stromatolites, partly dedolomitized
Ford Formation, shelf-edge reef facies	Claxheugh Rock, Cutting and Ford Quarry, Hawthorn Quarry, Hawthorn Hill Quarry, Hylton Castle Cutting, Stony Cut (Cold Hesledon), Tunstall Hills (N and S), Horden Quarry	Massive mainly dolomitized fossiliferous reef boundstone, comprising several subfacies: reef-base at Claxheugh Rock and Humbledon Hill; basal coquina at Tunstall Hills (N); reef-core at Claxheugh 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, Horden Quarry and Stony Cut; reef-top erosion surface at Hawthorn Quarry, Humbledon Hill Quarry and Tunstall Hills ace renowned historical fossil sites

DURHAM PROVINCE

	Site	Interest
Ford Formation, backreef facies	Claxheugh (Ford) Cutting and Ford Quarry	Reef/backreef contact; spectacularly fossiliferous dolomitized mudstone/wackestone, with allochthonous slide-blocks or olistoliths (best seen in cutting)
	Gilleyiew Plantation Quarry, Silksworth	Dolomitized oolid grainstones overlain by shelly algal-bivalvous patchreef; coarse encrusts and bacellar stromatolites at top
	Trimdon Grange Quarry, Trimdon	Typical crossbedded/massive shallow-water oolid grainstones, extensively replaced by calcite after secondary sulphation; 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; spectacular fabric joints and fractures
	High Moorsley Quarry	Typical lithology with thin debris flow and evidence of large scale downslope sediment sliding; mineralized; cambered (Quaternary Ice-wave)
	Trow Point	Typical lithology; much evidence of bioturbation; major submarine slide-plane overlain by debris flow with exceptionally large slide-blocks (olistoliths)
Marl Slate	Claxheugh Rock, Frenchman's Bay	Typical lithology; was locally fluidized 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)	Claxheugh Rock, Frenchman's Bay, Raisby Quarries	Typical lithology; top involved in submarine slide-breccia at Claxheugh Rock; remains of fluidized Marl Slate in fissures at Claxheugh 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



(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.